PROCEEDINGS

OF THE

EIGHTH MEETING OF THE

CANADA SOIL SURVEY COMMITTEE

Held at

CENTRAL EXPERIMENTAL FARM, OTTAWA

October 19 - 22, 1970

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PROCEEDINGS OF THE EIGHTH MEETING OF THE CANADA SOIL SURVEY COMMITTEE

W. A. Ehrlich - Chairman, C.S.S.C.

Foreword:

The eighth meeting of the Canada Soil Survey Committee (C.S.S.C.) was held from October 19 to 22, 1970, in the K. W. Neatby Building, Central Experimental Farm, Ottawa. Ten subcommittees reported, three papers were presented and separate sessions were held on the classification system, remote sensing, and on objectives and organization of soil survey.

Subcommittee Reports - These dealt with a variety of material related to soil survey. Summations follow:

(1) Classification of Land Forms - No agreement could be reached on the approach to be used on classification, therefore it was recommended that a request be made to the Geological Survey of Canada to either provide or assist the C.S.S.C. in establishing a nationally accepted scheme. The subcommittee will be continued.

(2) Soil Moisture Regimes - In the quest for improvements in criteria for soil drainage classes used in the soil classification system, the subcommittee reported that much more data on soil moisture are necessary before firm recommendations can be made. One recommendation specified the development of a system classifying moisture regimes in quantitative terms. Studies in this field are to be continued.

(3) Soil Climate - The subcommittee assisted by the Agrometeorology Section of the Plant Research Institute accumulated the data from 675 weather stations in Canada for the establishment of the climatic types, classes and subclasses shown on the map. The map was accepted by the C.S.S.C. on a provisional basis subject to changes when more information is obtained.

(4) Soil Survey Interpretation for Engineering Use - In this field greater interest than before in interpretations was indicated by various disciplines. Cooperation of pedologists with engineers was considered essential if valid engineering interpretations are to be made from soil survey information. It was recommended that reports of reconnaissance soil surveys include data of interest to the engineer but not engineering interpretations unless specifically requested, and that reports on detailed soil surveys should include engineering interpretations. The surveys should be conducted with local engineers and the reports should meet the objectives acceptable to the engineers.

(5) Crop Yield Assessments - The subcommittee reported that statistics on crop yields for different soils under different management levels are limited and it is recommended that a continued effort be made by workers to obtain this type of information. This information was emphasized as being important to many government programs and to resource planning.

(6) Soil Correlation - A summary of opinions on correlation follows:

(a) The general opinion was that the present lines of operation and communication in correlation are inadequate.

(b) That conceptual criteria and standards of taxonomy and classification should be developed by a common consensus through the C.S.S.C.

(c) That all regional units should adhere to the national approach to taxonomic classification.

(d) That primary authority for establishment of map units reside at the local level but should be correlated at the regional or interprovincial level so that the units can fit into a national framework.

(e) That there was need of a National Soil Correlation and Interpretation Service at Ottawa.

(7) Storage and Retrieval of Soil Survey Data - The need for a soil data bank was expressed by the members. Reasons were that storage and retrieval were imperative for greater accessibility, to facilitate interpretive work and to organize data in such a form that it can be used for research purposes. It was also recommended that the system be evolved at the Soil Research Institute in Ottawa and be the responsibility of the soil correlation staff.

(8) Soil Survey Reports - The terms of reference of this subcommittee were "to determine (a) the specific needs and interest of the various groups who use soil survey data and (b) to recommend methods of reporting that would best suit these needs." As a result of this study the subcommittee proposed and received unanimous approval of the following recommendations:

(a) Future soil survey reports have two main parts - one part which brings together general information on the soils and interpretations of their capability for use, the other part describing the morphology and classification of the soils.

(b) The interpretations for use be written by, or in consultation with, persons qualified in the particular discipline.

(c) The "Style Manual for Biological Journals" be the standard followed in editing soil survey reports.

(9) Soil Families - Although a general indifference exists on the need of the Soil Family category, the committee supported the recommendation for the continuation of this category. Some members of the subcommittee emphasized the need for use of soil families to sort and group series. It was contended that the sorting would point out discrepancies in the criteria used for series, family, or both, especially when some series, as defined by the classifiers, fell into more than one family.

(10) Organic Soils - It was recommended that the Folisol Great Group, the Typic Folisol and Lithic Folisol subgroups as defined be on a trial basis.

Other recommendations made and unanimously accepted were: (1) alter the definition of the control section by deleting "to a cryic contact plus 10 inches (25 cm) if such contract occurs at a depth shallower than either a or b"; (2) substitute "Silvo" for "Hypno" and redefine the subgroup; (3) establish an order of importance among the subgroups with the objective of limiting the number of combinations; (4) specify that the subdominant organic layer in the Terric Fibric, Terric Mesic and Terric Humic be 10 inches (25 cm) or more in thickness; (5) amend the definition of the hydric layer; (6) to redefine (c), under control section, to clarify the minimum thickness of peat over the hydric layer; and (7) to redefine the Organic Order. The recommendation for the criteria proposed at the 1968 meeting for the family and series level was accepted on a trial basis.

Soil Classification - On this subject the following received attention:

Solonetzic Order - Consideration was requested for the return of the Dark Brown Solonetz and the Dark Brown Solod in the soil classification system.

Luvisolic Order - Minor changes were recommended in the definitions of the Luvisolic Order and in the Gray Brown Luvisolic and Gray Wooded subgroups.

Podzolic Order - Minor changes were recommended and corrections pointed out in the definitions of the Podzolic Order and in the Orthic Ferro-Humic Podzol, Mini Humo-Ferric Podzol and Bisequa Humo-Ferric Podzol subgroups. Podzolized sandy soils with the morphology but lacking the chemistry of Podzolic soils were discussed and a recommendation was made for further study of these soils with particular reference to the criteria used for a Podzolic B horizon.

Brunisolic Order - Several minor changes were proposed for future consideration.

Gleysolic Order - It was recommended that the proposals presented at the meeting be studied and be considered at the next meeting.

Papers on Land Capability - These follow:

The first is on Biophysical Land Classification, its definition and its approach to a national system. This classification system uses landform within a climatic framework as the major determining factor of environment. On this premise the hierarchical system of land survey was established and on this basis it is assumed to be possible to examine and classify the lands at any level.

In the paper on Land Capability Analysis the emphasis is on the importance of the analysis for designating the best physical capabilities of the land for various uses. It points out that the analysis is not intended to provide land use plans, it is intended to show the capability patterns.

The final paper entitled Capability Classification of Organic Soils describes the approach used and criteria followed. The criteria are stage of organic matter decomposition, water conditions, reaction, climate, woody conditions, surface roughness, and thickness of peat. Each criterion is evaluated as it applies to the soil and all criteria are summated to a numerical value which establishes the soil class. Seven classes are defined.

The C.S.S.C. unanimously agreed that regional meetings both in the east and the west are needed and that they be held in years alternating with the national meeting. It was also agreed that tours be taken in areas with problems in soils under study.

The number of participants at the meetings was the highest on record (90) for a C.S.S.C. meeting. High interest was evident throughout. The members of the national committee were highly appreciative for the contributions made by the forest soil scientists, soil engineers, geologists, agrometeorologists, and soil scientists who were our guests.

Appreciation and thanks are expressed to the speakers, Mr. E. A. Godby, Dr. A. L. Gregory, Dr. J. N. de Villiers and Mr. R. O. Chipman, Program Planning Office, Department of Energy, Mines and Resources, for their reports on remote sensing. The topics were: (1) Introduction to remote sensing; (2) Organization of the Canadian program; (3) Airborne program; and (4) Earth Resources Technology Satellite (ERTS) and Skylab program. Thanks also are expressed to Mr. L. Philpotts, Economics Branch, Ottawa, who arranged and chaired this session.

Dr. A. A. Klingebiel and Dr. J. F. Douglass, Soil Conservation Service, U.S.D.A., Washington, D. C., represented the U. S. Division of Soil Surveys at our meeting. Also a former Canadian resident, Dr. R. Arnold, Professor of Soils, Cornell University, attended as our guest. Our appreciation is hereby expressed to the three U. S. soil scientists for their contributions to the discussions.

OPENING

The meeting was called to order by the chairman at 9:00 a.m. on Monday, October 19, 1970. Members and guests were introduced. The chairman then called on Dr. J. C. Woodward, Assistant Deputy Minister (Research) and Chairman of the Research Committee of the Canadian Agricultural Services Coordinating Committee (CASCC) to whom the C.S.S.C. reports, to address the meeting.

ADDRESS BY DR. J. C. WOODWARD

It is my pleasure, on behalf of the Canadian Agricultural Services Coordinating Committee and the Canada Department of Agriculture, to welcome you to this the eighth full-dress meeting of the Canada Soil Survey Committee.

Canadian soil surveys had their beginnings in Saskatchewan and Alberta in 1921. The National, now the Canada Soil Survey Committee, was established in 1940 to function as the coordinating body among the soil survey organizations in Canada as supported by the Canada Department of Agriculture, provincial departments of agriculture, departments of soil science at universities, and research councils.

Over the years, the self-coordinated effort of you and your predecessors, with but modest resources, has yielded rich benefits to Canada and to the world. From the earliest days your contributions to the knowledge and understanding of our soils have been put to practical use not only in agriculture but in a great variety of ways. In addition, your approach to soil survey and your expertise has been and is in world demand.

Recent contributions such as the handbook on the "System of Soil Classification for Canada", the soil map of Canada, and land capability assessments are landmarks of the progress that has been made.

We cannot, however, rest on our laurels. Our soils are our principal natural resource and use, management, and conservation are involving us in interdisciplinary studies involving not only pedologists but meteorologists, biologists, economists, and others. This is reflected in the program for this week's session. It becomes increasingly important to coordinate efforts both within and between disciplines to ensure real progress rather than simply applying band aids to specific problems.

Two factors are in your favour: the quickening interest of the public in environmental management and the rapid development of sophisticated technology to apply in the attainment of new knowledge and the solution of problems. Your early and continued emphasis on soil conservation must be nurtured into full bloom and you must be ready to make your contribution toward the exploitation of technological advances such as those heralded with plans for earth resource satellites and remote airborne sensing.

I wish you all success in your deliberations and that they will lead to inspiration which will enhance your individual and collective contributions.

REPORT OF THE SUBCOMMITTEE ON THE CLASSIFICATION OF LANDFORMS

D. F. Acton, Chairman

The terms of reference of this subcommittee, as outlined by Dr. W. Ehrlich, were "a system for national use is needed and it is hoped that a scheme can be submitted for trial purposes. Consideration should be given to those used in other disciplines".

After considerable discussion by correspondence and in subcommittee meetings it was apparent that there is no currently available system for classifying landforms which would be suited for use in soil surveys. Most of these subcommittee members felt a need for developing a system to serve our particular purposes. As a consequence of this, it was approved by the national committee that the Chairman of the Canada Soil Survey Committee ensure that a working committee be established to press toward the development of a landform classification scheme for Canada. Such a committee should have representation from the Canada Soil Survey Committee, the National Committee of Forest Lands and geomorphologists working regionally, but under national guidelines. An integral part of this development will be description and definition of local forms, field trips, and meetings in addition to the regular meetings of the Canada Soil Survey Committee to fully develop the system. It is apparent that a working committee must begin by establishing a number of terms of reference to be applied nationally. From discussion two are obvious: 1) Definition of landform or any other physical attributes to be included in the classification. Some individuals would include soils, vegetation, hydrology, etc. in a proposed scheme. Others feel a strictly geomorphological scheme should be developed and the title "Landform Classification" should be changed to "Geomorphological Classification"; 2) The basis for classification. Various approaches can be taken, e.g., physiographic, descriptive, genetic. There is strong feeling about the use of genesis in a classification scheme. Some feel they need a system where they can draw on intuitive judgments based on the inferred genesis of landforms. Others, primarily those involved with detailed soil surveys, prefer a system where form is stressed with little, if any, reference to genesis.

Considerable effort was forthcoming from members of the subcommittee in an attempt to provide description and classification of common or special types of land or peat forms for the particular area in which they have been working. These contributions and a brief resume of contents are:

1) Classification of Peat Landforms in Manitoba by C. Tarnocai, Department of Soil Science, University of Manitoba. A four category classification scheme is presented. All units are defined, briefly described, and very well illustrated with schematic diagrams and photographs. References.

2) Use of Land Classification Concepts as a Basis for a Reconnaissance Soil Survey in North Eastern British Columbia. K.W.G. Valentine, Can. J. Soil Sci., Vol. 50, 71-77.

3) Landforms of Ontario. John Gillespie, Department of Soil Science, University of Guelph. A four category classification scheme using pattern slope, frequency and soil profiles is presented. The highest level is illustrated by schematic diagrams.

4a) Field Symbolic Scheme Used by the B.C. Provincial Soil Survey Division.

4b) Description of Landforms (Cordillera and Pacific Coast). G.G. Runka. Ten genetic and 17 morphologic groupings are defined and briefly described.

4c) A Suggested Landform Classification by G.G. Runka and R.C. Kowall, Soils Division, B.C. Department of Agriculture. A three category system is presented here. The highest level separates forms occurring on unconsolidated non-residual materials from those on consolidated and unconsolidated residual materials. Various genetic and morpholigic units similar to those presented in 4b are used to subdivide the former group. The latter group is subdivided on rock type.

5) A Brief Description of Some Canadian Landforms. D.F. Acton, Saskatchewan Institute of Pedology, John Mitchell Building, University of Saskatchewan. A three category system is used as a basis for description of landform types in Canada with particular reference to forms in the Great Plains Region. Illustrated with photographs. References.

A consideration of the different material presented indicates, on the one hand, the distinct possibility of preparing a comprehensive classification scheme for the Cordilleran and Great Plains regions which would be suitable for soil mapping. On the other hand, this material also indicates the different approaches used by groups working in different regions of the country, particularly those where detailed soil surveys are more common.

The C.S.S.C. recommended that the subcommittee be continued.

REPORT OF THE SUBCOMMITTEE ON SOIL MOISTURE REGIMES

J. A. McKeague, Chairman

This subcommittee has considered possible improvements in the present soil drainage classes as well as other aspects of soil moisture regimes. The term "soil moisture regime" refers to the moisture status of the soil throughout the year. It includes several aspects: duration of flooding, depth to water table throughout the year, amount of water held by the soil at various tensions, capacity of the soil to transmit water, water contents at various depths throughout the season, and probably others.

Opinions of those asked varied widely regarding the adequacy of the present soil drainage classes. Some stated that they paid little attention to the present definitions but assigned drainage classes mainly on the basis of topography and vegetation. Others considered that the present classes were useful and that the definitions were sufficiently general to permit flexibility according to local conditions. In general, however, it was clear that the present soil drainage classes are far from ideal if they are intended to indicate soil moisture regimes. For example soils with widely different moisture regimes might be classified correctly as poorly drained:

1. A clay soil that transmits water very slowly in a subhumid region. The water table might be more than 10 feet below the surface.

2. A soil in a closed depression in a semiarid area. The soil might be flooded with 2 feet of water in the spring and be below the wilting point near the surface in the fall.

3. A sandy soil in level terrain in a humid area. The water table might fluctuate between 0 and 4 ft. throughout the year and the soil might be moist continuously below 1 foot.

A problem with the present definitions of the drainage classes is that they are based largely upon the occurrence of soil moisture in excess of field capacity for various periods. It was pointed out that field capacity is not an easily definable state and that it is difficult to estimate when a soil is at field capacity. It was suggested that "waterlogged, less than 10 cm tension" be substituted for "above field capacity" in the definitions of soil drainage classes but the general feeling seemed to be that this change would not simplify the distinction of the various drainage classes.

The set of 4 soil moisture regime classes and the subclasses proposed by the Soil Climate Subcommittee might replace the present soil drainage classes. However, since it seems to be difficult to distinguish consistently among 6 soil drainage classes, more problems would be encountered in trying to distinguish among 12 except in areas where many soil moisture regime data were available. In areas of reconnaissance surveys, most sites are visited only once and the soil drainage class must be estimated from soil morphology, vegetation and topography.

The subcommittee recommends no change in the present soil drainage classes. However, the criteria by which the drainage classes are assigned should be specified by each soil survey unit. These criteria should be given in the report on soil drainage classes whether or not they differ in various regions. This should make the soil drainage classes more meaningful and usable to those who are not familiar with the folklore associated with the recognition of soil drainage classes in various regions.

It became evident to the subcommittee that, for a number of soils, comprehensive data on the moisture regime were available. A system of classifying the various aspects of soil moisture regimes seemed desirable to encourage the collection of the necessary data and to provide a framework for recording such data. We considered the kinds of data that were necessary to permit a more useful and adequate characterization of soil moisture regimes. In order to do this, we had to think about how soil moisture regime information could be used. Broadly speaking, it seemed evident that if it is worthwhile to map the soils of the country and to assemble a large body of data on their morphologies, textures, chemical properties, etc., it would be useful to know the details of the moisture regimes of the soils mapped. Of course, soil moisture is a dynamic property and its characterization requires repeated measurements. All potential users of soil survey information are interested in one or more aspects of soil moisture regimes: agronomist and forester - available moisture holding capacity, water table, ...; wildlife specialist - duration of flooding ....; engineer - permeability, water table, moisture holding capacity ....; resource planner - all aspects presumably; hydrologist - infiltration rate, moisture holding capacity .... The list is incomplete and perhaps the most important aspects are not included but it seems evident that any user of soil would need information on soil moisture regimes. Some of the information of soil moisture regime can be inferred from other properties.

Unfortunately, a large gap exists between the potential relevance of soil moisture regime data and the uses that are made of this information. Several people on the subcommittee and others who contributed opinions stated that very little use was being made of existing soil moisture data. Two of the reasons for this were apparently that many data are buried in personal files, and that potential users in other disciplines do not know of the soil moisture data available from soils specialists. Soil moisture data are used in making crop yield predictions, planning drainage systems, calculating irrigation requirements, etc.

We made an attempt to list the soil moisture regime data that would be desirable assuming that it would be feasible to obtain these data and that the data would be known to and applied by potential users. Several kinds of data seemed desirable and it appears unnecessary to try to integrate these data to give one set of soil drainage classes. Rather, separate classes for surface water, water table depth, etc. are suggested. Many numbers would be involved but this is no problem if a computerized system of data storage and retrieval is established.

We propose that a system of classifying the various aspects of soil moisture regimes be developed over the next few years. This system would presumably be used in areas where detailed surveys were in progress and where many soil moisture data were either available or necessary for interpretive purposes. The system could not be used in areas where it was not feasible to obtain the necessary data. For example, seasonal changes in water table levels will not be available in areas where broad reconnaissance surveys are being done and where a site is seen only once. In cases where it is not feasible to obtain detailed soil moisture data, the former drainage classes would be used. Where adequate data can be obtained, the following aspects of soil moisture regime should be classified:

A. Surface water

1. None except for a few minutes after heavy rains (1a. standing; 1b. moving).
2. Occasionally for a few hours after heavy rains or during snowmelt. (2a. standing; 2b. moving).
3. A few days during snowmelt or after heavy rains.
4. A few weeks after snowmelt most years.
5. More than a month after snowmelt most years.
6. More than 3 months after snowmelt most years.

The classes are arbitrary. More useful ones could probably be suggested after a study of some data and after consultation with scientists in other disciplines. Remote sensing should yield useful information on duration of flooding.

B. Water table (the height at which water stands in an unlined borehole in the unconsolidated surface material).

Continuous records for several years are probably most useful and should be obtained if possible. However, high and low yearly levels are, perhaps, adequate and such data are easier to handle. The classes proposed by the Northeast Group of the Soil Moisture Committee of the Soil Conservation Service, U.S.D.A., are suggested for trial.

High water table	Annual fluctuation below the bottom of the apparent high water table class
1. < 0 inches	a) 0, b) 0-20, c) 20-40, d) 40-80 e) > 80 inches.
2. 0-10	a) to e) as above
3. 10-20	a) to e)
4. 20-40	a) 0, b) 0-40, c) 40-80, d) > 80
5. 40-80	a) 0, b) 0-80, c) > 80
6. > 80	

Thus class 3d would indicate that the high water table was between 10 and 20 inches and that the water table dropped to between 60 and 100 inches.

Probably a different system of coding water table data would be necessary in irrigated areas. In many humid areas, a measurement of the water table shortly after snowmelt and another in late August would define the high and low water tables.

Some system probably should be devised for classifying "perched" water tables. However, no clear definition was found and no data are available. Tentatively we suggest that a perched water table is an accumulation of free water above an impermeable layer within the control section when the underlying material is not saturated. Data are needed before classes can be suggested.

Also, some system should be devised for indicating the degree of aeration or stagnation of the water below the water table. Its salt content and pH should also be determined.

C. Soil moisture content

Quantification of soil moisture contents at various depths throughout the season would be desirable. Such data could be obtained only at a few specific sites in various regions but they would be useful in evaluating estimates based on climatic data, soil morphology, etc. Moisture content vs tension data would be necessary for the soils involved. No classes are suggested.

D. Infiltration rate, permeability, aeration.

Data on infiltration rates are necessary to assess surface runoff and erosion, and the amount of added water that actually enters the soil. It was pointed out that the values obtained depend greatly on surface cover, soil moisture content, etc. and that no adequate method is available. However, even approximate values would be better than no information.

Permeability values also depend strongly on the condition of the soil at the time of measurement and on the method of measurement. No generally accepted method that yields reliable values can be suggested. However, approximate data are better than none.

An index of aeration based on the volume of water drained from saturated soil at 100 cm tension might be useful. It is being used in Britain.

If a system for characterizing soil moisture regimes more quantitatively is to be developed, much information is necessary and clearly we will not be able to obtain and to assemble all of the desired data quickly. We have made some attempt to establish priorities but the choices may not be sound. Clearly, the priorities differ according to the climate, parent material and land use in the area. For example, water table information seems important in many humid areas and in irrigated areas but not in semiarid areas that are not irrigated.

Initially we were inclined to give first priority to long term (3 years or so) studies of water table fluctuations in some of the major soils of different regions. This seemed reasonable from several points of view.

1. Water tables are clearly important in the use of land for agriculture, forestry, construction, urban development.

2. Water table levels and fluctuations are known to be important in soil genesis and not enough is known about relationships among soil morphology, water tables and weathering.

3. Other countries ahead of us in the characterization of soil moisture regimes found it useful to obtain long term water table data. For example, in the Netherlands after the war, records were kept of water level fluctuations in some 30,000 observation wells. At present, in the United States and in Great Britain, long term data on water tables are being collected.

We attempted to assemble the existing information on water table fluctuations in soils in Canada and a partial list of sources of such information as well as other soil water data is included with this report. A main finding from this effort was that many potentially useful data on water tables had been unknown to us and probably we are still not aware of many other potentially useful data. Most of the available data have been measured by workers in other disciplines. Some major sources are:

1. Inland Waters Branch, Department of Energy, Mines and Resources. Long term (10 years) continuous measurements of water tables are being made at about 500 sites throughout the country. Many wells are in areas where soils have been mapped. Not all of the data will be relevant but some will.

2. Provincial groups involved in hydrological studies.
   e.g. Ontario Water Resources
   Saskatchewan Research Council
   Nova Scotia Department of Mines.

3. Canada Dept. of Forestry and provincial Forestry Depts.

Because of the vast amount of water table data available from other sources, the first step should probably be to evaluate these data in relation to our needs. We need to know the kind of soil, topography, etc. at each observation well site. Sufficient water table data may be available for many soils. Studies of variability in water table depths in associated soils should be designed around sites where good long-term data are available. Further studies might be designed to fill in the gaps and to test the feasibility of extrapolating water table data to similar areas in the vicinity of observation wells. We suggest that within the next year existing water table data should be evaluated. This would probably involve someone in each province to undertake the job of checking the observation well sites in the province and relating the data to specific soils. There is a need also to evaluate the usefulness of water tables for interpretive purposes in various regions. We feel strongly that much useful information can be obtained with very little expense if we make use of data accumulated by other agencies.

The second priority, in our opinion, should go to the determination of actual moisture contents throughout several years of some major soils in various regions. Some of these data are already available especially from the Swift Current and Lethbridge areas and the Agrometeorology group has established 11 sites for measurements on the prairies. These data involve measurements of soil moisture contents to a depth of 4 ft. at seeding time and at harvest time. For some interpretive purposes, moisture content data throughout the year may be necessary. The measurements should be made at several depths; perhaps 0-6, 6-12, 12-24, and 24-40 in. Such data would be useful in checking estimates of soil moisture based on climatic data, they are an important aspect of the soil moisture regime and they would be useful in setting up soil families. Thus we suggest that each province begin assembling existing long-term soil moisture content data and making further measurements for important soils. The choice of sites should be done cooperatively with the soil climate group when possible.

The U.S. Soil Moisture Committee reported that soil surveyors can estimate by feel soils that are below the wilting point. This should be checked and made a part of soil description if feasible.

Apart from water table data and actual soil moisture content data many other kinds of information related to soil moisture are desirable both to characterize soils and to make interpretations for various uses of them. The kinds of information that are most necessary probably vary from region to region. For agronomic uses, the capacity of the soil to supply water and air to plant roots throughout the season is, no doubt, important. Thus, soil moisture retention curves would be useful. For engineering interpretations some measure of shrinkage on drying, liquid limit, sensitivity, etc. are probably important. It might be useful to make further attempts to relate soil moisture characteristics to particle-size-distribution, organic matter content, kind of clay, etc. It has been pointed out that soil moisture is a dynamic entity and that no reasonable amount of measurements will adequately characterize the soil moisture regime. The best bet seems to be to depend as much as possible on information computed from meteorological data and from the principles of moisture distribution in soils. However, data are needed to check such computations. Calculations from meteorological data probably are most relevant to nearly level areas. Landform must be taken into account to assess soil moisture from meteorological data in most areas.

Obviously the manpower is not available to permit the accumulation of all kinds of data for all soils and this is not necessary. The usefulness of various kinds of soil moisture information for interpretative purposes should be assessed and data that are useful for specific purposes in various regions should receive priority. Assembling the data on various aspects of soil moisture regimes is important and no doubt a computerized system of data storage and retrieval should be developed.

A few points became increasingly evident during the considerations of this subcommittee.

1. There is a great need for more cooperation among agencies concerned with some aspects of soil moisture. Hydrologists, foresters, engineers and probably others are accumulating data and applying techniques that are relevant both to the characterization of soil moisture regimes and to the interpretation of the information. More cooperation with these groups is essential if we have any serious intention of characterizing efficiently and usefully the soil resource. There is also a need for closer liaison among some of the subcommittees of C.S.S.C. For example, soil climate, soil moisture, landforms, engineering properties, soil survey data and maybe others, probably should have some form of liaison.

2. A system of recording and retrieving soil moisture and other soil information so that it is available to all potential users is essential. Many potentially useful data are lost in personal files. Many relatively useless data are probably lost too, but they should be available in order that they might be evaluated for various interpretive purposes. Unless some system is developed there is a high probability of useless repetition of work and of failure to use what is available.

3. The "soil drainage classes" are not adequate for characterizing the various aspects of the soil moisture regime but they are useful where detailed information is not available.

Recommendations

This subcommittee, in cooperation with others concerned, should:

1. Develop a system of classifying the various aspects of soil moisture regimes: water table, water content, etc. in a more quantitative way. This system would be used mainly in areas where specific soil moisture regime data were needed. The slightly revised soil drainage classes would be used where data were not available.

2. Relate water table data collected by other agencies to specific soils, evaluate the need for further long-term water table data. This will involve a cooperative effort among one or more soils people from most provinces and scientists from other disciplines.

3. Assemble existing long term data on soil moisture contents, and make further measurements in order to check soil moisture contents computed from meteorological data.

4. Criteria upon which the recognition of soil drainage classes are based should be spelled out by each survey unit.

Discussion

Millette - He teaches students to delineate as many as 14 drainage classes, based on morphology and topography. A detailed study on soil moisture regimes is in progress at Macdonald College. It is important to determine the morphological features that are related closely to aspects of the soil moisture regime.

McKeague - Millette would be asked to write up drainage class criteria.

Jurdant - Characterization of the soil moisture regime should include an indication of presence or absence of seepage water. He could supply information on how to recognize seepage.

Dumanski - The groundwater observations outlined seem unrealistic. Probably we should rely on data such as the hydrogeological maps being prepared by the Research Council of Alberta.

Ehrlich - The subcommittee should compile data and interpret how it can be used.

- Water table information should be related to soil morphology.

Baril - Are soil series catalogued according to drainage classes?

Day - They are assigned to subgroups which imply drainage class.

Douglass - In the U.S. it has been found that drainage classes cannot be based upon morphology. It is necessary to know the actual moisture status of the soil.

Mackintosh - The quantification of soil moisture regime data is important. Work on relating water table fluctuations to mottling is continuing at Guelph.

de Jong - Money is not available to do this kind of work.

Rowles - Agreed that it is necessary to quantify soil moisture regime data. It is necessary also to know the dynamics of the system.

Rennie - Perhaps the water budget of a landscape unit should be considered rather than quantifying data for individual soils.

- Water budget involves many specific measurements.

I would like to thank the members of the subcommittee for their contributions of ideas and information. We appreciate the cooperation of those in other agencies and in other disciplines who supplied information. I thank G. C. Topp for recording the discussion.

Summary of Information on Soil Moisture Regimes in Canada

This summary is based upon information supplied by members of this subcommittee, scientists in the Forestry Department, and hydrologists with the Inland Waters Branch of the Department of Energy, Mines and Resources. We are aware that much relevant information has probably been missed and further sources of information are sought. Such information should be sent to the chairman of this subcommittee. Information on how the soil moisture data have been used would also be of interest.

I Water-table information

A. From soil scientists in agriculture.

1. B.C. a) Records for 4 to 10 years of water table fluctuations in 4 soils in the Fraser Valley and shorter term records for 12 other sites. The measurements were made by M. G. Driehuyzen to assess the effectiveness of drains.

2. Alta. a) Many unpublished data on water tables in the irrigated area are available from studies done at Vauxhall and Lethbridge.

   b) Published data:
   - Van Schaik and Milne 1963. Can. J. Soil Sci. 43, 135 - Upward movement of salts above a shallow water table.
   - Graveland 1970. Can. J. Soil Sci. 50, 43 - Water table in relation to applied water, and salt movement.
   - Rapp and Van Schaik 1970. Can. J. Agr. Eng. - Water table as influenced by irrigation.

3. Sask. a) Study in progress on water tables in and around a pothole.

4. Man. - Water table data over 3 or 4 years for a few soils.

5. Ont. a) Water table and associated measurements at Elora farm, by Soils Dept. at Guelph.

   b) Crown and Hoffman 1970. Can. J. Soil Sci. 50 - Water tables for 1 season in relation to morphology - 4 sites.

   c) McKeague 1965. Can. J. Soil Sci., 2 year water table, Eh, temperature and moisture data for 3 sandy and 3 clayey soils.

6. Quebec - ?

7. New Brunswick.

8. Nova Scotia a) Nowland - Current study of water table, Eh, moisture content, temperature in relation to morphology and development of soils of the Tormentine catena. Data for 1 year.

9. P.E.I. - ?

10. Nfld. a) Rayment - Water table in drained and undrained peat soils in relation to crop growth - several years.

11. Yukon and N.W.T.

B. From sources other than soil scientists in agriculture.

1. Inland Waters Branch, E.M.R. - About 500 water table wells throughout the country. Long term, continuous measurements of water tables are made. Specific locations will be supplied by Inland Waters as well as data when they are organized into summary form.

2. Canada Dept. of Forestry.

   a) Smith in B.C. - water tables measured in May, July and Sept. in 39 wells including 8 soils (Interior Western Hemlock zone?).

   b) Turnock in Man. - Southern Interlake and S.E. Man. - tamarack stands, water tables throughout 4-15 years in 6 organic and 1 mineral soil plots. Related to weather data.

   c) Oswald in Man. - water table data throughout several years for 32 sites in S.E. Manitoba. Sites range from dry to wet.

   d) Fraser in Ont. - Forestry Res. Div. Tech. Note No. 55, 1957 - water table data for soils in Petawawa forest.

3. Provincial agencies concerned with hydrology.

   B.C. - Dept. of Lands, Forests and Water Resources.
   Alta. Research Council - groundwater wells, hydrogeological maps.
   Sask. Research Council - 26 groundwater observation wells.
   Man. Dept. of Agriculture and Conservation.
   Ont. Water Resources. Many long term data on water levels in wells.
   Quebec Dept. of Natural Resources.
   N.B. Dept. of Natural Resources.

N.S. Dept. of Mines - 12 observation wells - groundwater levels in relation to climate.
P.E.I. Water Authority.
Nfld.
Yukon and N.W.T.

II. Information of soil moisture regimes other than water table data.

B.C.

- Moisture retention curves - 10 to 15 soils - Soils Dept.
- Permeability - field methods - 2 or 3 soils, cores 10 to 15.
- Current work includes in situ measurements of soil hydrologic properties (moisture retention curves) and a hydrometeorological study involving several agencies (Black, Soils Dept.)
- Permeability - auger hole method - Fraser Valley soils - Driehuyzen.

Alta.

- Moisture equivalent and wilting point - many samples.
- Hydraulic conductivities of disturbed samples - many measurements have been made at Edmonton and at Vauxhall.
- Infiltration rates, Edmonton area - Verma and Toogood, 1969. Can. J. Soil Sci. 49, 109.
- Groundwater movement (sites at Olds and Vegreville).
- 3 year data on moisture content to 4 ft., weekly readings, neutron probe, several soils at Breton.

Sask.

- Soil moisture content data at seeding time and harvest and wilting points, Swift Current. A great deal of long term data are available. Some has been published by Staple and associates: Can. J. Agr. Sci. 34, 553; Can. J. Soil Sci. 40, 80; Can. J. Soil Sci. 45, 207. Other data are available in Research Reports from Swift Current and some are unpublished in any form. The data have been related to yields.
- Long term soil moisture data are being obtained at the Matador site.
- Infiltration rate - Bisal, Can. J. Soil Sci. 47, 33.

Man.

- Moisture retention data for all classes of soils - Soils Dept.
- A few hydraulic conductivity and oxygen diffusion rate data - Soils Dept.
- Shaykewich and Zwarich, Can. J. Soil Sci. 48, 199. - Related wilting point, field capacity, bulk density - available water to particle-size-distribution organic matter and $CaCO_3$ for 39 Chernozemic soils.

Ont.

- Infiltration rate and runoff on Guelph l. - 9 yrs. Can. J. Soil Sci. 38, 44.
- Baier, Can. J. Soil Sci. 49, 181. Comparison of measured and estimated soil water contents throughout several years at C.E.F., Ottawa.
- Some soil moisture retention curves - Soils Dept. Guelph.
- Soil moisture retention data - Petawawa Forest - C.R. Clements.

Quebec

- Hamid and Warkentin. Can. J. Soil Sci. 38, 44 - lateral movement of water below the water table of Ste. Rosalie clay.

N.B.

- Many data on wilting point, moisture equivalent, porosity for all horizons of a number of soils. Soil Survey.

N.S.

P.E.I.

Nfld.

Yukon and N.W.T.

REPORT OF THE SUBCOMMITTEE ON SOIL CLIMATE IN RELATION TO SOIL CLASSIFICATION AND INTERPRETATION

A. R. Mack, Chairman

In 1968 at the seventh meeting of the C.S.S.C., Mr. Earl Bowser presented the first report of this subcommittee. In his report the subcommittee suggested that geographic areas and soil groups should be defined with more precise climatic attributes. He pointed out that a body of climatic data for various areas was being accumulated and that sophisticated computational methods were becoming available for application.

In the last several years research workers in a few provinces have been summarizing aerial data and associating it with certain soil features. However, few have organized climatic data of the soil system itself on a national basis.

Since the time of the first report in 1968, Mr. J. Clayton has been organizing meteorological soil data. He evolved a comprehensive soil climatic map and a framework for characterizing various climatic aspects of the soil regimes. Much of the data was made available through the excellent cooperation of various members of the Agrometeorology Section, C.D.A. Mr. Clayton first presented a tentative proposal for a soil climate map (1:5,000,000) and for a framework to characterize regional soil climate at the National Meeting of the Canada Soil Fertility Committee in February, 1970, Ottawa. Later, they were submitted to the Soil Climate Subcommittee of the C.S.S.C. for consideration. Suggestions from the members were received particularly as to the reasonableness of the boundary lines in each of the provinces and many of these were incorporated in the revised map (October, 1970).

The work in developing the FAO/UNESCO Map of North America and the Soil Map of Canada has necessitated serious consideration of climatic phases for characterization of map units and made it imperative that further work be done in this regard. Fortunately, concurrent with these activities by members of the C.S.S.C., was the publication of considerable data on soil temperatures from the Meteorological Branch, DOT, and a series of publications from the Agrometeorology Section, C.D.A., enabling a more sophisticated evaluation of soil moisture and temperature data from meteorological records.

From these accumulated data, a quantitative approach to characterize soil moisture and temperature was attempted which would enable correlation with similarly developing concepts of soil moisture and temperature relationships used in the classification of soils for the FAO/UNESCO project and in the classification of soils in the United States. Hopefully, it may serve as a broad framework for practical interpretation of a regional environment and as a basis for more sophisticated macro- and micro-soil climatological studies in the future. Thus, close cooperation has been maintained by Mr. Clayton with Dr. Dudal, Rome, and with Dr. Smith and Dr. Grossman in the U. S.

The Soil Climate Map of Canada reviewed by the subcommittee recognizes two separate criteria: (1) soil heat and (2) soil moisture.

(1) Soil Heat:

Soil heat relationships were used as the criterium for the initial division into "classes". The classes may be grouped with respect to severity of temperature limiting the growing conditions, e.g., Arctic; and the classes may be subdivided as to magnitude of the difference between the seasons (Continental, Maritime). Classes (soil heat) proposed:

1. Extremely Cold, Arctic - with permafrost
2. Very Cold, Subarctic - with local or discontinuous permafrost
3. Cold (Continental, Maritime)
4. Very Cool (Continental, Maritime)
5. Cool (Continental, Maritime)
6. Mild (Continental, Maritime)
7. Moderately Warm (Continental, Maritime)
8. Warm
9. Very Warm
10. Hot

To assess the soil heat criterium, soil temperature at the 50-cm depth (20 inch) was selected to provide the basic data supplemented by that from other depths (10-, 20- and 100-cm). At the 50-cm depth, variation is minimal and the general trend of mean soil temperatures of shallower depths is reflected. Data from the network of stations of the Meteorological Branch, Department of Transport, provided the best comprehensive body of soil temperatures on a comparable basis that was available for this purpose. Graphs were developed by manual and auto-computer plotter showing the temperatures at selected depths (20, 50, 100-cm) throughout a 550-day period for several of the stations. Calculations were made from the data and from these graphs of the length, degree, and intensity of various seasons of the year. The data were tabulated and grouped according to geographic regions. Aerial data from over 700 meteorological stations were also utilized, e.g., crop heat units to provide supplemental information. Incorporating this information with known physiographic features of the landscape together with natural vegetation, cultivated cropping practices, soil types, etc., a provisional map (scale 1:5,000,000) was prepared, reviewed by members of the subcommittee representing each province, and presented at the plenary session for acceptance by the C.S.S.C. subject to revision.

In addition to the proposed classes for a Soil Climate Map, the subcommittee was presented with a proposal for a framework to describe and characterize the soil temperature conditions of an area in more detail than would the map. Hopefully, selected parameters will eventually provide a quantitative basis for a climatic classification of the soil ecosystem. Table 1 presents the basis for characterizing the seasons with respect to the soil biosystem. By this approach the year is divided into seasons during which biological activity in the soil biosystem usually is active and relatively inactive. Temperature at the 50-cm depth was selected as the criterium on which to make this division, and 5°C (41°F) was taken as the temperature for separating these two main growth conditions (Seasons). Provision was made to divide the Seasons into Periods to further describe the soil heat conditions. At present, each season was divided into Periods < and > 15°C (59°F) within the Growing Season, and < and > 0°C (32°F) within the Dormancy Season.

Table 1. Characterization of the Seasons and Periods

S_1: Growing Season - the periods when the soil temperature (50 cm) is > 5°C (41°F)

P_1: Mild Growth Period

> 5°C (41°F) but < 15°C (59°F)

P_2: Thermal Growth Period

> 15°C (59°F)

S_2: Dormancy Season - the periods when the soil temperature (50 cm) is < 5°C (41°F)

P_3: Cool Dormant Period

< 5°C (41°F) but > 0°C (32°F)

P_4: Frozen Dormant Period

< 0°C (32°F)

The depth of the soil frozen during the "Frozen Dormant Period" may be expressed and coded as:

Code	Depth of Freeze
0	No freezing at 20 cm (8-inch)
1	Frozen at 20 cm (8-inch)
2	Frozen at 50 cm (20-inch)
3	Frozen at 100 cm (40-inch)

Each season or period may be characterized by parameters such as:

- Length of season or period in days
- Accumulated degree-days within the respective temperature levels
- Mean soil temperature for the months the temperature is within the respective defined levels or for December, January and February as may be stipulated.

This could later be extended if found necessary.

In order that terminology associated with time periods and temperature conditions may be consistent, descriptive terms (i.e., adjectives) were coded and assigned to specific numbers of days (months) and temperature ranges. These terms could then be used to describe or code each of the seasons or periods of the soil biosystem as to the length and intensity if its heat condition. These are presented in Tables 2 and 3. The symmetry of the time scale for long and short periods is illustrated in Figure 1.

An illustration of how these various aspects may be integrated in a classification system is presented in Chart 1 when the mean temperature is used as the classifying base for the period in question. Included also in Chart 1 are the associated biological conditions and present United States soil temperature regimes.

Table 2. Descriptive Time-scale Terminology

Code Number	Description Term	Time Months	Period Days
0	none	0	0
1	insignificant	< 0.5 months	< 15 days
2	very short	0.5-2 months	15-60 days
3	short	2-4 months	60-120 days
4	moderately short	4-6 months	120-180 days
5	moderately long	6-8 months	180-240 days
6	long	8-10 months	240-300 days
7	very long	10-11.5 months	300-345 days
8	nearly continuous	11.5-12 months	345-365 days
9	continuous	12	365 days

Table 3. Descriptive Temperature-scale Terminology

Code	Temperature (°F)	Descriptive Term
1	< 20°F	extremely cold
2	20° - < 32°	very cold
3	> 32° - 36°	cold
4	> 36° - 41°	very cool
5	> 41° - 47°	cool
6	> 47° - 59°	mild
7	> 59° - 65°	moderately warm
8	> 65° - 72°	warm
9	> 72° - 85°	very warm
10	> 85°	hot

The Temperature Climatic Coding thus is based on a combination of the Code Number for a particular Time and Temperature for a season or period.

e.g. 45 is moderately short, cool
62 is long, very cold
56 is moderately long, mild

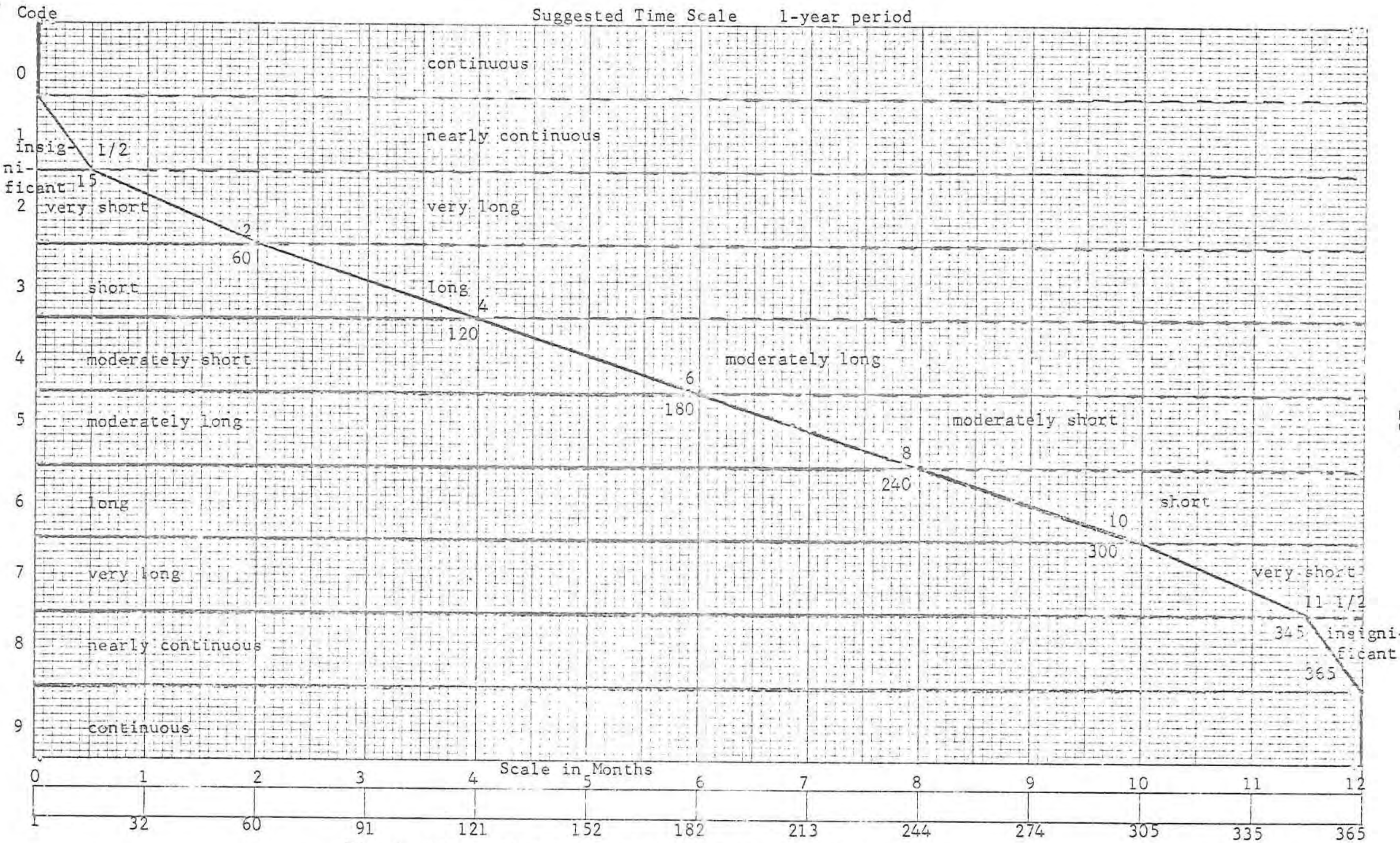


Fig. 1. Consecutive numbering of days in an ordinary year

Chart 1. Relationship of the descriptive Temperature-Scale Terminology to the association of biological conditions and Present Temperatures when mean temperature (50-cm depth) are considered

Temperature Code *	1	2	3	4	5	6	7	8	9	10
Temperature limits* °C	‹-7°	-7°-0°	0°-2°	2°-5°	5°-8°	8°-15°	16°-18°	18°-22°	22°-30°	›30°
°F	‹20°	20°-32°	32°-36°	36°-41°	41°-47°	47°-59°	59°-65°	65°-72°	72°-85°	›85°
Temperature * Description	Extremely cold	Very cold	Cold	Very cool	Cool	Mild	Moderately warm	Warm	Very warm	Hot
Associated and Biological Condition of soil Environment	FROZEN DORMANCY		COOL DORMANCY		MILD GROWING		THERMAL GROWING		HYPERTHERMIC GROWING	
	Extremely cold frozen no biologic activity	Very cold no significant biologic activity	Cold dormancy insignificant biological activity	Very cool dormancy limited growth + biological activity	cool growing conditions	mild growing conditions	Moderately warm	warm	very warm	hot
							Growing and maturing growth conditions		increasing growth limitations for specified plants	
Present American temperature Regimes	PERGELIC		CRYIC			MESIC	THERMIC		HYPERTHERMIC	
Annual period	Dry frost		Boreal							
Summer period	Moist permafrost				Dry Cryic		FRIGID			
					wet cryic 13°		Boreal			
			Cryic boreal							

* Temperature coding and description may be used to describe any time interval, whether Annual, Seasonal or selected

(2) Soil moisture:

Soil moisture relationships were used to establish subclasses within the heat classes of the Soil Climate Map. Ten divisions were mapped to differentiate a range of moisture conditions from that having free water surface (Aqueous) to that of having a very short moist period (Perarid). Provision was included in the system for 2 additional dry conditions, Aridic and Torric. A series of parameters were assigned to the divisions and used collectively in mapping the moisture subclasses (Chart 2). The Irrigation Requirement* and the Climatic Moisture Index** were used extensively as summarized in Table 4. It is recognized that the framework for a moisture characterization is still quite inadequate and future consideration must be given to aspects of surplus moisture.

Table 4. Descriptive requirements for the moisture subclass of the Moist Regime

Symbol	Moisture	Irrigation Requirement	Climatic Moisture Index
j	perarid	> 12"	< 25
h	arid	> 7.5" - 12"	25 - 45
g	semi arid	5 - 7.5"	45 - 58
f	sub-humid	2.5 - 5.0"	58 - 73
e	humic	1 - 2.5"	73 - 84
d	perhumid	0 - 1"	84 +

Irrigation Requirement in inches

Based on 50% risk. Storage capacity 2" and transpiration at .75 of potential rate.

Climatic Moisture Index

Expressing seasonal precipitation as a percentage of potential water use by annual crops.

*Soil Moisture Criteria as taken from computations by Coligado, Baier and Sly. 1968 Tech. Bull. Nos. 17-58, 61-77, Agrometeorology Section, Plant Res. Inst., Can. Dep. Agr., Ottawa, 34 pp.

**A climatic moisture index for land and soil classification in Canada. W. K. Sly. Can. J. Soil Sci. 50: 291-301. 1970.

Chart 2. Mapping Classification and Coding for Soil Moisture Subclasses

MOISTURE REGIME	AQUEOUS free water surfaces	AQUIC SOILS Saturation within capillary distance of surface including freeze period			MOIST AND SUBMOIST SOILS Moisture held at tensions from 1/3 to 15 bars with increasing periods and degree of growing seasonal deficits above $41^{\circ}F$						DRY SOILS Moisture held at tensions > 15 bars	
CLASSIFICATION	0	a	b	c	d	e	f	g	h	j	k	l
Moisture Subclass	Aqueous	PerAquic	Aquic	Sub Aquic	Perhumid	humic	subhumid	semiarid	arid	Perarid	Aridic and Xx. Xenc	Torric
descriptive conditions Associated drainage clsss. Canadian	free surface water	Saturated for very long periods Very poorly drained 6	Saturated for moderate periods Poorly drained 5	Saturated for short periods Imperfectly drained 4	Moist with no significant seasonal deficits 2 and 3	Moist with very slight seasonal deficits 1 and 2	Moist with significant seasonal deficits 1 and 2	Moist with moderately severe seasonal deficits 1 and 2	Moist with severe seasonal deficits 1 and 2	Moist with very severe seasonal deficits 1 and 2	Severe deficits with short dry domin- and periods	Severe deficits with short to long dry domin- and period
Suggested Criteria and Related Combinations Saturation Period in months	Continuous 11.5 - 12	Very long > 10	Moderately short to long 4 - 10	Very short to short < 4	insignificant < 0.5	insignificant < 0.5	none	none	none	none	Xeric none to insignificant in winter	none
Moist Period in Months	insignificant < 0.5	very short < 2	short to moderately long 2 - 8	very long to long 8 - 11.5	very short to very long 4 - 11.5	mod. short to very long 4 - 11.5	mod. short to very long 4 - 11.5 > 75% of season	mod. short to long 4 - 10 > 50% of season	mod. short mod. long 4 - 8 < 50% of season	very short to mod. long 2 - 8 < 25% of season	Xeric short moist winter period > 2 months	
Moisture deficit Period in Months in Growing Season		none	none to infrequent	infrequent not annually	none to insignificant < 0.5	insignificant to very short 0 - 2	very short 0.5 - 2	short 2 - 4	moderately short 4 - 6	moderately short to long 4 - 10	short to long 2 - 8	
Dry Period in Months		none	none	none	none	none	none	none	none or infrequent	insignificant or very short	aridic short > 2 or > 50% of period > $41^{\circ}F$	dry > 75% of growing period > $41^{\circ}F$
Criteria of irrigation deficit in inches Criteria of Climatic Moisture Index %		none none 100%	none	none	0 - 1.0" > 84	1 - 2.5" 84 - 73	2.5" - 5" 73 - 58	5" - 7.5" 58 - 45	7.5" - 12" 45 - 25	> 12" < 25		
Suggested associated Natural Vegetation in cold cool and mild continental climates	Nymphae Potamageton	Hydrophytic Scirpus Typha	Meso-Hydrophytic Salix-carex wet forest	very moist forest	Mesophytic forest	Mesophytic forest and True Prairies	Mesophytic grasses and forbs and Fresh Zerophytic forest Fescue Prairies	Xerophytic Forest Meso-Xerophytic grasses Mixed prairies	Meso to xerophytic grasses continuous sward cover Short grass prairies	xerophytic bunch-grass forbs intermittent discontinuous sward cover	Xerophytic shrubs and cacti	Sparse xerophytic growth

In summary, the soil climate may be described and coded with respect to its soil heat and moisture using terminology in Tables 1, 2, 3 and 4 and Chart 2. For a place such as Vauxhall this would be:

S_1 Growing Season: 56 h - Moderately long, mild, arid

P_2 Warm Growth Period: 37 - Short moderately warm

S_2 Dormancy Season: 43 - Moderately short, cold

P_4 Frozen Dormant Period: 32.3 - Short, very cold, frozen to 40 inches

Therefore, the total coding to represent the soil temperature and moisture condition for the seasons and periods (S_1-P_2-S_2-P_4) for Vauxhall is:

56 h - 37 - 43 - 32.3

The seasonal soil-temperature patterns for Ottawa and Swift Current illustrate the seasonal characteristics for the respective locations supplemented by associated data summarized from meteorological records (Fig. 2 and 3). A copy of the legend which accompanied the Soil Climate Map of Canada (Revised October 1970) is given in Table 5.

Reports were presented to the subcommittee meeting on October 20 by the following members of the Agrometeorology Section, C.D.A. The papers are appended to the report.

Dr. Baier: Soil temperature and soil moisture regimes in Canada.
Dr. W. Sly: Soil moisture index.
Mr. D. Williams: Computer plotting of climatic areas.

The following recommendations were approved by the subcommittee and presented to the plenary session. Moved by A. R. Mack, seconded by J. Clayton. After considerable discussion on item No. 1, they were approved by the plenary session.

<u>The subcommittee recommend:</u>

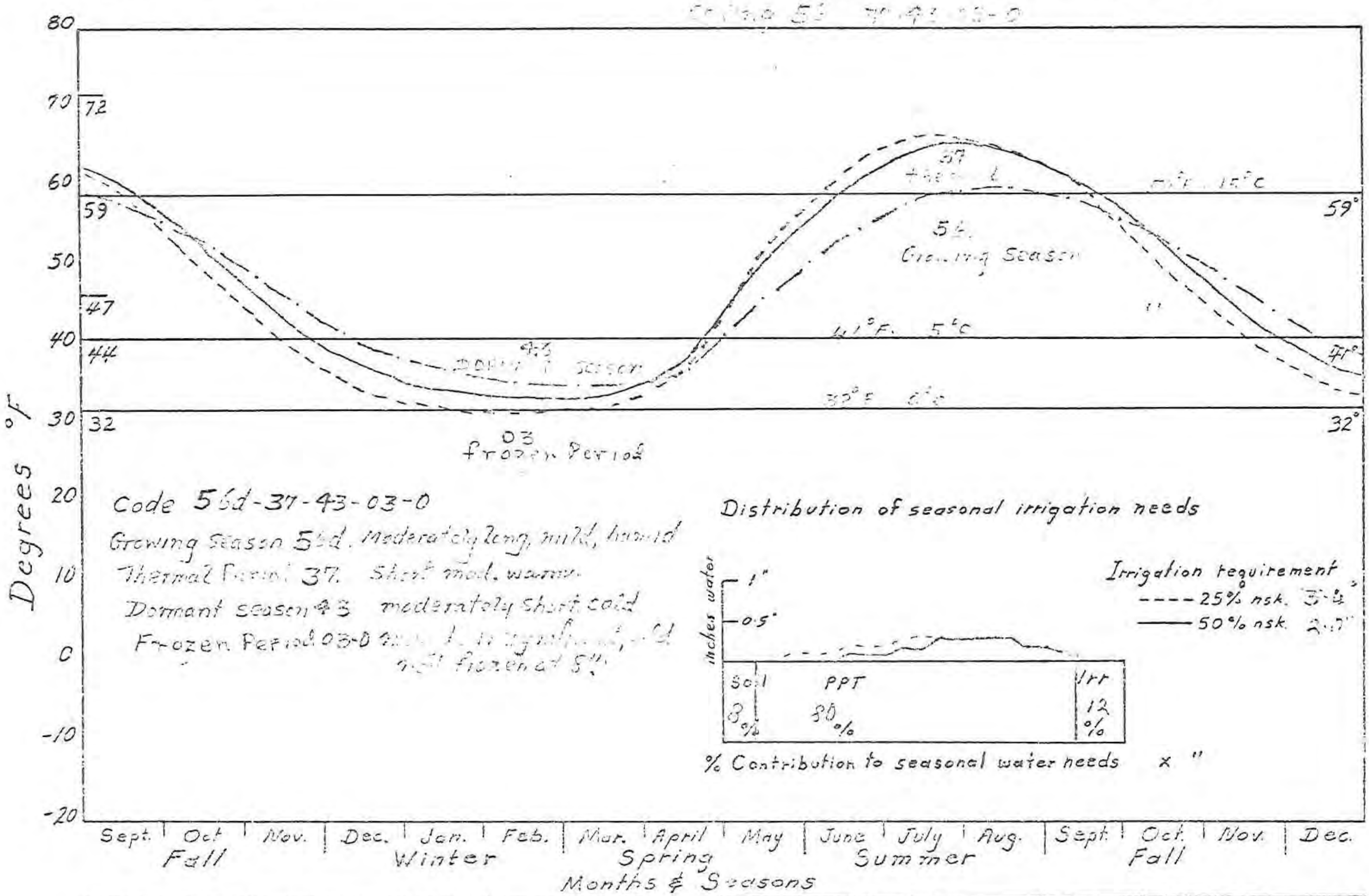
1. That the soil climate map of Canada as presented be accepted for use on a provisional basis subject to subsequent revisions within its broad framework. It is expected that it would constitute a segment of an overall environmental map of the soil-air ecosystem. The committee wishes to promote testing of parameters on which it is based.

2. The Agrometeorology Section, Plant Research Institute, in close cooperation with the Soil Research Institute and other members of the subcommittee continues the development and application of agroclimatic techniques for generating climatic data and for estimating selected parameters of the climate, the soil temperature and soil moisture regimes in Canada.

3. That information from studies being conducted on soil-climate interactions be coordinated among the university departments and research groups in Canada and encouragement be given to develop techniques for the solution of selected problems.

Fig 2. Soil Climatic Charts — Monthly Soil Temperatures

Station. Location. Soil Climate.



Data Temp.	20 cm	50 cm	100 cm
Mean ann. Soil Temp	[illegible]	[illegible]	[illegible]
Mean summer Soil Temp	[illegible]	[illegible]	[illegible]
No. of months < 32°	0	[illegible]	[illegible]
No of months > 41°	[illegible]	[illegible]	[illegible]
No of months > 59°	3.3	[illegible]	1.0

Moisture Data	Annual	Seasonal M.S
Precipitation	31	11.6
Pot. Evapotranspiration	22.9	11.3
Pot. Water requirement	[illegible]	
Irrigation requirement 50% risk level	2.0	

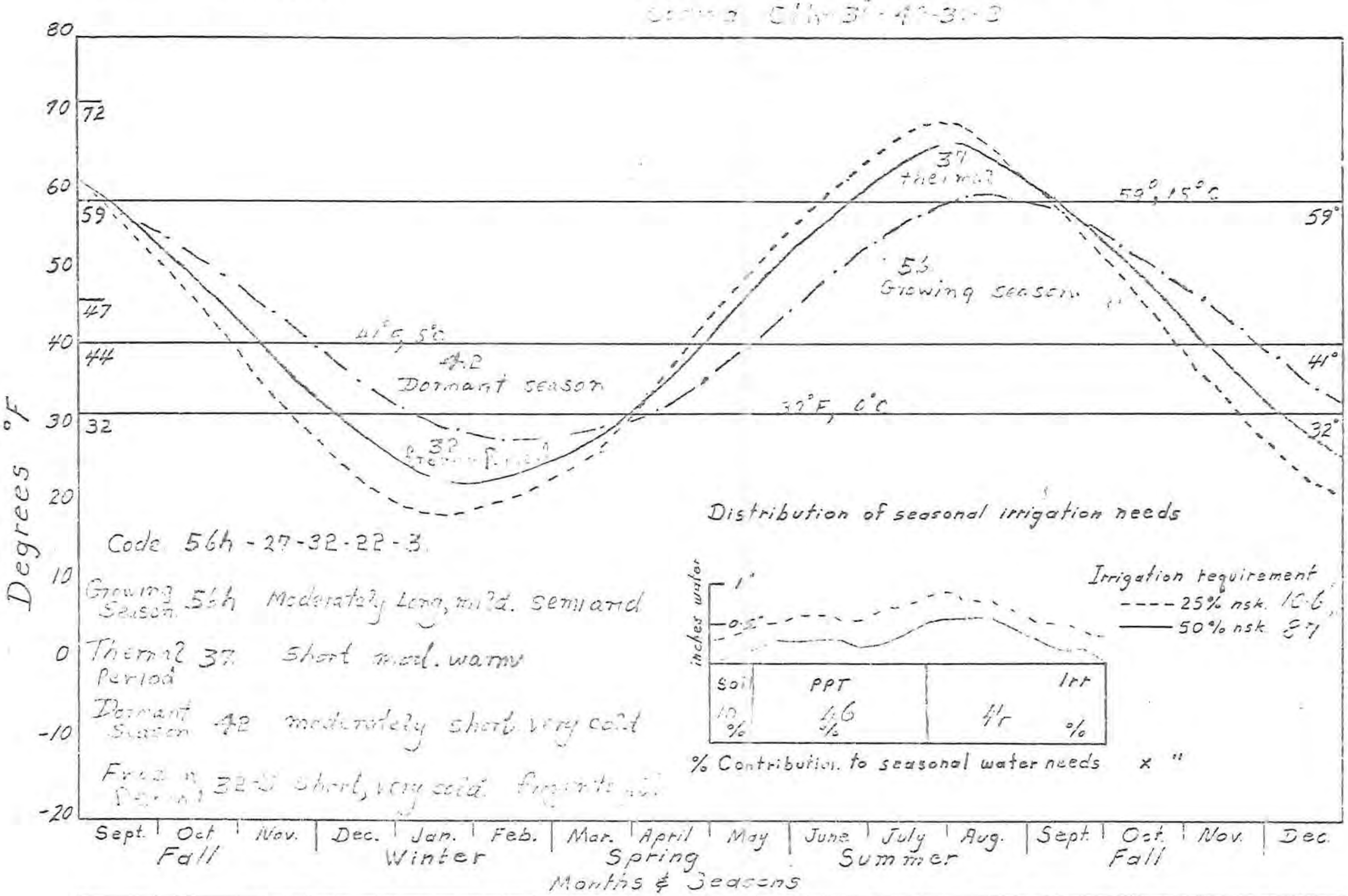
Fig 3. Soil Climatic Charts   Monthly Soil Temperatures

------ 20 cm depth
—— 50 cm depth
—·—·— 100 cm depth

Station.
SWIFT CURRENT

Location.

Soil Climate.
Ch. Moderately Cool Semiarid Continental
Code: Clh 37-42-32-3



Data Temp.	20 cm	50 cm	100 cm
Mean ann. Soil Temp	[illegible]	[illegible]	[illegible]
Mean summer Soil Temp	[illegible]	[illegible]	[illegible]
No. of months < 32°	[illegible]	[illegible]	[illegible]
No. of months > 41°	[illegible]	[illegible]	[illegible]
No of months > 59°	[illegible]	2.4	[illegible]

Moisture Data	Annual	Seasonal M.S.
Precipitation	[illegible]	[illegible]
Pot. Evapotranspiration	[illegible]	[illegible]
Pot. Water requirement	[illegible]	
Irrigation requirement 50% risk level	8.7	

Table 5. SOIL CLIMATIC MAP of CANADA.

1, 5.000.000.

LEGEND.

CLIMATIC TYPES, CLASSES & SUB-CLASSES.

C.S.S.C. October 1970.

TYPES.

A	Arctic types.	Cold Climates. Severely limited Growing Seasons with or without Permafrost.
C	Continental types.	Cold to Warm Climates with wide diurnal & Seasonal variations.
M	Maritime types	Cold to Warm Climates with modified diurnal & seasonal variations due to marine influence.
Mt	Mountain types.	Climates with complexes of varying temperature and Moisture Regimes due to significant variations in Vertical zonation or aspect.

CLASSES & TYPES. temperature Regimes.

- 1A. Extremely Cold. Arctic with permafrost beneath solum.
- 2A Very Cold. Sub-Arctic with local or discontinuous permafrost below solum
- 3C Cold Continental
- 3M Cold Maritime
- 4C VERY Cool Continental.
- 4M VERY COOL Maritime
- 5C COOL Continental.
- 5M COOL Maritime.
- 6C Mild continental.
- 6M Mild MARITIME.
- 7C Moderately WARM. Continental.
- 7M Moderately Warm Maritime
- 8C Warm Continental
- 9. Very WARM — x x
- 10 Hot. — x x

Climatic boundary coincident with Soil Map Unit Separation

Conjectural boundary, or one non-coincident with Soil Map Unit Separation

( ) boundary of areas in which inclusions of Aquic Moisture subclasses are considered to occupy significant portions, >15% of imperfectly to very poorly drained segments of the landscape.

x x Classes & Subclasses believed not to occur in Canada.

Sub-classes. Moisture regimes.

AQUEOUS Regimes. free water surfaces

- 0 Icefields
- Permanent Lakes.

AQUIC REGIMES* with saturation for significant periods within the growing season

- a. Per-AQUIC. Long periods. very poorly drained
- b Aquic. Moderate periods. poorly drained
- c Sub-Aquic. Very short periods. imperfectly drained
- (*) brackets indicate a significant occurrence within area designated. ( )

MOIST. Unsaturated Regimes. with varying periods and intensities of growing season deficits

- d Per-humid. no to insignificant deficits
- e Humid. very slight deficits
- f. Sub-Humid. significant deficits
- g. Semi-Arid. moderately severe deficits.
- h Arid. Severe deficits
- j Per-Arid Very Severe deficits. — x x

DRY REGIMES. Continuously dry for significant periods within Growing Season.

- K Aridic Very severe deficits with a dry dormancy period — x x
- KX Xeric Very severe deficit in growing Season with a moist winter period — x x
- t Torric. Dry in Hot Periods. — x x

4. That the regional members of the subcommittee be responsible for conveying information on studies pertaining to soil-climate to the chairman or other designated person for its dissemination.

5. Efforts should be continued to calculate, plot and map by computer areal distribution of the climatic parameters from site estimates by staff members of the Soil Research and Plant Research institutes.

6. The continued development of the coding system to relate quantitatively parameters of the air climate and soil climate (soil temperature and soil moisture regimes, such as deficits, surplus, length of growing season and degree days) to the proposed classes and subclasses of the Soil Climate Map.

7. Consideration should be given to collection of standardized soil temperature data and the development of physical models for estimating soil temperature and moisture regimes at various levels from standard climatic and special microclimatic observations.

8. Liaison be maintained with developments in remote sensing techniques especially in its application to soil-climatic studies.

9. Continued cooperation with similar projects undertaken by comparable committees in the U. S. and elsewhere.

SOIL TEMPERATURE AND SOIL MOISTURE REGIMES IN CANADA

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Abstract

This report describes techniques which require standard climatic data as input and provide parameters of the soil temperature and soil moisture regimes as presently used in the Canadian soil climatic coding system. Daily air or soil temperatures are interpolated from monthly averages and plotted. Dates when these daily temperatures cross selected thresholds are tabulated. These dates are then used to define the beginning and end of the growing, dormant and freeze seasons. Because of the complex interactions between air temperature, radiation and snow cover, air temperature alone is not a reliable estimator for soil temperature in Canada. A computer technique is available for analyzing the soil moisture regime for periods as determined by air or soil temperature thresholds from daily standard climatic data. The tabulated output contains for each of six storage capacities: average and probable spring soil moisture contents, growing season deficits and surplus from precipitation as well as from rain for the growing, dormant and freeze seasons. Results from these analyses for 67 selected stations in Canada are briefly discussed. Suggestions are offered as to future applications of these techniques in a modified Canadian soil climatic coding system.

Introduction

This analysis of the soil climate at selected locations across Canada initiated from the 1968 recommendations of this subcommittee for a much more precise definition of geographic areas and soil groups in terms of soil temperature and moisture characteristics. The committee suggested to prepare information on:

(1) Complete average and probable temperature and moisture data.
(2) Temperature conditions and surplus water available for leaching.
(3) Frequency and duration of conditions of deficit moisture.

In the first approach, J. S. Clayton developed a soil climatic coding and classification system using soil temperature observations and agroclimatic data mainly derived from techniques by staff members of the Agrometeorology Section, Plant Research Institute. The derived data included estimates of degree days (Williams and Sharp, 1967), potential evapotranspiration (Baier and Robertson, 1965), irrigation requirements (Coligado et al. 1968) and a climatic moisture index (Sly, in press). The soil climatic classes were then defined in terms of seasonal temperatures and subdivided according to moisture conditions. A preliminary soil climatic map was prepared by the Soil Research Institute. This map is unique and presents for the first time combined information derived from soils and climatic data. Certain limitations result from a lack of data and techniques. In particular, monthly soil temperature averages were available only for 44 stations over various lengths of time. Soil moisture criteria were taken from irrigation requirements and a moisture index computed on a calendar basis (April 30 to September 30) and not for the growing season as determined by air or soil temperatures.

Techniques are being developed for estimating soil temperature from air temperature records. From these data together with observed daily precipitation and computed potential evapotranspiration, additional soil moisture characteristics were obtained including average and probable moisture contents at the beginning of the growing season, deficit and surplus resulting from precipitation and from rain only during the growing, dormant and freeze seasons. These techniques, which require only standard climatic data as input, will be briefly described and preliminary results will be presented for 67 selected stations across Canada.

Procedure

For quick reference, a definition of terms used in the soil temperature and soil moisture analyses is given on page 42.

Soil Temperature

The soil temperature at 50 cm (20 inches) depth was taken as the control for the beginning and end of the seasons used in Clayton's soil climatic coding. This depth was selected because the diurnal temperature variations are small but still reflect the weather conditions during the preceding days. Researchers in the U. S. also used this control depth in their soil-climate classifications. For comparison purposes, soil temperature analysis based on available records are here presented for depths of 20 cm (8 inches), 50 cm (20 inches) and 100 cm (40 inches) as well as for air temperatures in the screen at 4 feet height.

The present soil climatic coding system makes use of soil temperature and soil moisture characteristics during four seasons which are based on the average soil temperature at 50 cm depth, as follows:

Growing season	> 41°F	(5°C)
Thermal season	> 59°F	(15°C)
Dormant season	< 41°F	(5°C)
Freeze season	< 32°F	(0°C)

A special computer program (B121) was developed which requires as input average monthly air or soil temperatures, interpolates daily values and outputs the information necessary for the soil climatic coding in tables and plottings. Mathematical techniques used in these computations were described earlier by Williams and Sharp (1967). Examples for the program output are given for air temperature (Fig. 1) and soil temperature at 50 cm depth (Fig. 2) at Ottawa.

At present, monthly long-term average soil temperatures at 50 cm depth are available for some 45 stations but air temperatures for more than 1,200 stations. Originally, it was hoped that missing soil temperature data could be obtained in time for this study from a model being developed by Mr. Ouellet of this Section. Because of the complexity of such a model and the interaction between air temperature, soil temperature and other climatological variables especially snow cover, it soon became clear that more research and time would be required before satisfactory estimates can be expected.

While this model approach is still pursued for various purposes and future large-scale applications, a shortcut technique was developed for estimating the dates when soil temperatures cross the selected thresholds in spring as well as in fall, from the corresponding dates for air temperature. Fairly good relationships were obtained between the soil and air temperature dates except for 32°F in fall (Table I). Visual inspection of the observed data revealed that average monthly soil temperatures at 50 cm depth did not drop below 32°F at stations situated in British Columbia, Southern Ontario, Western Quebec and in the Maritimes. By comparison with monthly average air temperature maps published by the Meteorological Service, it was found that the 18.5°F isotherms of mean air temperature for December separated fairly well areas with frost and no frost at 50 cm depth during the winter. The exception is for southern Alberta where the mean air temperature for December does not drop below 18.5°F but the soil temperature late in the winter does drop below 32°F probably because of lack of snow. Consequently, missing soil temperature data were estimated either by regression equations and, if necessary, adjusted to conform with available data from adjacent stations. For those stations located in areas where the December mean air temperature is greater than 18.5°F (except Prairies), it was assumed that the soil temperature remains above 32°F throughout the year. Improved estimates of these data can be expected when the earlier described soil temperature model will be completed.

Soil Moisture

The present version of the soil climatic coding system uses only irrigation requirements and moisture index as criteria for the subclasses. New parameters of the moisture regime such as spring soil moisture contents, deficits and surplus for periods as determined by soil temperatures have become available from a special computer program (B133). The technique described by Baier and Russelo (1968) for calculating risks of irrigation requirements from observed daily precipitation, maximum and minimum temperatures, and estimated potential evapotranspiration (PE), was modified. Periods are now based on dates when the soil temperature at 50 cm depth crosses the selected thresholds. At those stations where the soil temperature at 50 cm depth does not drop below 41°F, a dormant season lasting from December 1 to March 15 was assumed.

The program outputs probable values and arithmetic means of the following moisture criteria:

(1) Soil moisture contents at the beginning of the growing season
(2) Growing season deficit
(3) Growing season precipitation
(4) Growing season potential evapotranspiration (PE)
(5) Growing season surplus from precipitation
(6) Dormant season precipitation

(7) Dormant season PE
(8) Dormant season surplus from precipitation
(9) Freeze season precipitation
(10) Freeze season PE
(11) Freeze season surplus from precipitation
(12) Growing season rain
(13) Growing season surplus from rain
(14) Dormant season rain
(15) Dormant season surplus from rain
(16) Freeze season rain
(17) Freeze season surplus from rain

Examples for the program output are given for Swift Current when the growing season is based on air temperature (Table II) or on soil temperature at 50 cm depth (Table III).

Since the precipitation data used as input did not distinguish between rain or snow, a simple test had to be developed for this separation. Through a special data inspection program, it was found that the daily maximum temperatures when smoothed over 5 days can be used as a criteria whether the precipitation is in the form of rain or snow. Different threshold values had to be used in fall and spring and in different regions of Canada. Through repeated computer runs with various thresholds and by comparison between estimated and published snowfall data, it was found that precipitation can be expected to occur as snow when the daily maximum temperature is below the following thresholds:

Region	Fall July - December	Spring January - June
"Cold" stations:		
Central B.C., Prairies, Western Ont.	< 41°F	< 45°F
"Warm" stations:		
Southern B.C., Eastern Ont., Que., Maritimes	< 33°F	< 35°F

The arbitrary developed thresholds were verified by comparing average annual amounts of observed snowfall (Meteorological Branch, 1967) with the estimates from daily computations over 30 years at 67 stations. At 55 stations the errors were less than ± 1 inch, at 11 stations ± 2 inches and at one station (Creston, B. C.) it was -2.7 inches.

In this study, the data on moisture contents, deficit and surplus are given for storage capacities of 1, 2, 3, 4, 5 and 6 inches and for a consumptive use factor of 0.75.

Results

The results from the soil temperature analysis are summarized in Tables 1 - 4 and those from the soil moisture analysis in Tables 5 - 15. In addition, detailed information is tabled but not presented in this report, as follows:

(1) Computer plottings of daily interpolated air temperatures for 89 stations.

(2) Computer plottings of daily interpolated soil temperatures at 20 cm, 50 cm and 100 cm depths for 44 stations.

(3) Tables of average and probable spring soil moisture, growing season deficit and surplus from precipitation or rain for the growing, dormant and freeze seasons at 67 stations based on (1) air temperature and (2) soil temperature at 50 cm depth.

Highlights of the results are discussed in the following paragraphs. Emphasis is here on the "differences" in the results caused by using either air or soil temperature as control for the length of the growing season. In the following discussion of the results, "differences" refer to this effect unless otherwise stated.

Air vs. soil temperature (50 cm)

The computed data derived from monthly observed air temperatures (Table 1) and soil temperatures at 50 cm depth (Table 3) give useful information as to the selection of either air or soil temperatures for classification purposes.

In spring, the date when the soil temperature at 50 cm depth exceeds 41°F lags behind the corresponding date for air temperature by 38 days at Fort Simpson, 20 - 30 days over the northern and 10 - 20 days over the southern sections of the Prairies, and 5 - 15 days in eastern Canada. In fall, this lag is in western Canada (10 - 20 days) shorter, but in eastern Canada (20 - 30 days) longer than the lag in spring. Consequently, the length of the growing season when based on soil temperature (> 41°F) differs remarkably from that based on air temperature across Canada. It is 33 days shorter at Fort Simpson and up to 10 days shorter on the Prairies. In eastern Canada this period is 1 - 3 weeks longer, at St. John's as much as 32 days.

These wide variations in the lengths of the growing seasons based on either mean air or soil temperatures clearly show that air temperature alone is not a reliable indicator for soil temperature. It is obvious that a rather complex model is required which accounts for these variations mainly caused by different air masses and interactions between radiation, air temperature, snow cover and soil temperature distribution.

Spring soil moisture

In spite of the variations in the dates for air and soil temperatures, the differences in soil moisture contents at the beginning of the growing season based on either air or soil temperature exceeding 41°F are less pronounced (Table 8). In fact, there is almost no difference in B. C. where the storage is recharged to capacity every winter. On the Prairies, soil moisture is not restored to capacity and differences in moisture contents are as much as 1 inch. In eastern Canada, the soil moisture contents in spring are close to capacity every year and there is no difference in the contents at either date. This pattern is caused not only by the rate of recharge during winter but also by the net loss of moisture resulting from the balance between precipitation and PE in spring during the period as determined by the dates when air and soil temperatures exceed 41°F.

Growing season deficit

Whether air or soil temperature was used in controlling the beginning and end of the growing season resulted in almost the same growing season deficits for a given storage capacity and station (Table 9). This is so because deficits are negligible in spring and fall during the period of time when soil temperature lags behind air temperature. There are, however, significant differences in deficits due to storage capacity and between stations. Highest deficits (close to 10 inches for 2 inch storage capacity) occur in the interior valleys of B. C., in southern Alberta and in Saskatchewan, whereas the average deficits are almost nil in the Maritimes.

Surplus

Differences in surplus from precipitation during the growing season due to length of growing season are small in western Canada, although the absolute surplus data here vary from 30 inches in the Lower Fraser Valley to almost nil over the southern parts of the Prairies (Table 10). In eastern Canada, surplus is up to 5 inches higher when the growing season is controlled by soil rather than air temperatures. Absolutely, average surplus (e.g. for 2 inch storage) is about 4 - 6 inches in Ontario, 8 - 10 inches in Quebec and exceeds 10 inches in the Maritimes.

Differences in surplus from precipitation are mostly less than 2 inches whether the growing season is controlled by air or soil temperature (Table 11). Average surplus (2 inch capacity) ranges from about 28 inches in the Lower Fraser Valley to less than 2 inches in Saskatchewan, it exceeds 10 inches in Ontario and Quebec and 20 inches in N. B. and Nfld.

Table 12 gives surplus from precipitation (rain plus snow) during the freeze season, that is when the mean air or soil temperature is below 32°F. This situation occurs when the soil is assumed to be frozen but the daily air temperature is above the thresholds (page 38) so that snow melts and precipitation falls as rain. No surplus under all six storage capacities indicates that there is no freeze season at this station.

Areas with light to moderate surplus during the freeze season are northern Alberta, Manitoba and western Ontario. Substantial surplus occurs in eastern Ontario, Quebec and in the Maritimes but here only when the freeze season is based on air temperature.

Finally, Tables 13 - 15 contain data on surplus from rain during the growing, dormant and freeze seasons. The tables are self-explanatory and clearly show the distribution of surplus from rain across Canada and the differences due to the use of air or soil temperature as control. The corresponding average surplus from snow can be derived by subtracting surplus rain from surplus precipitation data. This additional information should be useful in climatic interpretations in relation to runoff, drainage and soil leaching problems.

Conclusions

The purpose of this report is to describe the techniques used for analyzing the soil temperature and soil moisture regimes and to interpret some results in view of their possible use in a more detailed coding system for soil classification. An interpretation and discussion of all the data available is beyond the scope of this paper. Some thoughts come to my mind as to the present status and future steps to be taken in our efforts for utilizing climatic data in soil classification work.

1. Computer techniques and climatic data are available for analyzing climate in terms of average and probable data on spring soil moisture content, deficits and surplus from precipitation and rain for periods as determined by observed air temperature or estimated soil temperature.

2. Air temperature alone is not a reliable indicator of the soil temperature at 50 cm depth since the relationship between air and soil temperatures is affected by soil characteristics, radiation, snow cover, soil moisture and other environmental factors. A soil temperature estimator model is urgently required. In the meantime, use can be made of relationships between the dates when air and soil temperatures cross certain thresholds.

3. The differences in air and soil temperature dates have comparatively little effect on parameters of the moisture regime when these are computed for seasons determined by temperature thresholds.

4. The efficiency of the new soil moisture regime parameters in the present coding system has as yet not been tested. Data for 67 stations across Canada are available for such an evaluation. Shortcut methods have to be developed before use can be made of these parameters in large-scale applications of the long-term average climatic data available for 1200 stations in Canada.

5. Results from the soil temperature and soil moisture analyses should be mapped. Such maps have been prepared under an ARDA contract for those climatic parameters which are employed in the present coding system. Mapping of the new parameters should be performed by modern computer techniques. Staff members of the Agrometeorology Section, Plant Research Institute, are already engaged in a study of data analysis and plotting by computer with the assistance of trained staff and equipment available to the Soil Research Institute.

Acknowledgment

The data processing staff of this Section wrote the programs and arranged for data processing by the Canada Department of Agriculture Data Processing Service. Thanks are due to Dr. A. R. Mack and Mr. J. S. Clayton of the Soil Research Institute and Mr. Sly of this Section for valuable suggestions and comments. Mr. A. Taylor, a C.D.A. summer student working in the Plant Research Institute, contributed to this study by preparing data and writing programs for testing and summarizing results.

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Definition of terms used in the soil temperature and soil moisture analyses

Growing Season -	Period between first and last dates of a mean daily air or soil temperature at 50 cm depth > 41°F (5°C).
Dormant Season -	Period between first and last dates of a mean daily air or soil temperature at 50 cm depth ≤ 41°F (5°C).
Freeze Season -	Period between first and last dates when mean daily air or soil temperature at 50 cm depth ≤ 32°F (0°C). Note that freeze season is part of dormant season.
Precipitation -	Rain plus snow.
Rain -	Precipitation is considered as rain if the maximum air temperature smoothed over 5 days is ≥ 41°F from 1 July to 31 December and ≥ 45°F from 1 January to 30 June for "cold" stations and ≥ 33° and ≥ 35° respectively at the "warm" stations.

Snow - Precipitation is considered as snow if the maximum air temperature smoothed over 5 days is < 41°F from 1 July to 31 December and < 45°F from 1 January to 30 June at the "cold" stations and < 33° and < 35° respectively at the "warm" stations.

Spring Soil Moisture - Soil moisture content at the beginning of the growing season as defined above for storage capacities as indicated.

Growing Season Deficit - Accumulated deficits during the growing season for storage capacities as indicated and consumptive use factor of 0.75.

Surplus - Accumulated surplus water on days when soil moisture exceeds storage capacity as indicated.

Water Balance Computation - Spring soil moisture deficits and surplus were calculated by a daily climatological water budget which requires as input daily precipitation and estimated potential evapotranspiration as described by Baier and Russelo (1968). All data are given in inches and for selected probability levels as indicated at the top of the page: 10, 25, 50, 75 and 90 percent probability. Lowest and highest observations indicate the lowest and highest computed values in any particular year during the 30-year period (1931-1960).

Mean - The arithmetic mean over 30 years.

50% probability - The median value for all cases of which non-zero data are available. Years with zero values are excluded in the computation of all data as described by Baier and Russelo (1968).

TABLE 1 AIR TEMPERATURES IN DEG F

STATION	MEANS SEASON	MEANS YEAR	DEGREE DAYS >32	DEGREE DAYS >41	DEGREE DAYS >59	NO OF DAYS >32	NO OF DAYS >41	NO OF DAYS >59	DATES >32 FRM	DATES >32 TO	DATES >41 FRM	DATES >41 TO	DATES >59 FRM	DATES >59 TO
ABBOTSFORD	61.6	49.5	6405	3469	267	365	262	93	1	365	63	324	163	255
AGASSIZ	62.8	50.4	6749	3821	395	365	266	106	1	365	62	327	158	263
CHILLIWACK	62.9	50.3	6709	3705	407	365	264	107	1	365	63	326	157	263
CRESTON	63.6	45.0	5302	3209	451	261	206	87	63	323	92	297	164	250
FORT ST JOHN	58.8	35.2	4018	2286	80	208	175	47	94	301	111	285	181	227
HEDLEY	64.5	45.8	5627	3465	539	265	215	99	60	324	86	300	158	256
KAMLOOPS	68.4	48.2	6405	4159	944	276	226	125	56	335	79	304	136	260
NEW WESTMINSTER	62.8	50.4	6765	3742	387	365	267	103	1	365	61	327	158	260
PRINCE GEORGE	56.9	38.0	3876	2063	0	222	179	14	86	307	106	287	193	206
PRINCETON	60.9	42.2	4814	2805	222	246	200	71	69	314	95	294	173	244
SAANICHTON	60.5	49.4	6361	3287	172	365	272	77	1	365	66	338	172	248
STEVESTON	60.8	49.0	6257	3274	195	365	259	80	1	365	66	324	169	248
SUMMERLAND	66.9	48.0	6196	3940	794	284	225	120	56	339	81	305	142	261
VANCOUVER	62.6	50.1	6641	3564	343	365	273	96	1	365	60	335	157	252
WHITEROCK	59.7	48.7	6128	3064	97	365	278	66	1	365	64	344	175	240
WISTERIA	54.3	36.6	3351	1641	0	219	164	0	88	306	120	283	365	1
FT. SIMPSON	59.0	24.9	3418	1994	113	172	143	51	114	265	126	268	173	223
BEAVERLODGE	57.9	35.7	3878	2155	38	209	173	38	95	303	113	285	182	219
CALGARY	58.8	38.3	4160	2307	114	217	180	47	92	308	111	290	182	228
CAMPSIE	57.9	34.7	3853	2123	55	209	174	38	94	302	111	284	182	219
EDMONTON	60.0	36.6	4280	2498	160	213	181	58	92	304	108	288	175	232
FT. VERMILION	58.9	29.0	3688	2117	99	188	158	49	104	291	110	276	176	224
HANNA	61.2	36.8	4364	2594	259	212	179	65	93	304	109	287	172	236
HIGH PRAIRIE	58.4	34.5	3908	2192	67	207	173	42	95	301	112	284	181	222
LACOMBE	59.2	36.1	4069	2319	123	211	177	49	94	304	111	287	179	227
LETHBRIDGE	62.6	41.7	4866	2945	364	232	196	76	85	316	103	298	169	244
MANY BERRIES	64.3	39.9	4946	3096	512	219	189	83	90	308	105	293	165	247
MEDICINE HAT	65.4	41.5	5269	3357	599	227	197	93	86	312	101	297	151	249
INDIAN HEAD	63.0	35.6	4532	2791	389	208	178	78	96	303	111	288	165	242
KAMSACK	62.5	33.7	4399	2696	353	203	174	76	99	301	113	286	167	242
MELFORT	61.5	33.4	4217	2545	272	200	170	69	100	299	116	264	169	237
OUTLOOK	64.1	37.2	4803	3018	474	212	184	85	93	304	107	290	160	244
REGINA	62.8	35.3	4482	2763	377	206	175	77	96	301	111	285	166	242
SASKATOON	63.4	35.6	4601	2853	419	208	180	79	95	302	109	283	164	242
SCOTT	60.6	33.7	4147	2444	216	204	173	61	97	300	112	264	174	234
ST. WALBURG	59.0	32.1	3855	2189	119	200	169	48	99	298	114	282	180	227
SWIFT CURRENT	63.1	38.4	4648	2852	409	214	183	76	93	306	110	292	168	243
BRANDON	64.2	35.8	4719	2964	484	209	180	85	96	304	110	289	160	244
MORDEN	66.4	38.2	5145	3341	691	214	186	100	94	307	109	294	150	251
PORTAGE	64.9	37.3	4849	3049	549	213	185	86	95	307	111	295	159	244
THE PAS	61.2	31.2	3986	2384	279	193	162	65	106	298	122	263	173	237
WINNIPEG	65.3	36.5	4920	3146	588	210	183	92	96	305	110	292	157	248
ARMSTRONG	59.0	31.0	3596	2025	122	193	154	53	106	298	128	261	176	228
BELLEVILLE	68.4	45.7	6027	3933	939	253	212	119	79	331	108	311	144	262
DELHI	68.0	46.5	6057	3924	903	260	215	119	75	334	98	312	146	264
FT. FRANCIS	67.8	38.9	5308	3512	646	213	186	109	95	307	109	294	159	247
GUELPH	66.3	44.5	5629	3591	719	247	206	110	83	329	102	307	150	259
HARROW	70.7	48.8	6669	4471	1250	267	222	133	71	337	94	315	139	271
KAPUSKASING	60.6	33.3	3994	2341	205	201	164	67	104	304	124	267	169	235
NORTH BAY	63.3	38.9	4721	2900	404	221	183	87	95	315	112	294	160	246
OTTAWA	67.0	42.0	5545	3592	763	233	199	111	88	320	103	301	145	255
VINELAND	69.0	48.1	6342	4128	1649	271	222	123	71	341	97	318	147	269
WHITE RIVER	58.8	33.0	3729	2104	86	198	161	52	105	302	120	284	176	227
AMOS	60.1	33.5	3953	2506	162	202	164	64	104	305	122	265	170	233
LA. POCATIERE	63.2	39.5	4695	2639	410	227	184	85	93	319	114	297	163	247
L.ASSOMPTION	66.3	41.4	5427	3476	700	234	196	108	69	322	105	300	148	255
LENNOXVILLE	64.5	41.1	5138	3190	516	236	195	96	88	323	106	300	155	250
NORMANDIN	60.4	34.0	4042	2370	185	205	168	66	105	309	121	288	169	234
BATHURST	63.0	39.4	4644	2607	412	225	181	80	95	319	114	295	167	246
FREDERICTON	63.9	41.5	5055	3098	478	238	193	91	87	324	108	300	161	251
MONCTON	62.9	41.4	4819	2906	391	236	188	86	90	325	113	300	165	250
ST. JOHN	60.9	41.9	4723	2729	241	246	197	74	85	330	112	308	174	247
KENTVILLE	63.8	44.1	5279	3198	492	253	207	92	82	334	107	313	164	255
NAPPAN	62.2	42.0	4863	2872	344	244	198	82	88	331	111	308	169	250
CHARLOTTETOWN	63.7	43.0	5113	3114	511	246	198	88	89	334	114	311	169	256
SUMMERSIDE	63.0	42.1	4913	2963	441	240	193	85	92	331	116	308	170	254
ST. JOHNS	56.6	40.4	3835	1949	59	240	170	43	96	335	131	305	192	234

TABLE 2 SOIL TEMPERATURES 20 CM

STATION	MEANS SEASON	MEANS YEAR	DEGREE DAYS >32	DEGREE DAYS >41	DEGREE DAYS >59	NO OF DAYS >32	NO OF DAYS >41	NO OF DAYS >59	DATES >32 FRM	DATES >32 TO	DATES >41 FRM	DATES >41 TO	DATES >59 FRM	DATES >59 TO
PRINCE GEORGE	57.5	42.6	3960	2094	20	275	174	36	81	359	125	298	194	229
SAANICHTON	65.3	53.6	7908	4620	712	365	351	131	1	365	28	13	143	273
SUMMERLAND	69.6	51.6	7196	4562	1155	365	244	136	1	365	84	327	139	274
VANCOUVER	66.0	53.2	7770	4527	757	365	322	132	1	365	33	354	142	273
FT. SIMPSON	55.3	34.9	2813	1455	0	177	127	0	122	298	143	269	365	1
BEAVERLODGE	56.6	40.6	3583	1669	0	226	162	21	104	329	128	289	202	222
CALGARY	60.0	41.8	4183	2431	189	238	169	73	80	322	124	292	177	249
FORT VERMILION	60.3	40.1	3855	2212	187	212	157	67	105	316	127	283	171	257
LETHBRIDGE	62.1	44.4	4853	2809	365	281	185	84	62	342	116	300	171	254
OUTLOOK	62.5	40.2	4464	2703	370	220	173	80	97	316	120	292	168	247
REGINA	59.7	40.6	4105	2340	222	226	169	62	100	325	128	296	182	243
SASKATOON	62.2	40.6	4550	2760	320	232	174	82	82	313	116	289	164	249
SWIFT CURRENT	64.4	41.9	4896	3022	543	231	186	86	92	322	114	299	165	250
WINNIPEG	59.6	42.0	4271	2446	202	244	171	73	101	344	134	304	179	251
GUELPH	63.7	47.4	5665	3554	491	329	215	103	73	36	111	325	161	263
HARROW	68.0	50.5	6822	4372	1060	333	236	132	64	28	106	335	150	261
KAPUSKASING	61.1	44.9	4741	2618	264	365	177	84	1	365	127	303	169	252
OTTAWA	64.1	46.8	5445	3529	510	309	201	104	75	18	117	317	157	260
LA. POCATIERE	60.9	44.3	4633	2673	246	269	187	78	366	1	123	309	172	249
NORMANDIN	57.5	42.6	3949	2140	37	285	164	44	107	19	141	304	193	236
FREDERICTON	64.8	46.1	5286	3278	584	281	192	103	75	355	121	312	158	260
KENTVILLE	63.6	46.8	5441	3206	503	360	202	94	65	59	116	317	167	260
CHARLOTTETOWN	59.8	46.0	5169	2816	202	365	208	76	1	365	123	330	180	255
ST. JOHNS	55.5	44.0	4405.	2139.	0	365	197	7	1	365	131	327	206	212

TABLE 3 SOIL TEMPERATURES 50 CM

STATION	MEANS SEASON	MEANS YEAR	DEGREE DAYS >32	DEGREE DAYS >41	DEGREE DAYS >59	NO OF DAYS >32	NO OF DAYS >41	NO OF DAYS >59	DATES >32 FRM	DATES >32 TO	DATES >41 FRM	DATES >41 TO	DATES >59 FRM	DATES >59 TO
PRINCE GEORGE	55.0	43.5	4223	1958	0	365	184	0	1	365	131	314	365	1
SAANICHTON	63.9	53.8	8007	4722	589	365	365	126	1	365	1	365	151	277
SUMMERLAND	69.2	52.7	7665	4771	1196	365	258	142	1	365	84	341	143	284
VANCOUVER	63.2	53.1	7738	4453	494	365	365	123	1	365	1	365	155	277
FORT SIMPSON	47.4	35.0	2039	742	0	188	110	0	135	322	164	273	365	1
BEAVERLODGE	54.6	41.1	3516	1714	0	250	163	0	107	356	136	298	365	1
CALGARY	57.5	42.3	4036	2211	43	243	172	51	89	340	131	302	194	246
FORT VERMILION	58.4	40.7	3726	2041	88	223	156	51	108	330	136	291	187	237
LETHBRIDGE	60.8	45.3	4970	2763	278	307	198	80	61	367	116	313	176	255
OUTLOOK	59.0	41.1	4177	2327	164	236	178	61	99	334	129	305	183	243
REGINA	55.1	40.2	3639	1880	23	239	161	34	107	345	145	305	204	237
SASKATOON	61.1	42.3	4544	2704	273	247	178	85	84	338	121	298	171	255
SWIFT CURRENT	61.7	42.9	4767	2813	356	246	191	77	93	338	121	311	176	252
WINNIPEG	57.8	42.5	4188	2309	115	256	172	62	105	360	140	311	189	250
GUELPH	60.9	47.6	5730	3149	284	365	224	92	1	365	114	337	173	264
HARROW	65.7	50.8	6906	4236	670	365	245	129	1	365	103	347	158	286
KAPUSKASING	58.3	45.0	4803	2409	94	365	185	66	1	365	131	315	165	250
OTTAWA	62.7	47.5	5700	3289	419	365	211	102	1	365	117	327	164	265
LA POCATIERE	58.5	44.3	4535	2448	109	324	189	64	98	48	139	318	185	248
NORMANDIN	56.1	42.8	3972	2026	0	356	168	20	100	455	142	309	204	223
FREDERICTON	62.3	46.5	5331	3109	388	365	201	94	1	365	121	321	168	261
KENTVILLE	62.8	47.5	5706	3287	476	365	212	97	1	365	114	325	170	266
CHARLOTTETOWN	56.5	45.4	4932	2459	25	365	208	44	1	365	130	337	200	243
ST. JOHNS	53.2	44.1	4448	1963	0	365	202	0	1	365	136	337	365	1

TABLE 4 SOIL TEMPERATURES 100 CM

STATION	MEANS SEASON	MEANS YEAR	DEGREE DAYS >32	DEGREE DAYS >41	DEGREE DAYS >59	NO OF DAYS >32	NO OF DAYS >41	NO OF DAYS >59	DATES >32 FRM	DATES >32 TO	DATES >41 FRM	DATES >41 TO	DATES >59 FRM	DATES >59 TO
PRINCE GEORGE	51.6	44.5	4580	1823	0	365	206	0	1	365	140	345	365	1
SAANICHTON	60.8	53.7	7972	4687	324	365	365	113	1	365	1	365	174	286
SUMMERLAND	66.9	53.4	7856	4778	1059	365	278	140	1	365	85	362	155	294
VANCOUVER	60.0	53.0	7688	4403	222	365	365	100	1	365	1	365	180	279
FORT SIMPSON	36.9	33.8	1008	62	0	179	52	0	172	350	215	266	365	1
BEAVERLODGE	49.1	41.1	3357	1236	0	365	166	0	1	365	152	317	365	1
CALGARY	53.7	42.1	3765	1835	0	294	174	0	104	28	141	314	365	1
FORT VERMILION	52.3	40.5	3221	1503	0	266	154	0	126	14	152	305	365	1
LETHBRIDGE	55.1	45.2	4845	2224	0	365	209	0	1	365	126	334	365	1
OUTLOOK	52.3	41.3	3670	1724	0	267	176	0	103	4	147	322	365	1
REGINA	49.1	39.9	3128	1378	0	243	155	0	132	9	165	319	365	1
SASKATOON	55.3	42.9	4141	2115	0	277	185	0	99	9	135	319	365	1
SWIFT CURRENT	54.9	42.8	4230	2193	22	266	192	31	102	2	139	330	213	243
WINNIPEG	52.1	42.7	3954	1887	0	313	182	0	107	54	152	333	365	1
GUELPH	58.2	47.7	5765	2924	129	365	236	74	1	365	119	354	191	264
HARROW	61.8	50.7	6881	3944	546	365	263	117	1	365	108	5	175	291
KAPUSKASING	53.3	44.6	4652	1980	0	365	201	0	1	365	142	342	365	1
OTTAWA	57.1	46.4	5315	2680	42	365	222	56	1	365	122	343	199	254
LA POCATIERE	53.6	44.2	4503	2039	0	365	199	0	1	365	141	339	365	1
NORMANDIN	51.4	42.7	3949	1654	0	365	176	0	1	365	152	327	365	1
FREFERICTON	56.9	46.2	5241	2574	40	365	216	51	1	365	125	341	201	251
KENTVILLE	57.5	47.1	5552	2776	111	365	227	66	1	365	121	347	194	259
CHARLOTTETOWN	53.1	45.4	4921	2184	0	365	216	0	1	365	137	352	365	1
ST. JOHNS	50.5	44.1	4447	1732	0	365	210	0	1	365	144	353	365	1

TABLE 5 TOTAL PRECIPITATION

	AIR			SOIL 50 CM		
	GROW	DORMANT	FREEZE	GROW	DORMANT	FREEZE
ABBOTSFORD	32.31	28.48	.00	33.35	27.36	.00
AGASSIZ	37.49	27.71	.00	37.42	27.73	.00
BALDONNEL	10.75	6.50	4.75	10.52	6.73	4.22
CHILLIWACK	39.35	29.42	.00	39.68	29.07	.00
CRESTON	8.12	11.18	7.98	9.28	9.98	.00
HEDLEY	6.89	4.34	2.35	7.27	3.95	.00
KAMLOOPS	6.07	4.02	2.81	6.67	3.40	.00
NEW WESTMINSTE	33.17	27.44	.00	33.00	27.61	.00
PRINCE GEORGE	12.92	11.94	8.01	13.61	11.24	.00
PRINCETON	5.82	8.53	7.03	6.59	7.73	.00
SAANICHTON	17.82	15.65	.00	16.63	16.88	.00
STEVESTON	20.94	18.93	.00	22.11	17.71	.00
SUMMERLAND	6.86	4.75	2.15	7.73	3.85	.00
VANCOUVER	25.42	18.44	.00	23.73	20.26	.00
WHITE ROCK	26.24	15.50	.00	23.33	18.50	.00
WISTARIA	7.89	10.01	5.48	7.91	9.99	.00
FORT SIMPSON	7.60	5.34	3.86	6.01	6.98	5.65
BEAVERLODGE	10.96	7.52	5.30	10.38	8.12	5.29
CALGARY	12.50	4.69	3.18	11.55	5.68	2.49
CAMPSIE	13.39	5.28	4.18	12.70	6.00	3.58
EDMONTON	13.34	5.41	4.06	11.72	7.08	4.61
FORT VERMILION	8.34	5.35	4.44	8.01	5.68	4.37
HANNA	10.10	3.67	2.02	9.44	4.36	1.57
HIGH PRARIE	11.63	6.35	4.83	11.32	6.66	4.10
LACOMBE	13.24	4.95	3.38	12.53	5.69	2.93
LETHBRIDGE	11.10	5.23	3.78	11.09	5.25	1.46
MANYBERRIES	8.11	3.62	2.55	7.70	4.04	1.59
MEDICINE HAT	9.80	4.34	2.98	9.01	5.16	1.09
INDIAN HEAD	11.10	4.79	2.68	10.40	5.52	2.93
KAMSACK	11.14	4.17	1.84	10.52	4.81	3.03
MELFORT	10.96	4.88	2.48	10.23	5.63	3.90
OUTLOOK	8.94	2.28	1.28	8.29	2.95	1.45
REGINA	10.69	3.57	1.96	9.32	4.99	2.61
SASKATOON	9.73	3.54	1.91	9.36	3.90	.61
SCOTT	9.61	4.19	2.45	8.97	4.85	2.82
ST. WABURG	9.87	3.59	2.29	9.54	3.94	2.89
SWIFT CURRENT	9.63	3.36	2.11	9.41	3.58	1.77
BRANDON	13.54	4.87	2.45	12.97	5.46	3.33
MORDEN	13.78	6.15	3.22	13.31	6.63	3.05
PORTAGE	14.17	5.34	2.60	13.73	5.80	2.42
THE PAS	11.36	6.68	4.53	10.77	7.30	5.80
WINNIPEG	14.11	5.90	2.45	13.17	6.86	4.19
ARMSTRONG	15.35	11.75	6.72	14.74	12.39	9.38
BELLEVILLE	18.47	15.32	11.25	19.36	14.40	.00
DELHI	21.43	15.89	10.73	22.38	14.92	.00
FORT FRANCES	19.85	8.15	4.69	18.96	9.07	4.34
GUELPH	19.63	13.91	9.53	21.01	12.48	.00
HARROW	18.43	10.66	7.12	19.63	9.61	.00
KAPUSKASING	15.37	13.75	8.45	16.24	12.85	10.95
NORTH BAY	19.77	14.57	10.96	20.30	14.02	7.66
OTTAWA	19.65	14.69	11.52	20.40	13.91	.00
VINELAND	19.09	12.81	8.11	19.90	11.97	.00
WHITE RIVER	15.93	16.43	10.97	15.31	17.07	12.60
AMOS	18.68	14.68	12.14	18.23	15.14	10.19
LA POCATIERE	21.82	18.37	14.17	22.43	17.74	10.12
LASSOMPTION	21.35	17.02	12.95	21.95	16.41	.00
LENNOXVILLE	22.92	18.90	14.39	23.57	18.21	.00
NORMANDIN	18.23	13.48	10.53	18.24	13.47	1.82
BATHURST	17.67	19.25	14.55	18.25	18.65	.00
FREDERICTON	21.93	21.63	15.70	23.62	20.08	.00
MONCTON	18.78	19.99	14.43	19.92	18.82	.00
ST. JOHN	25.42	27.37	19.85	27.47	25.26	.00
KENTVILLE	21.48	21.67	15.91	22.65	20.45	.00
NAPPAN	20.19	20.15	14.57	22.13	18.15	.00
CHARLOTTETOWN	22.24	21.11	15.36	23.99	19.30	.00
SUMMERSIDE	20.62	17.18	11.80	21.45	16.32	.00
ST. JOHNS	24.02	35.53	24.22	29.27	30.09	.00

TABLE 6 TOTAL RAIN

	AIR			SOIL 50 CM		
	GROW	DORMANT	FREEZE	GROW	DORMANT	FREEZE
ABBOTSFORD	31.98	26.52	.00	33.33	25.06	.00
AGASSIZ	37.41	25.53	.00	37.41	25.53	.00
BALDONNEL	10.16	.73	.22	9.98	.91	.03
CHILLIWACK	39.16	27.33	.00	39.61	26.85	.00
CRESTON	8.10	8.24	5.21	9.23	7.07	.00
HEDLEY	6.42	1.00	.29	6.82	.58	.00
KAMLOOPS	6.07	1.92	.99	6.57	1.40	.00
NEW WESTMINSTE	33.09	26.32	.00	32.99	26.42	.00
PRINCE GEORGE	12.82	2.64	.65	13.24	2.20	.00
PRINCETON	5.82	3.95	2.56	6.59	3.16	.00
SAANICHTON	17.80	15.14	.00	16.63	16.34	.00
STEVESTON	20.92	18.13	.00	22.11	16.89	.00
SUMMERLAND	6.84	1.15	.28	7.42	.55	.00
VANCOUVER	25.34	17.53	.00	23.73	19.28	.00
WHITE ROCK	26.14	14.92	.00	23.33	17.82	.00
WISTARIA	7.65	1.70	.42	7.69	1.66	.00
FORT SIMPSON	7.45	.58	.09	6.00	2.08	.41
BEAVERLODGE	10.37	.78	.29	9.85	1.29	.17
CALGARY	11.59	.49	.17	11.01	1.08	.10
CAMPSIE	13.09	.68	.18	12.51	1.28	.08
EDMONTON	12.87	.48	.11	11.57	1.82	.32
FORT VERMILION	8.22	.41	.13	7.83	.81	.08
HANNA	9.54	.37	.10	9.17	.75	.02
HIGH PRARIE	11.12	.96	.25	10.88	1.21	.11
LACOMBE	12.69	.78	.18	12.19	1.29	.11
LETHBRIDGE	10.31	.87	.42	10.02	1.17	.03
MANYBERRIES	7.82	.41	.15	7.38	.86	.06
MEDICINE HAT	9.14	.47	.16	8.74	.88	.02
INDIAN HEAD	10.70	.55	.14	10.18	1.09	.09
KAMSACK	10.79	.56	.09	10.37	1.00	.13
MELFORT	10.63	.46	.08	10.02	1.09	.13
OUTLOOK	8.66	.38	.07	8.15	.90	.04
REGINA	10.40	.48	.10	9.13	1.80	.15
SASKATOON	9.44	.44	.12	9.15	.75	.00
SCOTT	9.34	.46	.08	8.75	1.07	.07
ST. WABURG	9.74	.41	.08	9.34	.83	.09
SWIFT CURRENT	9.33	.51	.13	9.08	.77	.07
BRANDON	13.35	.58	.12	12.79	1.16	.12
MORDEN	13.33	.78	.31	12.94	1.18	.18
PORTAGE	13.87	.67	.23	13.39	1.17	.13
THE PAS	11.20	.86	.27	10.55	1.53	.34
WINNIPEG	13.66	.84	.25	12.87	1.66	.23
ARMSTRONG	14.88	2.09	.46	14.42	2.56	.41
BELLEVILLE	18.46	8.34	4.77	19.13	7.64	.00
DELHI	21.41	10.06	5.85	22.08	9.36	.00
FORT FRANCES	19.32	1.22	.31	18.74	1.82	.16
GUELPH	19.62	7.74	3.98	20.75	6.57	.00
HARROW	18.43	7.69	4.40	19.47	6.62	.00
KAPUSKASING	15.12	1.81	.43	15.66	1.25	.56
NORTH BAY	19.77	7.26	3.73	20.26	6.75	1.88
OTTAWA	19.63	6.04	3.17	20.32	5.32	.00
VINELAND	19.09	8.73	4.85	19.79	8.00	.00
WHITE RIVER	15.72	3.06	.99	14.95	3.86	.83
AMOS	18.68	5.20	2.85	18.19	5.70	1.83
LA POCATIERE	21.78	7.54	3.52	22.41	6.89	1.94
LASSOMPTION	21.35	7.72	3.82	21.92	7.13	.00
LENNOXVILLE	22.92	9.60	5.22	23.57	8.93	.00
NORMANDIN	18.23	5.43	2.60	18.20	5.46	.53
BATHURST	17.64	9.58	4.95	18.22	8.99	.00
FREDERICTON	21.93	12.95	6.95	23.62	11.20	.00
MONCTON	18.76	11.62	6.22	19.90	10.45	.00
ST. JOHN	25.42	18.95	11.59	27.33	16.97	.00
KENTVILLE	21.48	12.67	7.28	22.63	11.47	.00
NAPPAN	20.19	11.78	6.44	22.02	9.89	.00
CHARLOTTETOWN	22.24	11.11	5.71	23.83	9.46	.00
SUMMERSIDE	20.62	9.52	4.68	21.38	8.72	.00
ST. JOHNS	23.99	22.30	11.67	29.19	16.90	.00

TABLE 7

TOTAL PE

	AIR			SOIL 50 CM		
	GROW	DORMANT	FREEZE	GROW	DORMANT	FREEZE
ABBOTSFORD	14.92	.03	.00	14.88	.06	.00
AGASSIZ	15.20	.01	.00	15.16	.06	.00
CHILLIWACK	15.28	.02	.00	15.23	.08	.00
CRESTON	21.68	.32	.00	21.24	.77	.00
BALDONNEL	17.45	1.27	.36	15.86	2.91	.42
HEDLEY	22.01	.35	.01	21.85	.52	.00
KAMLOOPS	25.06	.22	.01	24.97	.32	.00
NEW WESTMINSTE	18.86	.03	.00	18.78	.11	.00
PRINCE GEORGE	16.56	1.15	.22	14.81	2.96	.00
PRINCETON	20.63	.44	.01	19.94	1.16	.00
SAANICHTON	14.89	.00	.00	14.88	.00	.00
STEVESTON	18.51	.03	.00	18.46	.08	.00
SUMMERLAND	23.72	.19	.00	23.64	.28	.00
VANCOUVER	16.49	.00	.00	16.47	.03	.00
WHITE ROCK	17.73	.03	.00	17.67	.08	.00
WISTARIA	12.60	1.12	.09	10.85	2.92	.00
FORT SIMPSON	12.38	1.14	.48	8.86	4.76	1.74
BEAVERLODGE	17.24	1.26	.29	15.22	3.35	.81
CALGARY	19.24	2.00	.62	17.73	3.57	.47
CAMPSIE	17.68	1.76	.54	16.10	3.40	.59
EDMONTON	18.54	1.31	.31	15.60	4.35	1.44
FORT VERMILION	16.89	1.81	.74	15.37	3.39	.94
HANNA	21.32	1.63	.38	19.77	3.23	.34
HIGH PRARIE	17.15	1.39	.37	15.47	3.11	.47
LACOMBE	18.04	2.19	.59	16.94	3.34	.58
LETHBRIDGE	24.47	2.47	1.04	23.55	3.43	.33
MANYBERRIES	24.25	2.01	.78	22.93	3.38	.46
MEDICINE HAT	24.93	1.48	.52	23.56	2.89	.16
INDIAN HEAD	22.06	1.94	.63	20.34	3.72	.83
KAMSACK	20.36	1.57	.50	18.52	3.47	.91
MELFORT	18.54	1.33	.35	16.68	3.26	.82
OUTLOOK	25.31	2.21	.84	23.43	4.15	1.12
REGINA	24.41	2.59	.81	20.71	6.41	1.45
SASKATOON	23.16	1.79	.57	22.26	2.72	.20
SCOTT	22.87	2.35	.74	20.90	4.39	1.05
ST. WABURG	21.59	2.49	.94	19.63	4.52	1.48
SWIFT CURRENT	25.70	3.24	1.35	24.99	3.98	1.15
BRANDON	22.82	2.00	.68	21.16	3.72	.88
MORDEN	23.85	1.82	.64	22.16	3.57	.67
PORTAGE	22.48	1.72	.57	20.62	3.64	.68
THE PAS	16.95	2.08	.84	14.79	4.32	1.83
WINNIPEG	22.26	1.59	.54	19.24	4.72	1.03
ARMSTRONG	15.31	2.58	.96	13.20	4.77	1.85
BELLEVILLE	22.04	.93	.20	21.12	1.89	.00
DELHI	23.32	1.03	.20	22.46	1.92	.00
FORT FRANCES	19.82	1.51	.60	18.25	3.14	.72
GUELPH	20.47	.83	.20	19.76	1.56	.00
HARROW	25.03	1.06	.22	24.61	1.49	.00
KAPUSKASING	15.82	2.25	.86	15.39	2.69	1.72
NORTH BAY	20.02	1.86	.75	18.24	3.70	.86
OTTAWA	21.92	1.01	.37	21.04	1.91	.00
VINELAND	21.94	.81	.13	21.28	1.50	.00
WHITE RIVER	14.97	1.89	.74	13.10	3.82	1.43
AMOS	15.97	2.20	.96	14.20	4.03	1.67
LA POCATIERE	18.74	1.62	.62	17.45	3.15	.74
LASSOMPTION	22.49	1.37	.55	21.05	2.86	.00
LENNOXVILLE	19.31	1.14	.44	18.15	2.33	.00
NORMANDIN	15.26	1.41	.55	13.58	3.14	.20
BATHURST	18.64	1.74	.65	16.92	3.52	.00
FREDERICTON	17.74	1.14	.37	16.99	1.92	.00
MONCTON	21.37	2.57	.99	19.57	4.43	.00
ST. JOHN	14.97	1.67	.56	13.65	3.03	.00
KENTVILLE	18.97	1.27	.33	18.55	1.71	.00
NAPPAN	18.69	1.78	.70	17.26	3.27	.00
CHARLOTTETOWN	16.98	1.29	.33	15.90	2.41	.00
SUMMERSIDE	17.89	1.78	.62	16.09	3.65	.00
ST. JOHNS	14.95	2.54	.67	14.71	2.80	.00

TABLE 8 SPRING SOIL MOISTURE

	AIR STORAGE CAPACITY INCHES						SOIL 50 CM STORAGE CAPACITY INCHES					
	1	2	3	4	5	6	1	2	3	4	5	6
ABBOTSFORD	1.0	2.0	3.0	4.0	5.0	6.0	1.0	2.0	3.0	4.0	5.0	6.0
AGASSIZ	1.0	2.0	3.0	4.0	5.0	6.0	1.0	2.0	3.0	4.0	5.0	6.0
BALDONNEL	.6	1.6	2.6	3.6	4.6	5.5	.2	.9	1.9	2.9	3.9	4.8
CHILLIWACK	1.0	2.0	3.0	4.0	5.0	6.0	1.0	2.0	3.0	4.0	5.0	6.0
CRESTON	.9	1.9	2.9	3.9	4.9	5.9	.7	1.7	2.7	3.7	4.7	5.7
HEDLEY	.9	1.8	2.7	3.5	4.1	4.5	.8	1.8	2.7	3.6	4.1	4.6
KAMLOOPS	.9	1.9	2.8	3.6	4.0	4.3	.8	1.8	2.8	3.5	4.0	4.3
NEW WESTMINSTE	1.0	2.0	3.0	4.0	5.0	6.0	1.0	2.0	3.0	4.0	5.0	6.0
PRINCE GEORGE	.8	1.8	2.8	3.8	4.8	5.8	.4	1.3	2.3	3.3	4.3	5.3
PRINCETON	.8	1.8	2.8	3.8	4.8	5.7	.4	1.4	2.4	3.4	4.4	5.3
SAANICHTON	1.0	2.0	3.0	4.0	5.0	6.0	1.0	2.0	3.0	4.0	5.0	6.0
STEVESTON	1.0	2.0	3.0	4.0	5.0	6.0	1.0	2.0	3.0	4.0	5.0	6.0
SUMMERLAND	.9	1.9	2.9	3.8	4.5	5.0	.9	1.9	2.9	3.9	4.5	5.0
VANCOUVER	1.0	2.0	3.0	4.0	5.0	6.0	1.0	2.0	3.0	4.0	5.0	6.0
WHITE ROCK	1.0	2.0	3.0	4.0	5.0	6.0	1.0	2.0	3.0	4.0	5.0	6.0
WISTARIA	.7	1.7	2.7	3.7	4.6	5.6	.3	1.0	2.0	2.9	3.9	4.9
FORT SIMPSON	.6	1.6	2.6	3.6	4.5	5.3	.2	.5	1.4	2.4	3.3	4.2
BEAVERLODGE	.6	1.6	2.6	3.6	4.6	5.6	.2	.8	1.8	2.8	3.8	4.8
CALGARY	.4	1.4	2.3	3.2	4.0	4.6	.4	1.0	1.9	2.9	3.6	4.3
CAMPSIE	.5	1.5	2.5	3.5	4.4	5.4	.3	.9	1.8	2.8	3.8	4.7
EDMONTON	.5	1.5	2.5	3.5	4.4	5.3	.3	.7	1.6	2.5	3.5	4.4
FORT VERMILION	.4	1.3	2.3	3.3	4.2	4.8	.2	.6	1.6	2.6	3.4	4.1
HANNA	.4	1.3	2.2	2.8	3.3	3.7	.2	.8	1.5	2.2	2.7	3.1
HIGH PRARIE	.6	1.6	2.6	3.6	4.6	5.5	.3	.9	1.8	2.8	3.8	4.7
LACOMBE	.5	1.4	2.4	3.3	4.2	5.0	.3	1.0	1.9	2.8	3.7	4.6
LETHBRIDGE	.5	1.5	2.4	3.3	3.9	4.3	.4	1.1	2.1	3.0	3.7	4.0
MANYBERRIES	.4	1.4	2.1	2.5	2.8	2.9	.3	.9	1.5	2.0	2.3	2.4
MEDICINE HAT	.5	1.5	2.3	3.1	3.7	4.0	.3	1.0	1.9	2.7	3.4	3.8
INDIAN HEAD	.4	1.3	2.3	3.2	3.8	4.3	.3	.8	1.7	2.6	3.3	3.8
KAMSACK	.6	1.6	2.5	3.3	4.0	4.7	.2	.8	1.7	2.6	3.3	4.1
MELFORT	.6	1.6	2.6	3.5	4.4	5.1	.2	.9	1.9	2.8	3.7	4.5
OUTLOOK	.4	1.0	1.4	1.6	1.8	1.8	.2	.5	.8	1.1	1.3	1.4
REGINA	.4	1.2	2.0	2.5	2.8	2.9	.2	.4	.8	1.3	1.5	1.7
SASKATOON	.4	1.4	2.2	2.7	3.2	3.4	.4	1.0	1.8	2.4	2.8	3.1
SCOTT	.4	1.2	2.0	2.7	3.2	3.6	.1	.5	1.2	1.9	2.3	2.7
ST. WABURG	.4	1.2	2.0	2.6	3.0	3.2	.1	.4	1.0	1.6	1.9	2.1
SWIFT CURRENT	.2	.9	1.6	1.9	2.1	2.2	.3	.7	1.3	1.7	1.9	2.0
BRANDON	.5	1.4	2.4	3.3	4.1	4.7	.3	.9	1.8	2.7	3.5	4.2
MORDEN	.5	1.5	2.5	3.5	4.4	5.3	.3	1.0	1.9	2.8	3.8	4.7
PORTAGE	.5	1.5	2.4	3.3	4.1	4.8	.3	.9	1.8	2.7	3.4	4.2
THE PAS	.6	1.5	2.5	3.5	4.5	5.4	.2	.8	1.7	2.7	3.7	4.6
WINNIPEG	.6	1.6	2.6	3.6	4.6	5.4	.2	.7	1.5	2.5	3.5	4.4
ARMSTRONG	.6	1.6	2.6	3.6	4.6	5.6	.4	1.1	2.1	3.1	4.1	5.1
BELLEVILLE	.9	1.9	2.9	3.9	4.9	5.9	.7	1.7	2.7	3.7	4.7	5.7
DELHI	.9	1.9	2.9	3.9	4.9	5.9	.7	1.7	2.7	3.7	4.7	5.7
FORT FRANCES	.6	1.6	2.6	3.6	4.6	5.6	.5	1.4	2.3	3.3	4.3	5.3
GUELPH	.9	1.9	2.9	3.9	4.9	5.9	.8	1.8	2.8	3.8	4.8	5.8
HARROW	.9	1.9	2.9	3.9	4.9	5.9	.8	1.8	2.8	3.8	4.8	5.8
KAPUSKASING	.7	1.7	2.7	3.7	4.7	5.7	.5	1.5	2.5	3.5	4.5	5.5
NORTH BAY	.7	1.7	2.7	3.7	4.7	5.7	.5	1.4	2.4	3.4	4.4	5.4
OTTAWA	.9	1.9	2.9	3.9	4.9	5.9	.8	1.7	2.7	3.8	4.7	5.7
VINELAND	.9	1.9	2.9	3.9	4.9	5.9	.8	1.8	2.8	3.8	4.8	5.8
WHITE RIVER	.8	1.8	2.8	3.8	4.8	5.8	.6	1.5	2.5	3.5	4.5	5.5
AMOS	.6	1.6	2.6	3.6	4.6	5.6	.5	1.4	2.4	3.4	4.4	5.4
LA POCATIERE	.8	1.7	2.7	3.8	4.7	5.7	.6	1.5	2.6	3.6	4.6	5.6
LASSOMPTION	.9	1.9	2.9	3.9	4.9	5.9	.6	1.6	2.6	3.6	4.6	5.6
LENNOXVILLE	.9	1.9	2.9	3.9	4.9	5.9	.7	1.7	2.7	3.7	4.7	5.7
NORMANDIN	.8	1.8	2.8	3.8	4.8	5.8	.5	1.5	2.5	3.5	4.5	5.5
BATHURST	.8	1.8	2.8	3.8	4.8	5.8	.6	1.5	2.5	3.5	4.5	5.5
FREDERICTON	.9	1.9	2.9	3.9	4.9	5.9	.8	1.8	2.8	3.8	4.8	5.8
MONCTON	.8	1.8	2.8	3.8	4.8	5.8	.6	1.5	2.4	3.4	4.4	5.4
ST. JOHN	.9	1.9	2.9	3.9	4.9	5.9	.8	1.8	2.8	3.8	4.8	5.8
KENTVILLE	.9	1.9	2.9	3.9	4.9	5.9	.8	1.8	2.8	3.8	4.8	5.8
NAPPAN	.9	1.9	2.9	3.9	4.9	5.9	.7	1.7	2.7	3.7	4.7	5.7
CHARLOTTETOWN	.9	1.9	2.9	3.9	4.9	5.9	.8	1.7	2.7	3.7	4.7	5.7
SUMMERSIDE	.8	1.8	2.8	3.8	4.8	5.8	.7	1.6	2.6	3.6	4.6	5.6
ST. JOHNS	.8	1.8	2.8	3.8	4.8	5.8	.8	1.8	2.8	3.8	4.8	5.8

TABLE 9

GROWING DEFICIT

	AIR STORAGE CAPACITY INCHES						SOIL 50 CM. STORAGE CAPACITY INCHES					
	1	2	3	4	5	6	1	2	3	4	5	6
ABBOTSFORD	3.2	2.0	1.2	.7	.0	.0	3.2	2.0	1.2	.7	.0	.0
AGASSIZ	2.8	1.6	.9	.5	.3	.2	2.8	1.6	.9	.5	.3	.2
BALDONNEL	5.4	3.6	2.5	1.7	1.1	.6	5.0	3.6	2.5	1.7	1.1	.6
CHILLIWACK	3.1	2.0	1.2	.7	.4	.0	3.1	2.0	1.2	.7	.4	.0
CRESTON	9.5	8.3	7.3	6.3	5.3	4.3	9.5	8.3	7.3	6.3	5.3	4.3
HEDLEY	10.4	9.1	8.1	7.3	6.7	6.2	10.4	9.1	8.1	7.3	6.7	6.2
KAMLOOPS	12.7	11.6	10.7	10.0	9.5	9.2	12.7	11.6	10.7	10.0	9.5	9.2
NEW WESTMINSTE	5.0	3.6	2.5	1.7	1.0	.6	5.0	3.6	2.5	1.7	1.0	.6
PRINCE GEORGE	3.3	2.0	1.2	.5	.3	.0	3.2	2.0	1.2	.5	.3	.0
PRINCETON	9.9	8.7	7.7	6.8	5.8	5.0	9.9	8.7	7.7	6.8	5.8	5.0
SAANICHTON	5.4	4.2	3.3	2.3	1.4	.7	5.4	4.2	3.3	2.3	1.4	.7
STEVESTON	5.8	4.5	3.4	2.5	1.7	1.0	5.8	4.5	3.4	2.5	1.7	1.0
SUMMERLAND	11.3	10.2	9.2	8.3	7.5	7.0	11.3	10.2	9.2	8.3	7.5	7.0
VANCOUVER	4.2	3.0	2.0	1.2	.7	.3	4.2	3.0	2.0	1.2	.7	.3
WHITE ROCK	5.0	3.7	2.7	1.9	1.1	.6	5.0	3.7	2.7	1.9	1.1	.6
WISTARIA	3.6	2.4	1.6	.9	.4	.3	3.3	2.4	1.6	.9	.4	.3
FORT SIMPSON	3.7	2.5	1.6	.9	.5	.2	2.9	2.3	1.6	.9	.5	.2
BEAVERLODGE	4.6	3.1	2.1	1.4	.9	.5	4.2	3.1	2.1	1.4	.9	.5
CALGARY	5.3	3.7	2.5	1.8	1.3	1.0	4.9	3.6	2.5	1.8	1.3	1.0
CAMPSIE	3.8	2.1	1.2	.7	.4	.3	3.3	2.1	1.2	.7	.4	.3
EDMONTON	4.2	2.4	1.4	.8	.5	.3	3.5	2.2	1.4	.8	.5	.3
FORT VERMILION	5.9	4.6	3.6	2.7	2.0	1.6	5.4	4.6	3.6	2.7	2.0	1.6
HANNA	7.7	6.2	5.2	4.6	4.2	3.8	7.2	6.2	5.3	4.7	4.2	3.8
HIGH PRARIE	4.3	2.8	1.8	1.2	.7	.4	3.9	2.7	1.8	1.2	.7	.4
LACOMBE	4.0	2.3	1.4	.8	.4	.2	3.7	2.3	1.4	.8	.4	.2
LETHBRIDGE	9.5	7.7	6.4	5.4	4.7	4.3	9.3	7.8	6.5	5.5	4.8	4.4
MANYBERRIES	11.0	9.5	8.6	8.1	7.7	7.6	10.6	9.5	8.7	8.2	7.8	7.7
MEDICINE HAT	10.4	8.9	7.9	7.0	6.3	5.9	10.1	8.9	7.9	7.0	6.3	5.9
INDIAN HEAD	7.6	6.0	4.9	4.0	3.4	3.0	7.1	5.9	5.0	4.1	3.5	3.0
KAMSACK	6.6	4.9	3.9	3.1	2.5	2.1	6.2	4.8	3.8	3.1	2.5	2.0
MELFORT	5.5	3.8	2.7	1.9	1.4	1.1	5.2	3.8	2.8	2.0	1.5	1.2
OUTLOOK	11.2	9.9	9.3	8.9	8.7	8.6	10.6	9.7	9.1	8.7	8.5	8.5
REGINA	9.3	7.6	6.6	5.9	5.6	5.4	7.9	6.9	6.3	5.7	5.4	5.3
SASKATOON	9.1	7.4	6.4	5.8	5.4	5.1	8.9	7.5	6.5	5.9	5.4	5.2
SCOTT	8.7	7.4	6.5	5.7	5.3	4.9	8.1	7.3	6.4	5.7	5.3	4.9
ST. WABURG	7.8	6.4	5.5	4.9	4.6	4.4	7.0	6.1	5.4	4.8	4.5	4.4
SWIFT CURRENT	10.9	9.5	8.6	8.1	7.8	7.7	10.6	9.5	8.7	8.2	7.9	7.8
BRANDON	6.7	4.7	3.5	2.6	2.0	1.5	6.3	4.7	3.5	2.6	2.0	1.6
MORDEN	7.5	5.3	4.1	3.2	2.4	1.9	7.1	5.3	4.1	3.2	2.5	1.9
PORTAGE	6.1	4.3	3.2	2.5	1.9	1.5	5.6	4.2	3.2	2.5	2.0	1.5
THE PAS	4.2	2.7	1.8	1.2	.7	.4	3.6	2.6	1.8	1.2	.7	.4
WINNIPEG	6.1	4.2	3.1	2.3	1.7	1.2	5.3	4.1	3.1	2.3	1.7	1.2
ARMSTRONG	2.1	1.0	.5	.2	.1	.0	1.8	1.0	.5	.2	.1	.0
BELLEVILLE	5.2	3.7	2.7	1.8	1.1	.6	5.2	3.7	2.7	1.8	1.1	.6
DELHI	4.6	2.8	1.9	1.2	.8	.6	4.6	2.8	1.9	1.2	.8	.6
FORT FRANCES	2.8	1.2	.5	.2	.0	.0	2.7	1.2	.5	.2	.0	.0
GUELPH	3.6	2.0	1.2	.7	.4	.2	3.6	2.0	1.2	.7	.4	.2
HARROW	6.1	4.4	3.4	2.6	1.9	1.4	6.1	4.4	3.4	2.6	1.9	1.4
KAPUSKASING	2.3	1.0	.4	.1	.0	.0	2.2	1.0	.4	.1	.0	.0
NORTH BAY	3.0	1.4	.6	.3	.1	.0	2.9	1.4	.6	.3	.1	.0
OTTAWA	3.7	2.2	1.4	.9	.5	.3	3.7	2.2	1.4	.9	.5	.3
VINELAND	4.6	3.1	2.2	1.3	.7	.4	4.6	3.1	2.2	1.3	.7	.4
WHITE RIVER	2.3	1.1	.5	.2	.0	.0	2.2	1.1	.5	.2	.0	.0
AMOS	1.6	.5	.2	.0	.0	.0	1.4	.5	.2	.0	.0	.0
LA POCATIERE	1.8	.5	.1	.0	.0	.0	1.8	.5	.1	.0	.0	.0
LASSOMPTION	3.5	1.7	.7	.3	.1	.0	3.4	1.7	.7	.3	.1	.0
LENNOXVILLE	1.7	.4	.1	.0	.0	.0	1.7	.4	.1	.0	.0	.0
NORMANDIN	1.2	.3	.1	.0	.0	.0	1.1	.3	.1	.0	.0	.0
BATHURST	2.6	1.3	.6	.2	.1	.0	2.6	1.3	.6	.3	.1	.0
FREDERICTON	1.9	.7	.3	.0	.0	.0	1.9	.7	.3	.0	.0	.0
MONCTON	3.8	2.2	1.4	.9	.4	.2	3.6	2.2	1.4	.9	.4	.2
ST. JOHN	1.0	.2	.0	.0	.0	.0	1.0	.2	.0	.0	.0	.0
NAPPAN	2.7	1.5	.7	.2	.0	.0	2.7	1.5	.7	.2	.0	.0
KENTVILLE	2.9	1.6	.8	.3	.0	.0	2.9	1.6	.8	.3	.0	.0
CHARLOTTETOWN	2.0	.9	.3	.1	.0	.0	2.0	.9	.3	.1	.0	.0
SUMMERSIDE	2.4	1.3	.7	.3	.0	.0	2.3	1.3	.7	.3	.0	.0
ST. JOHNS	1.0	.3	.1	.0	.0	.0	1.0	.3	.1	.0	.0	.0

TABLE 10

GROWING SEASON
SURPLUS PRECIPITATION

	AIR STORAGE CAPACITY INCHES						SOIL 50 CM STORAGE CAPACITY INCHES					
	1	2	3	4	5	6	1	2	3	4	5	6
ABBOTSFORD	24.3	23.1	22.3	21.8	21.6	21.5	25.4	24.2	23.4	22.8	22.6	22.5
AGASSIZ	28.9	27.7	27.0	26.6	26.3	26.2	28.9	27.7	27.0	26.6	26.3	26.2
BALDONNEL	3.0	1.7	1.3	1.2	1.2	1.1	3.1	1.7	1.3	1.2	1.1	1.1
CHILLIWACK	31.0	29.8	29.1	28.6	28.2	28.1	31.3	30.2	29.5	28.9	28.6	28.4
CRESTON	1.6	.9	.7	.6	.5	.5	2.7	1.6	1.0	.7	.4	.3
HEDLEY	1.1	.7	.5	.4	.3	.2	1.3	.7	.4	.3	.2	.2
KAMLOOPS	.4	.1	.0	.0	.0	.0	.7	.2	.1	.0	.0	.0
NEW WESTMINSTE	24.0	22.6	21.5	20.7	20.0	19.6	23.9	22.5	21.4	20.6	19.9	19.5
PRINCE GEORGE	3.7	2.4	2.0	1.7	1.7	1.6	5.1	3.8	3.0	2.6	2.5	2.4
PRINCETON	.5	.1	.0	.0	.0	.0	1.1	.4	.1	.0	.0	.0
SAANICHTON	12.1	10.9	9.9	9.0	8.1	7.4	10.9	9.7	8.7	7.8	7.0	6.4
STEVESTON	12.8	11.5	10.5	9.6	8.8	8.3	14.0	12.7	11.7	10.8	10.0	9.4
SUMMERLAND	.6	.2	.2	.1	.1	.0	1.3	.6	.3	.2	.1	.0
VANCOUVER	17.3	16.1	15.0	14.3	13.9	13.6	15.6	14.4	13.4	12.6	12.2	11.9
WHITE ROCK	18.0	16.7	15.7	14.8	14.1	13.5	15.1	13.8	12.8	12.0	11.2	10.7
WISTARIA	1.9	1.1	.9	.8	.8	.8	2.3	1.4	1.0	.8	.8	.8
FORT SIMPSON	1.8	1.0	.6	.5	.5	.4	1.6	.8	.4	.3	.3	.3
BEAVERLODGE	2.5	1.5	1.0	1.0	1.0	1.0	2.5	1.5	1.0	.9	.9	.8
CALGARY	3.4	2.4	2.0	1.8	1.7	1.5	3.0	1.9	1.5	1.3	1.3	1.2
CAMPSIE	4.0	2.7	2.2	1.9	1.9	1.9	3.7	2.4	1.8	1.6	1.5	1.5
EDMONTON	3.7	2.4	1.9	1.7	1.7	1.6	3.2	1.9	1.4	1.2	1.2	1.1
FORT VERMILION	1.4	.7	.4	.4	.3	.2	1.5	.7	.4	.3	.3	.2
HANNA	1.9	1.0	.7	.6	.5	.4	1.6	.7	.4	.3	.2	.1
HIGH PRARIE	3.1	2.1	1.7	1.5	1.5	1.5	3.1	2.0	1.6	1.4	1.4	1.3
LACOMBE	3.7	2.4	2.0	1.8	1.6	1.6	3.3	2.1	1.5	1.3	1.2	1.2
LETHBRIDGE	2.5	1.4	.9	.8	.7	.5	2.6	1.4	9	.7	.6	.5
MANYBERRIES	1.2	.5	.3	.2	.0	.0	1.1	.4	.2	.1	.0	.0
MEDICINE HAT	1.8	1.0	.7	.5	.4	.2	1.4	.7	.4	.3	.3	.2
INDIAN HEAD	2.4	1.3	1.0	.9	.8	.7	2.1	1.1	.8	.7	.6	.6
KAMSACK	2.7	1.4	1.0	.7	.6	.5	2.5	1.2	.7	.5	.5	.4
MELFORT	2.6	1.5	1.0	.9	.9	.8	2.4	1.3	.8	.7	.7	.6
OUTLOOK	1.4	.6	.3	.1	.0	.0	1.3	.5	.2	.0	.0	.0
REGINA	2.0	.9	.5	.3	.1	.0	1.6	.7	.4	.2	.0	.0
SASKATOON	1.7	.7	.4	.2	.1	.0	1.6	.6	.3	.2	.1	.0
SCOTT	1.2	.5	.3	.2	.2	.2	1.1	.4	.2	.1	.0	.0
ST. WABURG	1.5	.7	.4	.3	.1	.1	1.6	.7	.4	.3	.2	.0
SWIFT CURRENT	1.4	.5	.3	.1	.0	.0	1.3	.5	.3	.1	.0	.0
BRANDON	3.3	2.0	1.4	1.2	1.0	.8	3.2	1.8	1.2	1.0	.9	.8
MORDEN	3.6	2.0	1.4	1.2	1.0	.9	3.5	1.8	1.2	.9	.7	.6
PORTAGE	3.5	2.1	1.5	1.3	1.2	1.1	3.5	2.1	1.5	1.3	1.1	1.0
THE PAS	2.7	1.5	1.2	1.0	.9	.9	2.7	1.5	1.1	.9	.9	.8
WINNIPEG	3.6	2.2	1.5	1.3	1.2	1.2	3.6	2.1	1.4	1.0	.9	.9
ARMSTRONG	5.7	4.7	4.3	4.2	4.1	4.1	6.1	5.1	4.7	4.5	4.4	4.4
BELLEVILLE	7.1	5.6	4.7	4.0	3.7	3.6	8.5	6.9	5.9	5.1	4.5	4.1
DELHI	8.5	6.8	5.9	5.4	5.2	5.1	9.8	8.1	7.1	6.5	6.1	5.9
FORT FRANCES	7.8	6.2	5.7	5.4	5.4	5.4	7.5	5.9	5.4	5.1	5.0	5.0
GUELPH	7.8	6.3	5.7	5.4	5.2	5.1	9.5	8.0	7.2	6.7	6.4	6.3
HARROW	5.7	4.2	3.6	3.3	3.1	3.0	7.1	5.3	4.5	3.9	3.6	3.4
KAPUSKASING	5.6	4.4	3.9	3.7	3.6	3.6	6.6	5.3	4.7	4.5	4.4	4.4
NORTH BAY	7.5	6.0	5.3	5.0	4.9	4.9	9.0	7.5	6.7	6.4	6.2	6.2
OTTAWA	6.8	5.3	4.7	4.4	4.2	4.1	8.1	6.5	5.8	5.2	5.0	4.8
VINELAND	7.2	5.7	4.9	4.2	3.9	3.8	8.4	6.8	5.9	5.1	4.6	4.5
WHITE RIVER	6.8	5.6	5.1	4.8	4.7	4.6	7.2	6.1	5.5	5.2	5.1	5.0
AMOS	7.9	6.9	6.6	6.6	6.5	6.5	8.5	7.5	7.2	7.1	7.1	7.0
LA POCATIERE	9.4	8.0	7.7	7.6	7.6	7.6	10.7	9.4	9.0	8.9	8.9	8.9
LASSOMPTION	7.8	6.1	5.3	4.9	4.9	4.8	9.2	7.4	6.5	6.1	5.9	5.9
LENNOXVILLE	10.1	8.8	8.5	8.5	8.5	8.5	11.4	10.1	9.8	9.7	9.7	9.7
NORMANDIN	7.8	6.9	6.7	6.7	6.7	6.7	8.7	7.8	7.6	7.6	7.5	7.5
BATHURST	6.2	5.0	4.5	4.4	4.4	4.4	7.7	6.4	5.8	5.6	5.5	5.5
FREDERICTON	10.5	9.2	8.8	8.6	8.6	8.6	12.5	11.4	10.9	10.7	10.7	10.7
MONCTON	6.4	4.9	4.3	4.0	3.9	3.8	8.4	6.9	6.1	5.7	5.4	5.2
ST. JOHN	15.0	14.4	14.1	14.1	14.1	14.1	18.0	17.2	17.0	17.0	17.0	17.0
KENTVILLE	10.1	8.8	8.0	7.5	7.3	7.2	11.5	10.2	9.4	8.9	8.6	8.6
NAPPAN	8.8	7.5	6.8	6.4	6.3	6.3	11.6	10.3	9.6	9.1	8.9	8.9
CHARLOTTETOWN	11.4	10.3	9.7	9.5	9.4	9.4	13.8	12.7	12.1	11.9	11.8	11.8
SUMMERSIDE	9.4	8.3	7.7	7.3	7.1	7.1	11.4	10.3	9.6	9.2	9.0	9.0
ST. JOHNS	13.7	13.0	12.7	12.6	12.6	12.6	19.1	18.4	18.1	18.1	18.1	18.1

TABLE 11

DORMANT SEASON
SURPLUS PRECIPITATION

	AIR STORAGE CAPACITY INCHES						SOIL 50 CM STORAGE CAPACITY INCHES					
	1	2	3	4	5	6	1	2	3	4	5	6
ABBOTSFORD	26.7	26.7	26.7	26.6	26.6	26.6	25.5	25.5	25.5	25.5	25.5	25.5
AGASSIZ	27.1	27.1	27.1	27.1	27.1	27.1	27.1	27.1	27.1	27.1	27.1	27.1
BALDONNEL	5.8	5.3	4.6	3.9	3.3	2.9	5.7	5.3	4.6	3.9	3.3	2.9
CHILLIWACK	28.0	28.0	28.0	28.0	28.0	28.0	27.7	27.7	27.7	27.7	27.7	27.7
CRESTON	10.4	9.9	9.1	8.2	7.2	6.3	9.3	9.1	8.7	8.1	7.3	6.4
HEDLEY	3.7	2.9	2.1	1.4	.9	.6	3.5	2.9	2.1	1.4	.9	.6
KAMLOOPS	3.4	2.6	1.7	1.0	.6	.3	3.1	2.4	1.7	1.0	.6	.3
NEW WESTMINSTE	26.6	26.6	26.6	26.6	26.6	26.6	26.7	26.7	26.7	26.7	26.7	26.7
PRINCE GEORGE	11.2	11.1	10.7	10.3	10.1	10.0	9.8	9.8	9.7	9.5	9.3	9.2
PRINCETON	7.8	7.1	6.2	5.2	4.3	3.4	7.2	6.8	6.1	5.2	4.3	3.5
SAANICHTON	15.1	15.1	15.1	15.1	15.1	15.0	16.3	16.3	16.3	16.3	16.2	16.1
STEVESTON	18.2	18.2	18.2	18.2	18.1	18.1	17.0	17.0	17.0	17.0	17.0	16.9
SUMMERLAND	4.3	3.6	2.7	1.8	1.1	.6	3.7	3.2	2.6	1.8	1.1	.6
VANCOUVER	17.2	17.2	17.2	17.1	17.0	17.0	18.8	18.8	18.8	18.8	18.7	18.6
WHITE ROCK	14.9	14.9	14.9	14.9	14.9	14.9	17.9	17.9	17.9	17.8	17.8	17.8
WISTARIA	9.4	8.9	8.3	7.7	7.3	7.1	8.9	8.7	8.2	7.7	7.3	7.1
FORT SIMPSON	4.7	4.3	3.8	3.2	2.6	2.6	5.0	4.5	4.0	3.4	3.0	2.8
BEAVERLODGE	6.9	6.4	5.9	5.3	4.7	4.4	6.9	6.5	5.9	5.4	4.9	4.5
CALGARY	3.5	2.9	2.1	1.6	1.2	1.1	3.8	3.4	2.6	2.0	1.6	1.4
CAMPSIE	4.2	3.7	3.3	3.1	2.8	2.7	4.5	4.0	3.7	3.4	3.2	3.0
EDMONTON	4.5	4.0	3.5	3.1	2.8	2.6	5.0	4.5	4.0	3.6	3.3	3.1
FORT VERMILION	4.5	3.8	3.1	2.2	1.6	1.3	4.5	3.9	3.2	2.3	1.7	1.4
HANNA	2.7	2.1	1.4	1.0	.7	.4	3.0	2.4	1.8	1.3	1.0	.6
HIGH PRARIE	5.4	4.9	4.4	3.9	3.5	3.2	5.5	5.0	4.5	4.0	3.6	3.3
LACOMBE	3.7	3.2	2.7	2.3	2.1	1.9	4.0	3.6	3.1	2.8	2.5	2.3
LETHBRIDGE	3.8	3.0	2.2	1.4	.8	.5	3.7	3.0	2.3	1.4	.9	.6
MANYBERRIES	2.3	1.5	.8	.4	.2	.0	2.4	1.6	.9	.5	.2	.1
MEDICINE HAT	3.2	2.6	1.9	1.2	.6	.4	3.6	2.9	2.2	1.4	.8	.4
INDIAN HEAD	3.7	3.1	2.3	1.6	1.0	.7	4.0	3.3	2.6	1.9	1.2	.9
KAMSACK	3.2	2.8	2.2	1.6	1.2	.9	3.4	3.0	2.4	1.9	1.3	1.0
MELFORT	4.1	3.6	2.9	2.3	1.8	1.7	4.3	3.8	3.2	2.5	2.1	1.8
OUTLOOK	1.1	.6	.3	.1	.0	.0	1.3	.8	.4	.2	.0	.0
REGINA	2.3	1.5	.8	.4	.3	.2	2.7	1.7	1.0	.5	.3	.2
SASKATOON	2.5	1.8	1.1	.6	.3	.1	2.5	1.9	1.2	.7	.4	.2
SCOTT	3.0	2.3	1.6	1.0	.6	.3	3.1	2.4	1.8	1.2	.8	.4
ST. WABURG	2.4	1.7	1.1	.7	.5	.4	2.4	1.7	1.2	.7	.5	.3
SWIFT CURRENT	2.0	1.2	.5	.2	.0	.0	2.0	1.2	.5	.2	.0	.0
BRANDON	3.7	3.0	2.4	1.7	1.3	1.0	3.8	3.2	2.5	1.9	1.4	1.1
MORDEN	5.1	4.5	3.9	3.2	2.6	2.2	5.1	4.6	4.1	3.5	2.9	2.4
PORTAGE	4.4	4.0	3.5	3.0	2.6	2.3	4.4	4.0	3.6	3.1	2.7	2.3
THE PAS	5.7	5.3	4.9	4.5	4.1	3.8	5.7	5.3	4.9	4.5	4.1	3.9
WINNIPEG	5.0	4.6	4.2	3.6	3.1	2.7	5.1	4.8	4.4	3.9	3.4	2.9
ARMSTRONG	10.6	10.5	10.5	10.3	10.3	10.2	10.2	10.1	10.1	10.0	9.9	9.9
BELLEVILLE	14.5	14.5	14.4	14.1	13.7	13.3	13.1	13.1	13.1	13.1	13.0	12.8
DELHI	14.9	14.8	14.7	14.6	14.5	14.3	13.5	13.5	13.5	13.5	13.4	13.4
FORT FRANCES	7.4	7.3	7.1	7.0	7.0	6.9	7.7	7.6	7.5	7.4	7.4	7.4
GUELPH	12.9	12.9	12.7	12.5	12.4	12.2	11.2	11.2	11.2	11.1	11.1	11.1
HARROW	10.0	9.7	9.4	8.9	8.4	8.0	8.6	8.6	8.4	8.2	7.9	7.6
KAPUSKASING	12.6	12.5	12.4	12.3	12.3	12.3	11.7	11.7	11.6	11.5	11.5	11.5
NORTH BAY	13.2	13.2	13.1	13.0	12.9	12.9	11.9	11.8	11.8	11.8	11.7	11.7
OTTAWA	13.9	13.9	13.7	13.5	13.4	13.2	12.6	12.6	12.6	12.6	12.5	12.5
VINELAND	12.0	11.9	11.9	11.7	11.4	11.2	10.8	10.8	10.8	10.8	10.6	10.5
WHITE RIVER	15.4	15.4	15.3	15.3	15.3	15.3	14.9	14.9	14.9	14.9	14.9	14.9
AMOS	13.3	13.3	13.2	13.2	13.2	13.2	12.7	12.7	12.6	12.6	12.6	12.6
LA POCATIERE	17.1	17.1	17.1	17.1	17.1	17.1	16.0	16.0	16.0	16.0	16.0	16.0
LASSOMPTION	16.0	16.0	15.8	15.7	15.6	15.5	14.7	14.7	14.6	14.6	14.6	14.5
LENNOXVILLE	17.9	17.9	17.8	17.8	17.8	17.8	16.5	16.5	16.5	16.5	16.5	16.5
NORMANDIN	12.5	12.5	12.5	12.5	12.5	12.5	11.6	11.6	11.6	11.6	11.6	11.6
BATHURST	17.7	17.5	17.3	17.1	17.0	16.9	16.3	16.2	16.1	16.0	15.9	15.8
FREDERICTON	20.5	20.5	20.5	20.5	20.5	20.5	18.5	18.5	18.5	18.5	18.5	18.5
MONCTON	17.8	17.7	17.5	17.3	17.0	16.8	15.7	15.7	15.7	15.6	15.5	15.4
ST. JOHN	25.7	25.6	25.6	25.6	25.6	25.6	22.6	22.6	22.6	22.6	22.6	22.6
KENTVILLE	20.2	20.2	20.2	20.2	20.2	20.2	18.8	18.8	18.8	18.8	18.8	18.8
NAPPAN	18.5	18.5	18.5	18.4	18.3	18.3	15.7	15.7	15.7	15.7	15.7	15.7
CHARLOTTETOWN	19.7	19.7	19.7	19.7	19.7	19.7	17.3	17.3	17.3	17.3	17.3	17.3
SUMMERSIDE	15.9	15.9	15.9	15.9	15.8	15.8	13.9	13.9	13.9	13.9	13.9	13.9
ST. JOHNS	32.8	32.8	32.8	32.8	32.8	32.8	27.4	27.4	27.4	27.4	27.4	27.4

TABLE 12

FREEZE SEASON
SURPLUS PRECIPITATION

	AIR STORAGE CAPACITY INCHES						SOIL 50 CM STORAGE CAPACITY INCHES					
	1	2	3	4	5	6	1	2	3	4	5	6
ABBOTSFORD	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
AGASSIZ	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
BALDONNEL	4.5	4.0	3.4	2.8	2.3	2.0	4.1	3.8	3.4	2.9	2.4	2.1
CHILLIWACK	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
CRESTON	7.7	7.6	7.2	6.6	5.9	5.1	.0	.0	.0	.0	.0	.0
HEDLEY	2.1	1.6	1.2	.7	.4	.2	.0	.0	.0	.0	.0	.0
KAMLOOPS	2.6	2.1	1.4	.8	.4	.2	.0	.0	.0	.0	.0	.0
NEW WESTMINSTE	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
PRINCE GEORGE	7.8	7.8	7.8	7.6	7.4	7.3	.0	.0	.0	.0	.0	.0
PRINCETON	6.8	6.3	5.6	4.8	3.9	3.1	.0	.0	.0	.0	.0	.0
SAANICHTON	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
STEVESTON	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
SUMMERLAND	2.0	187	1.3	.8	.4	.2	.0	.0	.0	.0	.0	.0
VANCOUVER	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
WHITE ROCK	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
WISTARIA	5.4	5.2	4.6	4.4	4.2	4.1	.0	.0	.0	.0	.0	.0
FORT SIMPSON	3.6	3.3	2.8	2.4	2.1	1.9	4.4	4.1	3.6	3.2	2.8	2.6
BEAVERLODGE	5.0	4.7	4.3	3.8	3.3	3.0	5.1	4.8	4.5	4.1	3.7	3.4
CALGARY	2.5	2.0	1.4	1.0	.8	.7	2.1	1.7	1.2	.9	.7	.6
CAMPSIE	3.6	3.2	2.9	2.6	2.4	2.3	3.2	2.9	2.6	2.4	2.2	2.1
EDMONTON	3.5	3.1	2.6	2.3	2.1	1.9	4.0	3.7	3.3	3.0	2.7	2.6
FORT VERMILION	3.9	3.4	2.7	2.0	1.5	1.1	4.0	3.4	2.8	2.0	1.5	1.1
HANNA	1.5	1.0	.5	.3	.2	.1	1.3	.9	.5	.3	.2	.0
HIGH PRARIE	4.5	4.0	3.6	3.1	2.7	2.4	3.9	3.7	3.3	2.8	2.5	2.3
LACOMBE	2.7	2.3	1.9	1.6	1.4	1.3	2.5	2.2	1.8	1.6	1.4	1.3
LETHBRIDGE	3.0	2.4	1.6	1.0	.5	.4	1.3	1.1	.7	.3	.2	.1
MANYBERRIES	1.7	1.0	.5	.2	.0	.0	1.2	.7	.3	.1	.0	.0
MEDICINE HAT	2.4	1.9	1.3	.7	.4	.3	.9	.7	.4	.2	.0	.0
INDIAN HEAD	2.1	1.7	1.2	.8	.5	.3	2.5	2.1	1.5	1.0	.7	.4
KAMSACK	1.4	1.2	.9	.7	.5	.3	2.5	2.2	1.7	1.3	.9	.6
MELFORT	2.1	1.8	1.5	1.1	.8	.8	3.5	3.1	2.5	1.8	1.4	1.3
OUTLOOK	.7	.3	.1	.0	.0	.0	.9	.5	.3	.1	.0	.0
REGINA	1.3	.8	.4	.3	.2	.2	2.1	1.4	.7	.4	.2	.2
SASKATOON	1.4	1.0	.6	.4	.3	.1	.5	.3	.0	.0	.0	.0
SCOTT	1.9	1.4	1.0	.6	.4	.1	2.3	1.8	1.3	.8	.5	.2
ST. WABURG	1.7	1.2	.8	.5	.4	.3	2.2	1.6	1.0	.6	.4	.3
SWIFT CURRENT	1.4	.8	.3	.1	.0	.0	1.3	.8	.3	.1	.0	.0
BRANDON	2.0	1.6	1.2	.9	.6	.5	2.8	2.3	1.9	1.4	1.0	.8
MORDEN	2.8	2.5	2.2	1.9	1.5	1.2	2.7	2.4	2.1	1.9	1.5	1.2
PORTAGE	2.2	2.0	1.9	1.7	1.5	1.5	2.2	2.0	1.8	1.6	1.4	1.3
THE PAS	4.1	3.8	3.5	3.1	2.8	2.6	5.3	5.0	4.6	4.2	3.8	3.6
WINNIPEG	2.1	1.9	1.7	1.4	1.2	1.1	3.8	3.6	3.3	2.8	2.4	2.1
ARMSTRONG	6.4	6.4	6.3	6.2	6.1	6.1	8.9	8.8	8.7	8.7	8.6	8.6
BELLEVILLE	11.0	11.0	11.0	10.9	10.8	10.6	.0	.0	.0	.0	.0	.0
DELHI	10.4	10.4	10.4	10.3	10.3	10.3	.0	.0	.0	.0	.0	.0
FORT FRANCES	4.4	4.3	4.2	4.1	4.1	4.1	4.1	4.1	3.9	3.9	3.8	3.8
GUELPH	9.3	9.3	9.2	9.2	9.1	9.1	.0	.0	.0	.0	.0	.0
HARROW	6.9	6.9	6.7	6.4	6.1	5.7	.0	.0	.0	.0	.0	.0
KAPUSKASING	8.1	8.1	8.0	8.0	7.9	7.9	10.4	10.4	10.3	10.2	10.2	10.2
NORTH BAY	10.4	10.4	10.4	10.4	10.3	10.3	7.1	7.1	7.1	7.1	7.1	7.1
OTTAWA	11.3	11.3	11.3	11.2	11.1	11.0	.0	.0	.0	.0	.0	.0
VINELAND	7.9	7.9	7.9	7.8	7.7	7.6	.0	.0	.0	.0	.0	.0
WHITE RIVER	10.6	10.6	10.6	10.6	10.6	10.6	12.1	12.1	12.1	12.0	12.0	12.0
AMOS	11.6	11.6	11.5	11.5	11.5	11.5	9.3	9.3	9.3	9.3	9.3	9.3
LA POCATIERE	13.7	13.7	13.7	13.7	13.7	13.7	9.4	9.4	9.4	9.4	9.4	9.4
LASSOMPTION	12.6	12.6	12.6	12.5	12.5	12.4	.0	.0	.0	.0	.0	.0
LENNOXVILLE	14.0	14.0	14.0	14.0	14.0	14.0	.0	.0	.0	.0	.0	.0
NORMANDIN	10.1	10.1	10.1	10.1	10.1	10.1	1.7	1.7	1.7	1.7	1.7	1.7
BATHURST	13.9	13.8	13.8	13.6	13.5	13.5	.0	.0	.0	.0	.0	.0
FREDERICTON	15.2	15.2	15.2	15.2	15.2	15.2	.0	.0	.0	.0	.0	.0
MONCTON	13.5	13.5	13.4	13.3	13.2	13.2	.0	.0	.0	.0	.0	.0
ST. JOHN	19.1	19.1	19.1	19.1	19.1	19.1	.0	.0	.0	.0	.0	.0
KENTVILLE	15.3	15.3	15.3	15.3	15.3	15.3	.0	.0	.0	.0	.0	.0
NAPPAN	13.8	13.8	13.8	13.8	13.8	13.8	.0	.0	.0	.0	.0	.0
CHARLOTTETOWN	14.7	14.7	14.7	14.7	14.7	14.7	.0	.0	.0	.0	.0	.0
SUMMERSIDE	11.3	11.3	11.3	11.3	11.3	11.3	.0	.0	.0	.0	.0	.0
ST. JOHNS	23.2	23.2	23.2	23.2	23.2	23.2	.0	.0	.0	.0	.0	.0

TABLE 13

GROWING SEASON
SURPLUS RAIN

	AIR STORAGE CAPACITY INCHES						SOIL 50 CM STORAGE CAPACITY INCHES					
	1	2	3	4	5	6	1	2	3	4	5	6
ABBOTSFORD	24.0	22.8	22.0	21.5	21.3	21.1	25.3	24.1	23.4	22.8	22.6	22.5
AGASSIZ	28.8	27.6	26.9	26.5	26.3	26.2	28.9	27.6	26.9	26.5	26.3	26.2
BALDONNEL	2.6	1.5	1.1	1.0	.9	.9	2.7	1.5	1.1	1.0	1.0	.9
CHILLIWACK	30.8	29.6	28.9	28.4	28.1	27.9	31.2	30.1	29.4	28.9	28.5	28.4
CRESTON	1.5	.9	.6	.5	.5	.5	2.6	1.6	1.0	.7	.4	.3
HEDLEY	.7	.3	.2	.1	.1	.0	.9	.4	.2	.1	.1	.0
KAMLOOPS	.4	.1	.0	.0	.0	.0	.6	.2	.0	.0	.0	.0
NEW WESTMINSTE	23.9	22.5	21.5	20.6	20.0	19.5	23.9	22.4	21.4	20.6	19.9	19.5
PRINCE GEORGE	3.6	2.3	1.9	1.7	1.6	1.6	4.8	3.4	2.7	2.4	2.3	2.3
PRINCETON	.5	.1	.0	.0	.0	.0	1.1	.4	.1	.0	.0	.0
SAANICHTON	12.1	10.9	9.9	8.9	8.1	7.4	10.9	9.7	8.7	7.8	7.0	6.4
STEVESTON	12.8	11.5	10.5	9.6	8.6	8.2	14.0	12.7	11.7	10.8	10.0	9.4
SUMMERLAND	.6	.2	.2	.1	.1	.0	1.0	.4	.2	.1	.1	.0
VANCOUVER	17.2	16.0	15.0	14.3	13.6	13.5	15.6	14.4	13.4	12.6	12.2	11.9
WHITE ROCK	17.9	16.6	15.6	14.7	14.0	13.5	15.1	13.8	12.8	12.0	11.2	10.7
WISTARIA	1.7	1.0	.7	.6	.6	.6	2.2	1.2	.9	.8	.7	.7
FORT SIMPSON	1.8	1.0	.5	.4	.4	.4	1.6	.8	.4	.3	.3	.3
BEAVERLODGE	2.1	1.2	.8	.7	.7	.7	2.1	1.2	.8	.7	.7	.7
CALGARY	2.9	1.9	1.5	1.4	1.3	1.2	2.8	1.8	1.4	1.2	1.2	1.1
CAMPSIE	3.8	2.6	2.0	1.8	1.7	1.7	3.6	2.4	1.8	1.6	1.5	1.5
EDMONTON	3.4	2.2	1.7	1.5	1.4	1.4	3.1	1.9	1.4	1.2	1.1	1.1
FORT VERMILION	1.4	.7	.4	.4	.3	.2	1.4	.7	.3	.3	.2	.2
HANNA	1.5	.8	.5	.4	.3	.2	1.5	.7	.4	.3	.2	.1
HIGH PRARIE	2.7	1.8	1.4	1.3	1.3	1.2	2.7	1.7	1.3	1.2	1.2	1.1
LACOMBE	3.3	2.1	1.7	1.5	1.4	1.3	3.1	1.9	1.5	1.3	1.2	1.1
LETHBRIDGE	2.1	1.1	.7	.6	.5	.4	2.0	1.0	.6	.5	.4	.4
MANYBERRIES	1.0	.4	.2	.1	.0	.0	1.0	.4	.2	.1	.0	.0
MEDICINE HAT	1.4	.7	.4	.3	.2	.2	1.3	.6	.4	.3	.2	.1
INDIAN HEAD	2.2	1.2	.9	.8	.8	.7	2.0	1.0	.7	.6	.6	.6
KAMSACK	2.4	1.2	.7	.6	.5	.4	2.4	1.1	.7	.5	.5	.4
MELFORT	2.3	1.2	.8	.7	.6	.6	2.2	1.1	.7	.6	.6	.5
OUTLOOK	1.3	.4	.2	.0	.0	.0	1.2	.5	.2	.0	.0	.0
REGINA	1.8	.8	.5	.3	.1	.0	1.5	.6	.3	.2	.0	.0
SASKATOON	1.5	.6	.3	.2	.1	.0	1.5	.6	.3	.2	.1	.0
SCOTT	1.2	.5	.3	.2	.1	.1	1.1	.4	.2	.1	.0	.0
ST. WABURG	1.5	.7	.4	.2	.1	.1	1.5	.6	.3	.2	.1	.0
SWIFT CURRENT	1.3	.5	.3	.1	.0	.0	1.3	.5	.3	.1	.0	.0
BRANDON	3.3	1.9	1.4	1.1	1.0	.8	3.2	1.8	1.2	1.0	.9	.8
MORDEN	3.3	1.7	1.1	1.0	.8	.7	3.3	1.6	1.0	.8	.7	.6
PORTAGE	3.3	2.0	1.4	1.2	1.1	1.0	3.3	1.9	1.3	1.2	1.0	.9
THE PAS	2.6	1.5	1.1	.9	.8	.8	2.6	1.4	1.0	.9	.8	.8
WINNIPEG	3.3	1.9	1.3	1.0	.9	.9	3.4	1.9	1.2	.9	.8	.8
ARMSTRONG	5.3	4.3	3.9	3.8	3.6	3.8	5.8	4.8	4.4	4.2	4.2	4.2
BELLEVILLE	7.1	5.6	4.7	4.0	3.7	3.6	8.3	6.7	5.7	4.9	4.3	4.0
DELHI	8.5	6.7	5.9	5.4	5.1	5.1	9.5	7.8	6.9	6.3	5.9	5.7
FORT FRANCES	7.3	5.8	5.2	5.0	5.0	5.0	7.4	5.7	5.2	4.9	4.9	4.8
GUELPH	7.8	6.3	5.7	5.3	5.2	5.1	9.3	7.7	6.9	6.5	6.3	6.1
HARROW	5.7	4.2	3.6	3.3	3.1	3.0	6.9	5.2	4.4	3.8	3.5	3.3
KAPUSKASING	5.4	4.2	3.7	3.5	3.5	3.5	6.1	4.9	4.3	4.0	4.0	4.0
NORTH BAY	7.5	6.0	5.3	5.0	4.9	4.9	9.0	7.4	6.7	6.3	6.2	6.2
OTTAWA	6.8	5.3	4.7	4.4	4.2	4.1	8.0	6.4	5.7	5.2	4.9	4.7
VINELAND	7.2	5.7	4.9	4.2	3.9	3.8	8.3	6.7	5.8	5.0	4.6	4.4
WHITE RIVER	6.6	5.4	4.9	4.6	4.5	4.4	6.9	5.7	5.1	4.9	4.7	4.7
AMOS	7.9	6.9	6.6	6.6	6.5	6.5	8.5	7.5	7.2	7.1	7.0	7.0
LA POCATIERE	9.3	8.0	7.6	7.6	7.5	7.5	10.7	9.4	9.0	8.9	8.9	8.9
LASSOMPTION	7.8	6.1	5.3	4.9	4.9	4.8	9.1	7.4	6.5	6.1	5.9	5.9
LENNOXVILLE	10.1	8.8	8.5	8.5	8.5	8.5	11.4	10.1	9.7	9.7	9.7	9.7
NORMANDIN	7.8	6.9	6.7	6.7	6.7	6.7	8.6	7.8	7.6	7.5	7.5	7.5
BATHURST	6.2	5.0	4.5	4.4	4.4	4.3	7.6	6.4	5.8	5.5	5.4	5.4
FREDERICTON	10.5	9.2	8.8	8.6	8.6	8.6	12.5	11.4	10.9	10.7	10.7	10.7
MONCTON	6.4	4.9	4.3	4.0	3.9	3.8	8.4	6.9	6.1	5.7	5.3	5.2
ST. JOHN	15.0	14.4	14.1	14.1	14.1	14.1	17.8	17.1	16.9	16.9	16.9	16.9
KENTVILLE	10.1	8.8	8.0	7.5	7.3	7.2	11.5	10.2	9.3	8.9	8.6	8.6
NAPPAN	8.8	7.5	6.8	6.4	6.3	6.3	11.5	10.2	9.5	9.0	8.8	8.7
CHARLOTTETOWN	11.4	10.3	9.7	9.5	9.4	9.4	13.6	12.5	12.0	11.7	11.6	11.6
SUMMERSIDE	9.4	8.3	7.7	7.3	7.1	7.1	11.3	10.2	9.6	9.2	9.0	8.9
ST. JOHNS	13.7	13.0	12.7	12.6	12.6	12.6	19.0	18.3	18.1	18.0	18.0	18.0

TABLE 14

DORMANT SEASON
SURPLUS RAIN

	AIR STORAGE CAPACITY INCHES						SOIL 50 CM STORAGE CAPACITY INCHES					
	1	2	3	4	5	6	1	2	3	4	5	6
ABBOTSFORD	24.8	24.8	24.8	24.7	24.7	24.7	23.3	23.3	23.3	23.2	23.2	23.2
AGASSIZ	25.0	25.0	25.0	25.0	25.0	25.0	24.9	24.9	24.9	24.9	24.9	24.9
BALDONNEL	.3	.3	.2	.2	.2	.2	.2	.2	.2	.2	.1	.1
CHILLIWACK	25.9	25.9	25.9	25.9	25.9	25.9	25.5	25.5	25.5	25.5	25.5	25.5
CRESTON	7.5	7.0	6.3	5.6	4.9	4.2	6.4	6.3	5.9	5.5	5.0	4.3
HEDLEY	.6	.4	.2	.1	.1	.1	.4	.3	.2	.1	.1	.1
KAMLOOPS	1.5	1.0	.6	.4	.2	.1	1.2	.9	.6	.4	.2	.1
NEW WESTMINSTE	25.4	25.4	25.4	25.4	25.4	25.4	25.5	25.5	25.5	25.5	25.5	25.5
PRINCE GEORGE	2.1	2.0	1.7	1.6	1.6	1.5	.9	.9	.9	.9	.9	.9
PRINCETON	3.3	2.8	2.3	1.8	1.4	1.2	2.7	2.5	2.2	1.8	1.4	1.2
SAANICHTON	14.6	14.6	14.6	14.6	14.6	14.5	15.8	15.8	15.8	15.8	15.7	15.6
STEVESTON	17.4	17.4	17.4	17.4	17.3	17.3	16.2	16.2	16.2	16.2	16.2	16.1
SUMMERLAND	.9	.6	.4	.3	.2	.1	.4	.4	.4	.3	.2	.1
VANCOUVER	16.3	16.3	16.3	16.2	16.2	16.1	17.9	17.9	17.9	17.8	17.7	17.7
WHITE ROCK	14.4	14.4	14.4	14.4	14.4	14.4	17.2	17.2	17.2	17.2	17.1	17.1
WISTARIA	1.3	1.0	.9	.7	.6	.6	.8	.7	.6	.6	.5	.5
FORT SIMPSON	.3	.3	.2	.1	.1	.1	.5	.4	.4	.3	.3	.3
BEAVERLODGE	.5	.4	.4	.3	.3	.2	.4	.4	.4	.3	.3	.3
CALGARY	.1	.1	.1	.1	.1	.1	.3	.3	.3	.2	.2	.2
CAMPSIE	.2	.2	.1	.1	.1	.1	.4	.4	.3	.3	.3	.3
EDMONTON	.2	.1	.1	.1	.1	.1	.5	.4	.4	.4	.4	.4
FORT VERMILION	.2	.1	.1	.1	.1	.0	.2	.2	.2	.2	.1	.1
HANNA	.1	.0	.0	.0	.0	.0	.1	.1	.1	.1	.1	.1
HIGH PRARIE	.4	.4	.3	.3	.3	.3	.4	.4	.4	.4	.4	.4
LACOMBE	.3	.3	.3	.2	.2	.2	.5	.5	.4	.4	.4	.3
LETHBRIDGE	.3	.2	.2	.1	.0	.0	.4	.3	.3	.2	.1	.0
MANYBERRIES	.1	.0	.0	.0	.0	.0	.1	.1	.1	.1	.0	.0
MEDICINE HAT	.1	.1	.0	.0	.0	.0	.2	.1	.1	.1	.1	.0
INDIAN HEAD	.1	.1	.0	.0	.0	.0	.3	.2	.2	.2	.2	.2
KAMSACK	.2	.1	.1	.1	.1	.1	.2	.2	.1	.1	.1	.1
MELFORT	.2	.1	.1	.1	.1	.1	.2	.2	.2	.2	.2	.1
OUTLOOK	.1	.1	.0	.0	.0	.0	.1	.0	.0	.0	.0	.0
REGINA	.1	.1	.0	.0	.0	.0	.4	.3	.2	.2	.1	.0
SASKATOON	.1	.0	.0	.0	.0	.0	.1	.1	.1	.0	.0	.0
SCOTT	.0	.0	.0	.0	.0	.0	.2	.1	.1	.1	.1	.1
ST. WABURG	.0	.0	.0	.0	.0	.0	.1	.1	.1	.0	.0	.0
SWIFT CURRENT	.1	.0	.0	.0	.0	.0	.1	.1	.1	.0	.0	.0
BRANDON	.1	.1	.1	.1	.1	.0	.2	.2	.2	.2	.2	.1
MORDEN	.3	.2	.2	.2	.2	.2	.3	.3	.3	.3	.3	.3
PORTAGE	.3	.3	.2	.2	.2	.2	.3	.3	.3	.3	.3	.2
THE PAS	.3	.2	.2	.2	.2	.2	.3	.2	.2	.2	.2	.2
WINNIPEG	.4	.3	.3	.2	.2	.2	.4	.3	.3	.3	.3	.3
ARMSTRONG	1.3	1.3	1.3	1.2	1.2	1.2	.8	.7	.8	.8	.7	.7
BELLEVILLE	7.7	7.6	7.5	7.3	7.0	6.7	6.5	6.5	6.5	6.5	6.5	6.4
DELHI	9.1	9.1	9.0	8.9	8.8	8.6	8.1	8.1	8.1	8.0	8.0	8.0
FORT FRANCES	.8	.7	.7	.6	.6	.6	.8	.8	.8	.8	.8	.8
GUELPH	6.9	6.8	6.7	6.6	6.4	6.3	5.4	5.4	5.4	5.4	5.4	5.4
HARROW	6.8	6.6	6.3	5.9	5.6	5.4	5.6	5.6	5.5	5.4	5.2	5.0
KAPUSKASING	1.2	1.2	1.1	1.1	1.1	1.1	.5	.5	.5	.5	.5	.5
NORTH BAY	6.1	6.1	6.0	5.9	5.8	5.8	4.6	4.6	4.6	4.6	4.5	4.5
OTTAWA	5.4	5.4	5.2	5.1	5.0	4.9	4.2	4.2	4.2	4.2	4.2	4.2
VINELAND	8.0	8.0	7.9	7.7	7.5	7.4	7.0	7.0	7.0	6.9	6.9	6.8
WHITE RIVER	2.4	2.4	2.4	2.4	2.4	2.4	2.1	2.1	2.1	2.1	2.1	2.1
AMOS	4.1	4.1	4.0	4.0	4.0	4.0	3.6	3.5	3.5	3.4	3.4	3.4
LA POCATIERE	6.5	6.5	6.5	6.5	6.5	6.5	5.1	5.1	5.1	5.1	5.1	5.1
LASSOMPTION	6.8	6.8	6.6	6.5	6.4	6.4	5.5	5.5	5.5	5.5	5.4	5.4
LENNOXVILLE	8.8	8.8	8.7	8.7	8.7	8.7	7.5	7.5	7.5	7.5	7.5	7.5
NORMANDIN	4.5	4.5	4.5	4.5	4.5	4.5	3.7	3.7	3.7	3.7	3.7	3.7
BATHURST	8.3	8.1	7.9	7.8	7.7	7.7	6.9	6.8	6.7	6.6	6.6	6.6
FREDERICTON	11.9	11.9	11.9	11.9	11.8	11.8	9.8	9.8	9.8	9.8	9.8	9.8
MONCTON	9.9	9.8	9.6	9.4	9.1	9.0	7.8	7.8	7.8	7.7	7.6	7.6
ST. JOHN	17.6	17.6	17.5	17.5	17.5	17.5	14.7	14.7	14.7	14.7	14.7	14.7
KENTVILLE	11.6	11.6	11.6	11.5	11.5	11.5	10.2	10.2	10.2	10.2	10.2	10.2
NAPPAN	10.6	10.6	10.6	10.5	10.4	10.4	7.9	7.9	7.9	7.9	7.9	7.9
CHARLOTTETOWN	10.2	10.2	10.2	10.2	10.2	10.2	7.9	7.9	7.9	7.9	7.9	7.9
SUMMERSIDE	8.4	8.4	8.4	8.4	8.4	8.4	6.5	6.5	6.5	6.5	6.5	6.5
ST. JOHNS	19.9	19.9	19.9	19.9	19.9	19.9	14.6	14.6	14.6	14.6	14.6	14.6

TABLE 15

FREEZE SEASON
SURPLUS RAIN

	AIR STORAGE CAPACITY INCHES						SOIL 50 CM STORAGE CAPACITY INCHES					
	1	2	3	4	5	6	1	2	3	4	5	6
ABBOTSFORD	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
AGASSIZ	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
CHILLIWACK	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
CRESTON	4.9	4.9	4.6	4.2	3.7	3.1	.0	.0	.0	.0	.0	.0
BALDONNEL	.2	.2	.1	.1	.1	.1	.0	.0	.0	.0	.0	.0
HEDLEY	.3	.1	.1	.0	.0	.0	.0	.0	.0	.0	.0	.0
KAMLOOPS	.9	.7	.4	.2	.1	.1	.0	.0	.0	.0	.0	.0
NEW WESTMINSTE	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
PRINCE GEORGE	.6	.6	.6	.6	.6	.6	.0	.0	.0	.0	.0	.0
PRINCETON	2.4	2.1	1.8	1.5	1.1	.9	.0	.0	.0	.0	.0	.0
SAANICHTON	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
STEVESTON	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
SUMMERLAND	.3	.2	.2	.1	.1	.0	.0	.0	.0	.0	.0	.0
VANCOUVER	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
WHITE ROCK	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
WISTARIA	.4	.4	.3	.3	.2	.2	.0	.0	.0	.0	.0	.0
FORT SIMPSON	.0	.0	.0	.0	.0	.0	.1	.1	.1	.1	.1	.1
BEAVERLODGE	.3	.2	.2	.2	.2	.1	.0	.0	.0	.0	.0	.0
CALGARY	.1	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
CAMPSIE	.1	.1	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
EDMONTON	.1	.1	.0	.0	.0	.0	.1	.1	.1	.1	.1	.1
FORT VERMILION	.1	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
HANNA	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
HIGH PRARIE	.2	.2	.2	.2	.2	.1	.1	.1	.1	.1	.1	.1
LACOMBE	.1	.1	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
LETHBRIDGE	.2	.2	.1	.1	.0	.0	.0	.0	.0	.0	.0	.0
MANYBERRIES	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
MEDICINE HAT	.1	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
INDIAN HEAD	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
KAMSACK	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
MELFORT	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
OUTLOOK	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
REGINA	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
SASKATOON	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
SCOTT	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
ST. WABURG	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
SWIFT CURRENT	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
BRANDON	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
MORDEN	.2	.1	.1	.1	.1	.1	.1	.1	.1	.1	.1	.1
PORTAGE	.2	.1	.1	.1	.1	.1	.1	.1	.1	.1	.1	.1
THE PAS	.1	.1	.1	.1	.1	.1	.1	.1	.1	.1	.1	.1
WINNIPEG	.2	.1	.1	.1	.1	.1	.1	.1	.1	.1	.1	.1
ARMSTRONG	.4	.4	.4	.4	.4	.4	.1	.1	.1	.1	.1	.1
BELLEVILLE	4.7	4.7	4.7	4.6	4.6	4.5	.0	.0	.0	.0	.0	.0
DELHI	5.6	5.6	5.6	5.6	5.5	5.5	.0	.0	.0	.0	.0	.0
FORT FRANCES	.2	.2	.2	.2	.2	.2	.1	.1	.1	.1	.1	.1
GUELPH	3.9	3.9	3.8	3.8	3.8	3.7	.0	.0	.0	.0	.0	.0
HARROW	4.2	4.1	4.0	3.8	3.6	3.4	.0	.0	.0	.0	.0	.0
KAPUSKASING	.3	.3	.3	.3	.3	.3	.2	.2	.2	.2	.2	.2
NORTH BAY	3.4	3.4	3.4	3.3	3.3	3.2	1.5	1.5	1.5	1.5	1.5	1.5
OTTAWA	3.0	3.0	3.0	3.0	3.0	2.9	.0	.0	.0	.0	.0	.0
VINELAND	4.7	4.7	4.7	4.7	4.6	4.6	.0	.0	.0	.0	.0	.0
WHITE RIVER	.9	.9	.9	.9	.9	.9	.5	.5	.5	.5	.5	.5
AMOS	2.5	2.5	2.4	2.4	2.4	2.4	1.2	1.2	1.2	1.2	1.2	1.2
LA POCATIERE	3.2	3.2	3.2	3.2	3.2	3.2	1.6	1.6	1.6	1.6	1.6	1.6
LASSOMPTION	3.6	3.6	3.6	3.5	3.4	3.4	.0	.0	.0	.0	.0	.0
LENNOXVILLE	5.0	5.0	5.0	5.0	5.0	5.0	.0	.0	.0	.0	.0	.0
NORMANDIN	2.3	2.3	2.3	2.3	2.3	2.3	.4	.4	.4	.4	.4	.4
BATHURST	4.5	4.5	4.4	4.4	4.4	4.4	.0	.0	.0	.0	.0	.0
FREDERICTON	6.6	6.6	6.6	6.6	6.6	6.6	.0	.0	.0	.0	.0	.0
MONCTON	5.7	5.7	5.7	5.6	5.6	5.6	.0	.0	.0	.0	.0	.0
ST. JOHN	11.1	11.1	11.1	11.1	11.1	11.1	.0	.0	.0	.0	.0	.0
KENTVILLE	7.0	7.0	7.0	7.0	7.0	7.0	.0	.0	.0	.0	.0	.0
NAPPAN	6.1	6.1	6.1	6.1	6.1	6.1	.0	.0	.0	.0	.0	.0
CHARLOTTETOWN	5.5	5.5	5.5	5.5	5.5	5.5	.0	.0	.0	.0	.0	.0
SUMMERSIDE	4.4	4.4	4.4	4.4	4.4	4.4	.0	.0	.0	.0	.0	.0
ST. JOHNS	10.9	10.9	10.9	10.9	10.9	10.9	.0	.0	.0	.0	.0	.0

Table I. Relationships between dates when air and soil temperatures at 50 cm depth cross selected thresholds.

Date	Threshold	D.F.	Average air temp. date	Average soil temp. date	Diff.	Correlation coefficient	Standard error days
Spring	32°F	23	Apr.10	Apr.14	+4	0.87	10.5
	41°F	36	Apr.26	May 20	+24	0.84	10.4
Fall	32°F	24	Oct.28	Dec.6	+39	0.40	72.8
	41°F	37	Oct.11	Oct.27	+16	0.89	9.1

SWIFT CURRENT AIR

PERIOD VARIABLE	STORAGE INCHES	LOWEST OBS.	PERCENT PROBABILITY 10	25	50	75	90	HIGHEST OBS.	MEAN
SPRING S. M.									
	1	.00	.00	.00	.00	.35	.68	.97	.19
	2	.00	.12	.46	.88	1.28	1.65	1.97	.87
	3	.00	.50	1.02	1.59	2.16	2.67	2.97	1.56
	4	.00	.38	1.13	1.95	2.77	3.51	3.97	1.93
	5	.00	.22	1.12	2.11	3.10	4.00	4.64	2.11
	6	.00	.11	1.10	2.18	3.26	4.25	4.84	2.18
GROWING DEFICIT									
	1	3.47	7.06	8.90	10.94	12.97	14.82	16.24	10.87
	2	1.51	5.11	7.22	9.53	11.85	13.95	16.24	9.46
	3	.51	3.96	6.20	8.66	11.12	13.36	16.24	8.58
	4	.41	3.25	5.59	8.17	10.74	13.09	16.24	8.08
	5	.41	2.79	5.24	7.92	10.60	13.04	16.24	7.83
	6	.41	2.57	5.07	7.80	10.54	13.03	16.24	7.71
GROWING SEASON									
TOTAL PRECIPITATION		4.86	6.06	7.79	9.69	11.59	13.32	16.79	9.63
TOTAL PE		22.27	23.80	24.72	25.73	26.74	27.66	28.58	25.70
SURPLUS									
	1	.00	.00	.19	1.25	2.31	3.27	4.58	1.36
	2	.00	.00	.00	.00	.95	2.21	3.52	.53
	3	.00	.00	.00	.00	.31	1.39	2.52	.28
	4	.00	.00	.00	.00	.00	.74	1.52	.13
	5	.00	.00	.00	.00	.00	.14	.62	.04
	6	.00	.00	.00	.00	.00	.00	.00	.00
DORMANT SEASON									
TOTAL PRECIPITATION		1.02	1.66	2.30	3.16	3.94	4.65	5.38	3.36
TOTAL PE		2.24	2.33	2.67	3.04	3.41	3.75	4.66	3.24
SURPLUS									
	1	.00	.42	1.16	1.98	2.80	3.54	4.27	1.97
	2	.00	.00	.16	1.06	1.95	2.76	3.61	1.17
	3	.00	.00	.00	.00	.99	2.03	3.61	.54
	4	.00	.00	.00	.00	.00	1.21	3.14	.22
	5	.00	.00	.00	.00	.00	.00	2.14	.00
	6	.00	.00	.00	.00	.00	.00	1.14	.00
FREEZE SEASON									
TOTAL PRECIPITATION		.00	.10	1.06	2.11	3.17	4.12	5.14	2.11
TOTAL PE		.56	.85	1.05	1.27	1.49	1.69	1.84	1.35
SURPLUS									
	1	.00	.00	.21	1.25	2.28	3.23	4.27	1.37
	2	.00	.00	.00	.49	1.42	2.27	3.27	.78
	3	.00	.00	.00	.00	.43	1.30	2.27	.29
	4	.00	.00	.00	.00	.00	.17	1.27	.07
	5	.00	.00	.00	.00	.00	.00	.27	.00
	6	.00	.00	.00	.00	.00	.00	.00	.00

Table II- Averages and probable spring soil moisture contents, deficits and surplus in inches for seasons based on air temperature at Swift Current: 1931 - 60.

SWIFT CURRENT AIR

GROWING SEASON									
TOTAL RAIN		4.86	5.78	7.50	9.39	11.28	13.01	16.35	9.33
SURPLUS									
	1	.00	.00	.14	1.19	2.24	3.20	4.58	1.31
	2	.00	.00	.00	.00	.94	2.21	3.52	.53
	3	.00	.00	.00	.00	.30	1.38	2.52	.28
	4	.00	.00	.00	.00	.00	.74	1.52	.13
	5	.00	.00	.00	.00	.00	.14	.62	.04
	6	.00	.00	.00	.00	.00	.00	.00	.00
DORMANT SEASON									
TOTAL RAIN		.08	.00	.23	.52	.80	1.06	2.35	.51
SURPLUS									
	1	.00	.00	.00	.00	.00	.35	1.03	.06
	2	.00	.00	.00	.00	.00	.22	1.03	.04
	3	.00	.00	.00	.00	.00	.14	1.03	.04
	4	.00	.00	.00	.00	.00	.00	.67	.00
	5	.00	.00	.00	.00	.00	.00	.00	.00
	6	.00	.00	.00	.00	.00	.00	.00	.00
FREEZE SEASON									
TOTAL RAIN		.00	.00	.00	.08	.25	.41	.68	.13
SURPLUS									
	1	.00	.00	.00	.00	.00	.07	.16	.01
	2	.00	.00	.00	.00	.00	.00	.16	.01
	3	.00	.00	.00	.00	.00	.00	.16	.00
	4	.00	.00	.00	.00	.00	.00	.00	.00
	5	.00	.00	.00	.00	.00	.00	.00	.00
	6	.00	.00	.00	.00	.00	.00	.00	.00

PERCENT PROBABILITY

SWIFT CURRENT SOIL 50 CM

PERIOD VARIABLE	STORAGE INCHES	LOWEST OBS.	10	25	50	75	90	HIGHEST OBS.	MEAN
SPRING S. M.									
	1	.00	.00	.00	.11	.47	.79	1.00	.25
	2	.00	.00	.31	.77	1.22	1.63	1.92	.73
	3	.00	.00	.62	1.31	2.00	2.64	2.92	1.32
	4	.00	.00	.81	1.70	2.59	3.40	3.53	1.71
	5	.00	.00	.85	1.86	2.88	3.81	4.43	1.88
	6	.00	.00	.86	1.94	3.01	3.99	4.70	1.96
GROWING DEFICIT									
	1	3.75	6.93	8.73	10.70	12.68	14.47	15.38	10.64
	2	1.51	5.30	7.31	9.52	11.73	13.74	15.38	9.45
	3	.51	4.20	6.36	8.74	11.12	13.29	15.38	8.67
	4	.41	3.51	5.77	8.25	10.74	13.00	15.38	8.17
	5	.41	3.06	5.42	8.00	10.59	12.94	15.38	7.92
	6	.41	2.85	5.25	7.89	10.52	12.92	15.38	7.80
GROWING SEASON									
TOTAL PRECIPITATION		4.92	5.94	7.62	9.47	11.32	13.00	16.73	9.41
TOTAL PE		22.01	23.02	23.98	25.02	26.06	27.01	27.74	24.99
SURPLUS									
	1	.00	.00	.31	1.29	2.27	3.17	4.58	1.34
	2	.00	.00	.00	.00	.83	2.26	3.52	.52
	3	.00	.00	.00	.00	.13	1.40	2.52	.27
	4	.00	.00	.00	.00	.00	.74	1.52	.13
	5	.00	.00	.00	.00	.00	.14	.62	.04
	6	.00	.00	.00	.00	.00	.00	.00	.00
DORMANT SEASON									
TOTAL PRECIPITATION		1.16	1.66	2.47	3.37	4.27	5.08	5.98	3.58
TOTAL PE		3.01	2.97	3.33	3.73	4.13	4.49	5.30	3.98
SURPLUS									
	1	.00	.49	1.21	2.01	2.80	3.52	4.27	1.99
	2	.00	.00	.22	1.08	1.95	2.75	3.38	1.18
	3	.00	.00	.00	.00	1.03	1.97	3.38	.55
	4	.00	.00	.00	.00	.00	1.21	3.14	.22
	5	.00	.00	.00	.00	.00	.00	2.14	.00
	6	.00	.00	.00	.00	.00	.00	1.14	.00
FREEZE SEASON									
TOTAL PRECIPITATION		.00	.00	.60	1.71	2.82	3.83	5.14	1.77
TOTAL PE		.54	.63	.85	1.08	1.31	1.52	1.76	1.15
SURPLUS									
	1	.00	.00	.14	1.17	2.20	3.14	4.27	1.31
	2	.00	.00	.00	.43	1.40	2.28	3.27	.76
	3	.00	.00	.00	.00	.35	1.30	2.27	.28
	4	.00	.00	.00	.00	.00	.17	1.27	.07
	5	.00	.00	.00	.00	.00	.00	.27	.00
	6	.00	.00	.00	.00	.00	.00	.00	.00

Table III- Average and probable spring soil moisture contents, deficits and surplus in inches for seasons based on soil temperature at 50 cm depth at Swift Current: 1931 – 60

SWIFT CURRENT SOIL 50 CM

GROWING SEASON									
TOTAL RAIN		4.92	5.07	7.32	9.14	10.95	12.60	16.35	9.08
SURPLUS									
	1	.00	.00	.24	1.23	2.22	3.11	4.58	1.28
	2	.00	.00	.00	.00	.81	2.23	3.52	.51
	3	.00	.00	.00	.00	.07	1.36	2.52	.26
	4	.00	.00	.00	.00	.00	.74	1.52	.13
	5	.00	.00	.00	.00	.00	.14	.62	.04
	6	.00	.00	.00	.00	.00	.00	.00	.00
DORMANT SEASON									
TOTAL RAIN		.07	.00	.35	.75	1.16	1.53	2.73	.77
SURPLUS									
	1	.00	.00	.00	.00	.05	.45	1.03	.08
	2	.00	.00	.00	.00	.00	.38	1.03	.07
	3	.00	.00	.00	.00	.00	.33	1.03	.06
	4	.00	.00	.00	.00	.00	.00	.67	.00
	5	.00	.00	.00	.00	.00	.00	.00	.00
	6	.00	.00	.00	.00	.00	.00	.00	.00
FREEZE SEASON									
TOTAL RAIN		.00	.00	.00	.00	.14	.30	.50	.07
SURPLUS									
	1	.00	.00	.00	.00	.00	.07	.16	.01
	2	.00	.00	.00	.00	.00	.00	.16	.01
	3	.00	.00	.00	.00	.00	.00	.16	.00
	4	.00	.00	.00	.00	.00	.00	.00	.00
	5	.00	.00	.00	.00	.00	.00	.00	.00
	6	.00	.00	.00	.00	.00	.00	.00	.00

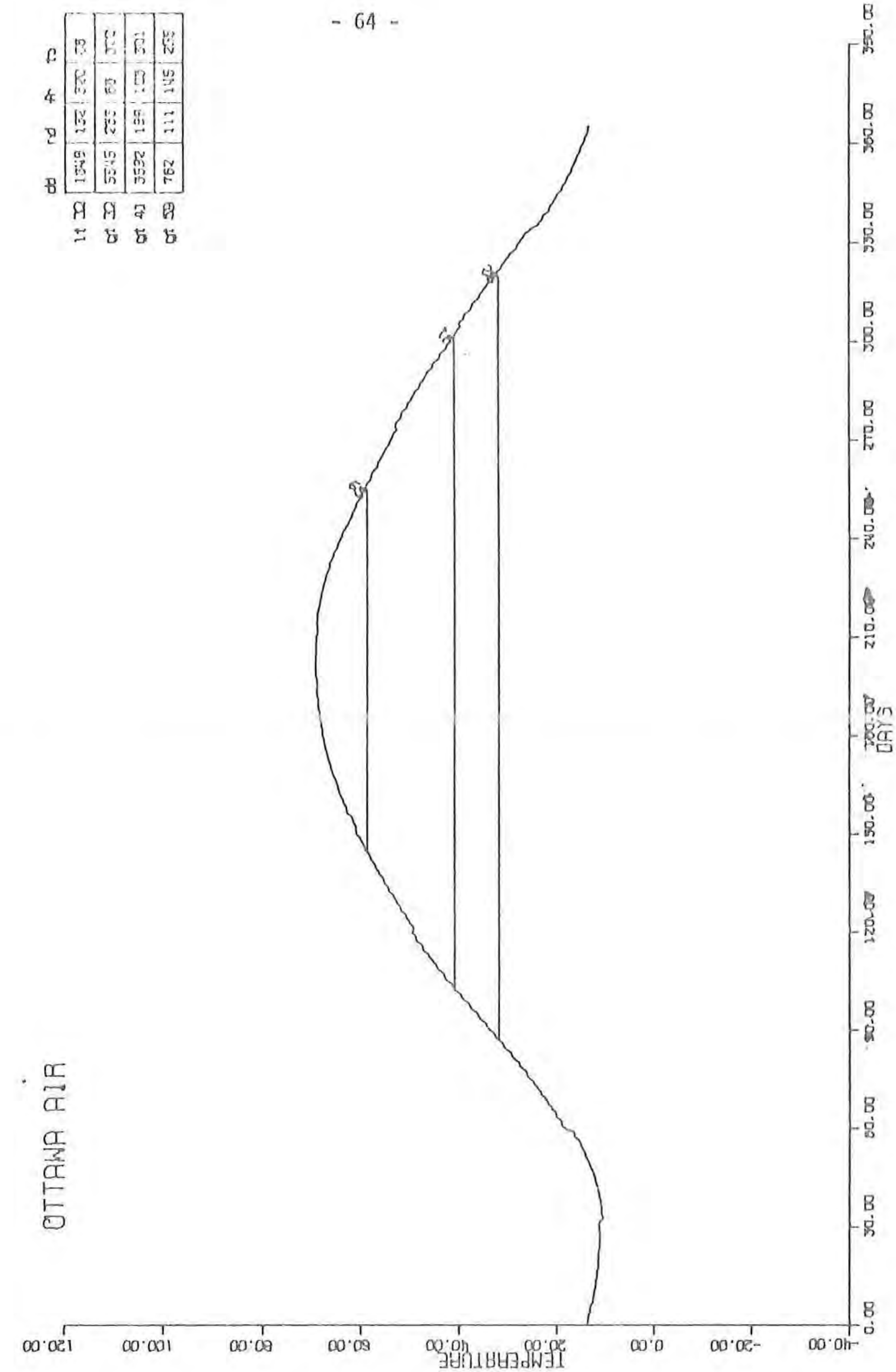

Fig. 1 - Daily interpolated average air temperature (°F) at Ottawa.

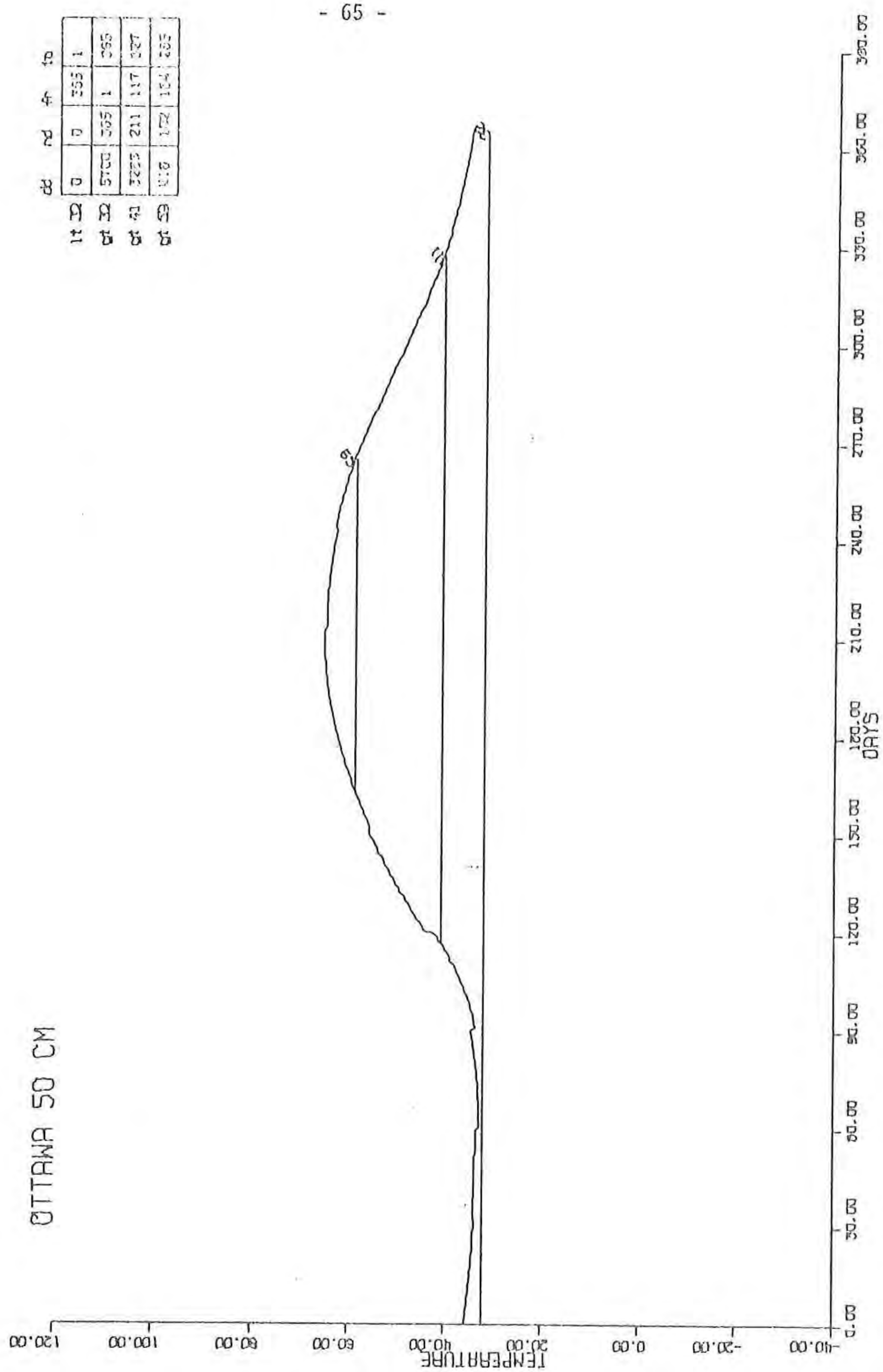

Fig. 2 - Daily interpolated average soil temperature (°F) at 50 cm depth at Ottawa.

THE EFFECT OF VARIOUS GROWING SEASON LENGTHS ON VALUES OF THE CLIMATIC MOISTURE INDEX

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Abstract

Data for growing seasons defined as: 1) the fixed May to September calendar period, 2) the period during which the air temperature is greater than 41°F, and 3) the period during which the 50 cm soil temperature is greater than 41°F are used to calculate climatic moisture indices for 23 climatic stations for which at least two years of soil temperature reports are available. These are compared and the reasons for the variations in the values discussed. Moisture deficits (irrigation requirements) for the three periods are nearly constant. Station indices, calculated from data for the longer growing periods based on soil and air temperatures, are within a few points of each other and both are somewhat larger than those based on the May to September growing season data. When stations are listed in the order of ascending values of their indices, those based on data for the periods when the air and 50 cm soil temperatures are greater than 41°F are essentially the same and differ significantly from the order for the May to September data only in cases where early spring or late fall rains are heavy in relation to summer precipitation. The physical interpretation of the index holds for all growing seasons but it becomes less meaningful in terms of capability for crop production in Canada when the growing season is defined on the basis of the values of the soil temperature at a depth of 50 cm.

Introduction

The objective of integrating climatic factors important to crop growth into an expression that would have a meaningful physical interpretation and be useful for country-wide comparisons led to the proposal that a "Climatic Moisture Index"

$$\frac{P}{P + SM + IR} \times 100 \qquad [1]$$

might satisfy these conditions and be useful in soil classification (3). SM represents the water in the soil at the beginning of the growing season that is readily available to crops and P is the growing season precipitation. If no stress is to develop the amount by which SM and P fail to meet the crop's demand for water must be supplied by irrigation (IR). The denominator of the expression [1] then, is an approximation of the water annual crops would use if the supply is not to be limited, and the index represents the percentage of this water that is provided by precipitation. Although seasonal precipitation is the predominant factor, index valves are influenced by temperature, sunshine, humidity and wind as these are used in calculating the evapotranspiration necessary for determining the irrigation requirements (1).

It has been possible to evaluate [1] only because information on irrigation requirements for selected Canadian stations has recently become available (2). This information includes average seasonal requirements based on the 1931-60 standard 30 year period. For these original calculations (of irrigation requirements or deficits) observed data on soil moisture contents at the beginning of the growing season and on the water holding capacity of the soils were not available except in isolated cases for individual years. To overcome this the soil water was assumed to be at field capacity at the beginning of the season and tables were presented for a wide range of soil water capacities. It has been shown (3) that when capacities for readily available water are two inches or more, different soil water contents at the beginning of the season at a station and different soil water capacities cause almost no change in the value of the resulting climatic moisture index. Not only does this add to the universality of the index, but it makes possible the comparison of indices calculated for localities where soil moisture and soil water holding capacities are known with those where arbitrary values of these factors have been assigned.

In the original calculations (2) the soil was assumed to have a two inch capacity for readily available water. Since soil water is assumed to be at capacity (SC) at the beginning of the season SM becomes SC = 2.00 inches and is the same for all stations. The growing season was taken as the period May to September inclusive and the irrigation requirements or deficits were calculated on a daily basis and averaged over 30 years. It was possible to calculate indices for 59 stations across Canada using the data presented.

The assumption of a growing season based on a calendar period may not be satisfactory for all purposes. Although most annual crops are planted and harvested within the May - September period in Canada, the growing season for forages may be considerably different. Internal Report No. 20 of the Agrometeorology Section, Plant Research Institute (Baier and Russelo) presents soil moisture deficits or irrigation requirements for periods when the air temperature is greater than 41°F and when the soil temperature at 50 cm is greater than 41°F for some 67 Canadian stations. In these calculations a storage capacity of two inches of readily available water is assumed. With this assumption, the techniques employed in the analysis provide estimates of the soil water content at the beginning of the growing season. These and seasonal water surpluses are included in the output of the computer program used. A special technique (described in Internal Report No. 20) was developed for obtaining the period in which the 50 cm soil temperature is above 41°F from air temperatures for stations where soil temperature data are not available.

Soil temperatures have been measured at some 23 stations for two years or longer and data for these stations were used for computing climatic moisture indices for periods defined by soil and air temperatures as mentioned above. The results of these calculations are presented in this report and their implications discussed.

Data and Discussion

Table 1 shows the stations with soil temperature measurements and their indices calculated for the various growing seasons. Columns 2, 4, and 6 show the respective growing season lengths (beginning from January 1 = 1 etc.) and columns 3, 5 and 7 show the resulting indices. The stations are presented in ascending order of the value of the original indices (3), i.e. those with a fixed May to September growing season.

In general the new growing seasons give indices slightly higher than those for the fixed May - September period. With the possible exception of Summerland (for the 50 cm based growing season) the only significant change in the order is brought about by Saanichton data* where the index increases 25 to 26 points. Details of the basic data for Saanichton and other selected localities are given in Table 2. Summerland, Prince George and Harrow were selected because after Saanichton they show the greatest change in index values. Swift Current is a typical prairie station and La Pocatiere is representative of a station with a large surplus of growing season rainfall. It will be noted that for the May to September season soil moisture (readily available water) is always assumed to be at two inches (capacity) at day 120 (the first of May) and that surpluses are not available.

In the case of Saanichton, the calculations show that soil moisture was at capacity with two inches of readily available water on day 74, the beginning of the growing season as determined by soil temperatures. The growing season continues to day 334, completely overlapping the May to September period. No additional deficit developed during this much extended (107 days) growing season but the precipitation increased from 5.7 to 16.6 inches. Part of this is used to balance the additional evapotranspiration but this is small and 9.7 inches appears as surplus. Surplus during the May - September period is not available, but from the figures given it will be deduced that it must be something less than 1.2 inches. The much higher index for the longer period reflects only the influence of the additional rain during this time, nearly all of which is assumed lost to deep percolation or run-off and does not directly contribute to plant growth. Considering the even longer period when the air temperature is greater than 41°F, the rain increases 1.2 inches from 16.6 to 17.8 but all of this increase shows up in the higher surplus figures.

At Summerland, with the extension of the growing period to that determined by soil temperatures, the precipitation increases by 2.6 inches. This is apportioned to the soil recharge and surplus according to the climatic conditions. On the average, the soil is not quite at capacity at the beginning of the growing season. The increase in the irrigation requirement or deficit for the longer growing season is only .5 inches,

*Where soil temperatures at 50 cm do not drop to 41°F the growing season is assumed to be March 15 to November 30. Saanichton is such a station.

about 5%. The growing season based on air temperatures greater than 41°F begins within three days of that based on soil temperatures but ends about seven weeks earlier in the fall. The deficit is the same as for the longer period but the precipitation and surplus are less. Half the .8 difference in the precipitation shows up as additional surplus for the longer period and the remaining .4 inches are lost to the additional evapotranspiration or remain in the soil. Again, at Summerland the change in the values of the climatic moisture index when other than May to September is chosen as the growing season is due to the increase in the precipitation during the longer season intervals without a corresponding increase in the deficits (irrigation requirements). In this case the additional precipitation mainly goes into soil moisture recharge in the fall and is not necessary for crops during the current year.

At Swift Current, a typical dry prairie station, the average soil moisture at day 121, estimated by the techniques used in Internal Report No. 20, is only .7 inches. In the original calculations (3) it was assumed to be two inches. Since all of the 1.3 shortage does not appear as additional deficit, some recharge of soil moisture must take place in the late spring, probably due to increased shower activity in June. It is likely that surplus figures for the May - September growing season, if available, would be larger than the .5 inches shown for the other cases. Variations in the SM + IR factor of this order due to this type of precipitation distribution may occur at dry stations. In these cases SM + IR is relatively large (10 inches or more) and the effect on the index value is not significant. At Swift Current lengthening the growing season has only a small effect on the index increasing it from 45 to 48, a change not significant in relation to the representativeness of the data involved.

At La Pocatiere precipitation is heavy and fairly evenly distributed throughout the year. Deficits are small and surpluses large. The slight increase in the index for the longer growing seasons reflects the increase in precipitation in the periods during which evapotranspiration is low and there is no increase in deficit.

From the data for the six localities in Table 2 it is readily deduced that, on the average, practically all deficits are accumulated in the May to September period. For growing seasons based on soil and air temperatures where soil moisture contents at the beginning of the seasons are known, they are identical. When the May to September growing season (where soil moisture is assumed to be at capacity) is included the variation is no more than .8 inches for dry stations and much less for moist stations. The data (not reproduced here) for the remainder of the stations listed in Table 1 support these observations. The change in the value of the indices, then, can be attributed almost entirely to the effects of precipitation occurring during the extended periods when the rain is not immediately required by crops. Where there is little additional rain during these extended periods such as on the prairies, or where precipitation is more or less evenly distributed throughout the season, there is no significant change in the value or order of the station indices. A major change in both occurs where there are heavy rains in the spring and fall in relation to those during the May to September period. The data for Saanichton is an ideal example, the index of 48 resulting from the use of May to September data places Saanichton in the same relative class as Saskatoon and Lethbridge (Table 1) as far as summer rainfall efficiency is concerned. Data for the period in which the 50 cm soil temperature is greater than 41°F would indicate climatic conditions during the period, as expressed by the index, are similar to those at Beaverlodge, Calgary, or Winnipeg. If the period in which air temperatures are greater than 41°F defines the growing season, Saanichton conditions (in regard to the moisture balance with a well drained soil) are represented as being similar to those at Harrow.

The climatic moisture index was conceived as a tool to provide climatic data in a form useful for comparing the capability of areas in relation to annual crop production and to provide a means of arriving at rough estimate of rainfall efficiency during the growing season for these crops. If the period when the air temperature is above 41°F can be considered as the growing season for forage crops, then the index based on data for this period can be interpreted in similar terms but in relation to forage crops. In the context of Canadian climate, where outbreaks of cold air or influxes of warm air may effectively change the above ground growing season relatively independent of the 50 cm soil temperature, indices based on a soil temperature growing season, while representing the climatic balance during this period, will have only an indirect relationship to crop production capability and a less meaningful physical interpretation.

Conclusions

The following conclusions are based on the data for 23 stations across Canada for which two or more years of observed soil temperature records are available. They must be re-examined as additional information becomes available.

1. As determined for this study, all significant soil water deficits or irrigation requirements developed during the May-September period.

2. Most heavy precipitation outside the May-September period shows up as surplus and is not immediately available for crop use.

3. Climatic moisture indices based on data for growing periods determined by soil or air temperatures greater than 41°F are larger than those based on the May to September period due to the additional rainfall in these periods.

4. Except for cases where there is heavy rainfall in early spring or late fall the order of the stations based on the size of the indices is essentially independent of the growing season selected for determining the data on which they are based.

5. If the period when the air temperature is greater than 41°F can

be considered as the growing season for forage crops then the index can be interpreted as originally intended except the reference will be to perennial crops rather than annual.

6. If the 50 cm soil temperature is to be used for determining growing season intervals, the index for this interval represents the rainfall-evapotranspiration relationship but its physical interpretation becomes less meaningful.

References

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Coligado, M. C., W. Baier and W. K. Sly, 1968. Risk analyses of weekly climatic data for agricultural and irrigation planning. Tech. Bull. Nos. 17-58 61-77, Agrometeorology Section, Plant Research Institute, Can. Dep. Agr. 34 pp.

Sly, W. K.,1970. A climatic moisture index for land and soil classification for Canada. Can. J. Soil Sci. (in press).

(1) Station	(2) Period	(3) Index	(4) Period	(5) Index	(6) Period	(7) Index
			50 cm Temp.		Air Temp.	
	May-Sept.		>41°F		>41°F	
Summerland	120-273	30	84-341	39	81-305	36
Outlook	"	42	128-305	45	107-290	45
Swift Current	"	45	121-311	48	110-292	48
Saanichton	"	48	74-334	73	66-338	74
Saskatoon	"	50	121-298	53	109-288	52
Lethbridge	"	50	116-313	55	103-298	55
Regina	"	52	145-305	56	111-285	55
Fort Vermilion	"	56	136-291	61	118-276	58
Fort Simpson	"	64	164-273	68	126-268	65
Beaverlodge	"	67	126-298	73	113-285	70
Calgary	"	68	131-302	72	111-290	71
Winnipeg	"	68	140-311	73	110-292	71
Harrow	"	68	103-347	76	94-315	74
Prince George	"	74	131-314	80	109-287	77
Guelph	"	80	114-337	85	102-307	83
Ottawa	"	80	117-327	84	103-301	83
Kentville	"	81	114-325	87	107-313	86
Kapuskasing	"	83	131-315	87	124-287	85
Charlottetown	"	84	130-337	90	114-311	89
Fredericton	"	87	121-321	90	108-300	89
La Pocatiere	"	88	130-318	92	114-297	91
St. John's	"	90	136-337	93	131-305	92
Normandin	"	90	142-309	91	121-288	90

Table 1: Columns 3, 5, and 7 are climatic moisture indices based on data for growing seasons indicated in columns 2, 4, and 6 respectively (January 1 = 1 etc.). Stations in column 1 are ranked in order of the magnitude of the index in column 3.

(1) °F	(2) Period	(3) Precip. (P)	(4) Soil Moisture (SM)	(5) Deficit (IR)	(6) Index	(7) Surplus
Saanichton	120-273	5.7	2.0	4.2	48	
50 cm temp. >41	74-334*	16.6	2.0	4.2	73	9.7
air temp. >41	66-338	17.8	2.0	4.2	74	10.9
Summerland	120-273	5.1	2.0	9.7	30	
50 cm temp. >41	84-341	7.7	1.9	10.2	39	.6
air temp. >41	81-305	6.9	1.9	10.2	36	.2
Prince George	120-273	11.4	2.0	1.9	74	
50 cm temp. >41	131-314	13.6	1.3	2.0	80	3.8
air temp. >41	109-287	12.9	1.8	2.0	77	2.4
Harrow	120-273	13.1	2.0	4.2	68	
50 cm temp. >41	103-347	19.6	1.8	4.4	76	5.3
air temp. >41	94-315	18.4	1.9	4.4	74	4.2
Swift Current	120-273	8.9	2.0	8.7	45	
50 cm temp. >41	121-311	9.4	.7	9.5	48	.5
air temp. >41	110-292	9.6	.9	9.5	48	.5
La Pocatiere	120-273	18.8	2.0	.5	88	
50 cm temp. >41	130-318	22.4	1.5	.5	92	9.4
air temp. >41	114-297	21.8	1.7	.5	91	8.0

Table 2: Basic data for selected stations. The growing period is given in days (January 1 = 1 etc.) for the intervals shown in column 1. Columns 3, 4, 5 and 7 are in inches of water. Indices are based on the data in their respective rows.

* Assumed growing season--see text for explanation

REMARKS ON RECENT PROGRESS IN AGROCLIMATIC RESEARCH AND MAPPING METHODS TO AID LAND CAPABILITY EVALUATION

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Over the past few years the Agrometeorology Section of the Plant Research Institute in Ottawa has been developing computer programs which estimate temperature normals for any point on the Canadian Great Plains, from the latitude, longitude and elevation of each point, using equations provided by Dr. J. W. Hopkins of N.R.C., and which then use these estimated normals and other data to obtain various derived climatic resource information.

In 1968, tabulations which included normal growing degree-days and freeze-free season durations, as well as the estimated temperature normals, for about 1200 survey control point locations on the Canadian Great Plains, were provided to several soil scientists working on land classification for the Canada Land Inventory. The degree-day estimation procedure required standard deviations of monthly mean temperatures in addition to the estimated monthly temperature normals, and as a short cut a single set of the 12 monthly standard deviations was used for all 1200 points. Since then the method of computing the degree-day normals has been improved by the inclusion in the program of equations for estimating standard deviations at any point on the Canadian Great Plains, using new coefficients provided by N.R.C., in the same way that the temperature normals are estimated for any point. The freeze-free season estimation has also been improved by the incorporation of equations developed by George Robertson for estimating freeze-free season dates and durations using monthly temperature normals.

While these are valuable improvement and refinements to the methods, the main emphasis in this research in the Agrometeorology Section in recent years has been on evaluations of climatic resources for specific uses rather than on employing general climatic indices such as degree days. The contention is that requirements vary so much from one type of use to another that the climatic resources must be assessed separately for each of a number of important uses.

An extreme example of the effects of the contrasting needs for different uses has been demonstrated by using the survey control point data to map growing degree-days (above 42°F) and heating degree-days (below 65°F) for northern Alberta. On the growing degree-day map the main pattern was one of high values in the valleys and low ones on the hills, whereas on the heating degree-days map the main pattern was a general increase in heating degree-days, and hence a decrease in the climatic resources for keeping a building warm, going from south-southwest to north-northeast. Thus the climatic resources for maturing a crop which developed at a rate proportional to degree days above 42 would be best in the valleys and poorest in upland areas anywhere in the region, whereas climatic resources for keeping a building warm would be best in the southwest and poorest in the northeast, without too much relationship to the upland and valley distribution, and any attempt to develop a single climatic index to rate an area for both needs would be a waste of time. The same difficulty would arise in rating a location for both summer growth of a crop and winter survival of perennials.

Even with too much less diverse land uses, such as the growing of barley as opposed to wheat, the difference in climatic resources for the two uses may be significant. In developing this concept of activity-by-activity or crop-by-crop evaluation of climatic resources, a preliminary map of the "photo-thermal" resources (thermal and photoperiodic) for maturing wheat on the Canadian Great Plains was prepared and published (Can. J. Soil Sci., 49:263-276, 1969). In this, daily temperature normals, interpolated from the estimated monthly normals, were computed for the survey control points and used together with photoperiod data on a biometeorological time scale equation to estimate what phenological stage wheat would normally reach at each location, and if this was the ripe stage the normal minimum temperature at the ripe stage was computed as an indication of the likelihood of satisfactorily maturing and harvesting the crop.

While photoperiod variations might perhaps be ignored in dealing with a small region, they must be considered when mapping a region with as large a latitudinal range as the Canadian Great Plains. A crop which appears to need a certain number of degree days to mature at Fort Simpson may need a considerably larger number of degree days around Calgary because of the shorter day length there. Since photoperiodic response varies from crop to crop, there may be no simple relationship between the climatic resource patterns for different crops.

A biometeorological time scale is currently being developed for barley. This will be used in mapping the climatic resources of the Canadian Great Plains for barley, as the next step in the activity-by-activity evaluation of Canadian climatic resources. In this study the normal number of days from ripening to first fall freeze will be mapped, instead of the minimum temperature at ripening as was done for wheat.

Considerable progress is being made concurrently in techniques for mapping such resource evaluations. Hand plotting of 1200 values on a map was very laborious. The need for this has now been eliminated by automation. Output from the computer program that calculates the values is now used in another program which prepares a magnetic tape for plotting the data positioned to correspond to a Lambert Conformal Conical Projection at some specified scale. The numerical data are then plotted on blank paper by the Calcomp plotter which uses an automatically controlled penz. The plotter output can then be used with a base map over a tracing table to draw the isolines in preparing the final map. This procedure is now fully operational.

Instead of drawing the isolines, one can use a program called SYMAP to have a computer produce a print-out showing areas between the isolines shaded, with isolines appearing white. This shading is achieved by various combinations and overprintings of the standard printer characters used in ordinary computer output listings.

The SYMAP shading is quite effective in showing distributions of variables such as climatic resource values, particularly when photographically reduced, but it is not too satisfactory for simultaneously showing boundaries, rivers, etc., that would be needed on a finished map. Such additional geographic information can, however, be digitized and stored on magnetic tape, and a flatbed plotter such as the Soil Research Institute's Grebber can be used to draw in the required boundaries, rivers, etc., and enter legends and titles on the SYMAP output, either before or after photographic reduction. Technical details of this procedure are currently being worked out and results so far are quite promising.

On the research side the aim is to develop climatic resources evaluations for a number of important land-use activities, which can then be combined with soils or other physical resource data. These should provide as objective and comprehensive information as possible to enable land-use planning authorities and others to make soundly based decisions among the various possible uses of land.

On the technical mapping side the objective is to enable the research worker to quickly obtain a complete and effective visual expression of his results. The automatically produced map helps to indicate the next step when a number of approaches are being tried in the research, and it may be photocopied for circulation for discussion purposes. In the final stages of a study several of the computer maps may be included with a manuscript for publication, thus avoiding the long delays involved when hand mapping is required.

REPORT OF THE SUBCOMMITTEE ON SOIL SURVEY INTERPRETATION FOR ENGINEERING USE

S. Pawluk, Chairman

Although soil surveys have for a long time received prominence in their application to agronomic practices, the interest in,and use made of,such surveys by the professional engineer warrants some revisions in the methods for reporting soil data and the interpretation of such data to more closely meet the engineer's aspirations and needs.

The engineer has always regarded soil as a construction material to either support foundations and structures in its natural state or to be remolded into a material which may be utilized to build structures such as highways, dams, conduits for sewage disposal and the like. For this reason, the engineer's concept of soil normally applies to the entire regolith or the unconsolidated sediments on the earth's crust and this is what he tries to manipulate to meet his specific objectives.

In order to fully understand the performance of what he considers to be soil, the engineer is interested in many properties which are of interest to the pedologist because they aid in the characterization of the pedogenically active portion of the regolith. It is for this reason that pedological information collected during soil surveys has been of value to the engineer although it was not originally intended to serve this purpose. The application of such information to the problems of the engineer was left to his discretion and his ability to use the information was often determined by his comprehension of soil survey methods. If the pedologist now desires to reorient his objectives in soil mapping in order to make his information more broadly applicable and at the same time more exacting, it will be essential to review mapping procedures and reconsider the list of recommended analytical data published in the soil survey report.

The pedologist does not wish to, and cannot, replace the engineer or reduce his usefulness to society, but does wish to establish closer coordination of efforts for the mutual advantage to both. Furthermore, unqualified pedologists interpreting soil survey data for engineering use without consultation with qualified engineers run the risk of making erroneous recommendations that could severely damage the image of pedology as a scientific discipline. It may be wise to remember that pedologists are no more competent in conducting engineering interpretations than engineers are in describing soil profiles. Therefore, it is recommended that interpretations should be prepared in consultation with the professional engineer and that every effort possible should be made to follow this procedure.

Although it is generally agreed that additional information in the way of relevant characteristics and properties would be very useful in all reports, the need for interpretations and the kinds of interpretations depend largely on the objectives in mapping and the map scale.

It is generally accepted that although reconnaissance maps of one inch to two miles and maps of smaller scale serve well as soil resource inventory maps and have been useful to agriculture, the variability within map units is not suited to on-site planning of the engineer. It may be of some value to the engineer for conducting very preliminary evaluations. Because of the limited value of such maps to the engineer, it is recommended that interpretations be either excluded from such reports or incorporated as broad generalizations. However, it is recommended that the following additional data on properties and characteristics be provided:

1. Atterberg limits and plasticity index.
2. particle size distribution according to the unified and/or A.A.S.H.O. system.
3. improved mapping of non-agricultural land, such as those presently distinguished as "alluvial soils" and "eroded soils" along major drainage ways.
4. a correlation of engineering and pedological terminology.
5. 0.33 bars and 15 bars moisture retention especially for agricultural engineers.

Semidetailed and detailed maps of larger scale are generally prepared with specific objectives in mind. Therefore, the specific objectives should provide guidance for interpretations if they are to be sufficiently meaningful to meet local requirements. Under such circumstances, the mechanics involved for conducting such interpretations become dependent upon facilities and personnel at hand. At the 1968 meetings of the C.S.S.C. in Edmonton, a conceptual model of what was most desired for conducting engineering interpretations was accepted. However, it is unlikely that soil survey units across Canada will be sufficiently equipped and staffed to follow this approach for some time.

Therefore, this committee recommends that individual soil survey units pursue this matter of engineering interpretations according to their own objectives and local needs. The mechanics involved should also be worked out locally through cooperation between the pedologist and engineer. Since the input of the engineer would be significant in determining the kinds and numbers of classes within any interpretive grouping, this too is of local concern.

On the basis of the foregoing, the committee will recommend only on a format, on the possible parameters that could be measured, on the methods of analyses and on the possible use of the data.

The format proposed at the 1968 Edmonton meetings of the C.S.S.C. appears to be adequate at the present time. Additional parameters, both measured and inferred, that could be reported are outlined in Table 1. The recommendations are grouped according to desirability and feasibility as suggested from summaries received from all soil survey units.

Since engineers do not have a unified system for analytical procedures on a national basis, procedures followed should be those acceptable on a local basis. These procedures are generally those outlined in Lambe[1], Terzaghi[2] and A.S.T.M.[3].

Data reported for civil engineers should deal with the C horizon and to a much lesser extent the B horizon. Data accumulated by engineers to date suggest little difference between the performance of the B and of the C horizons. The A horizon and often the B horizon is generally considered as overburden. The agricultural engineer, on the other hand, is generally concerned with the A and B horizons since his objectives are not the same.

Recommendations for use listed in Table 2 are based on the premise that site planning is not considered the sole responsibility of the engineer. On this basis interpretations for recreational use, landscape design, etc., are not regarded as engineering interpretations but rather as "land use" interpretations. Because such interpretations are multidisciplinary, they should be handled separately by a committee on "Interpretation for Multiple Land Use". In many instances provincial groups already function in this manner.

1. Lambe, T. W. — Soil Testing for Engineers. John Wiley and Sons, New York.

2. Terzaghi, K. and Peck, R. B. — Soil Mechanics for Engineering Practice. 2nd Edition. John Wiley and Sons, New York.

3. A.S.T.M. — Standards, American Society for Testing Material Philadelphia, Pa.

Table 1

Information Recommended as Being Useful for Engineering Interpretations

List A. Additional information recommended on a routine basis where methods are well established.

1. a. Atterberg limits.
   b. Plasticity index.

2. Shrinkage limit and shrinkage index.

3. Particle size distribution. Unified system and A.A.S.H.O. system.

4. Depth to water table where measurable with the use of hand tools. Only valid if related to time of year measurements made.

5. Depth to bedrock (and type) where measurable with hand tools.

6. Field moisture content at 8' to 10' where obtainable with the aid of powered "corer". Perhaps only necessary to go to this depth in areas about to be urbanized. Otherwise, maximum of 5' to 6' may be suitable.

7. 0.33 bars and 15 bars moisture tension.

8. Location of sand and gravel.

9. It is strongly recommended that "alluvial soils" and "eroded soils" along drainage ways be properly delineated into pedological map units as done for the general map area. Little or not any significance has been assigned to such soils on many reconnaissance maps. This is especially important in flood control studies.

10. Correlation of terminology (prepared by committee on terminology definitions).

11. Maximum dry densities.

List B. Additional information recommended on a routine basis but where research on methods and techniques is required to determine suitability and reliability.

1. Optimum moisture for maximum compaction.

2. Maximum depth of frost penetration and frost action.

3. Corrosion potential.

List C. Information that would be useful for detailed surveys conducted with engineering purposes in mind where complicated techniques and/or considerable time is involved in measurements.

1. Unconfined compressive strength (bearing strength) for cohesive soils.
2. *In situ* hydraulic conductivity.
3. Soil moisture curves.
4. Undisturbed pore space.

List D. Analysis that may be useful but not required specifically for engineering interpretation (generally presently reported).

1. Electrical conductivity.
2. Clay mineralogy.
3. Exchangeable cations and capacity.
4. Organic matter content.
5. Ca and Mg carbonates.
6. pH.

Table 2

List of Possible Engineering Applications

1. Highways, roadways and pathways.
2. Drainage requirements:
    - a. irrigation.
    - b. sewage disposal.
    - c. fields (i) game fields (ii) golf courses, etc.
    - d. campsites.
    - e. agricultural drainage.
    - f. road drainage.

3. Foundations:
   a. residential; urban and suburban.
   b. industrial
   c. cottages.
   d. airports.
   e. agricultural foundation (large silos, feedlots, barns, etc.)

4. Corrosion:
   a. pipelines (steel).
   b. telephone cables (aluminum).
   c. concrete (cement).
   d. aluminum irrigation pipe.

5. Earth-filled water diversion structures:
   a. terraces.
   b. waterways.
   c. dikes, levees.
   d. reservoirs.

6. Evaluation of suitable tillage equipment:
   a. according to tilth requirements for different soils.
   b. according to power requirements for different soils.

Discussion

D. Acton: Do engineers use the same size fractions when doing particle size distribution as we do (U.S.D.A.)?

Pawluk: Not entirely, they generally employ Casagrandes procedures.

D. Acton: What about use of the geological classification of particle size (Wentworth scale)?

Pawluk: Not used by soils engineers in Alberta. Engineers would rather see particle size distribution plots than textural class as the former is more meaningful for their purposes.

D. Acton: Would plots based on Wentworth scale be more meaningful?

Pawluk: Don't know! In any event clay size break is approximately equivalent.

White: In Ontario, the clay size break is not the same for engineers as for other disciplines. The break at 2 μ is being used and adopted, however, a reading from the hydrometer at the 5 μ break would be very useful for highway engineers. Ontario highway engineers do not use the Wentworth classification.

Pawluk: There appears to be no uniformity among geologists regarding use of a particle size classification. In Alberta, sedimentologists use the Wentworth system while surficial geologists employ the U.S.D.A. system.

D. Acton: Could we not help engineers more by giving topography or landforms?

Pawluk: In Alberta, the engineers are not too concerned with topography as this is supplied by topographical maps. This, of course, would be a local consideration.

White: Ontario has a good monograph on topography and physiography which highway engineers find most useful. Thus the regional availability of information in Canada is important in discussing guidelines for engineering interpretations.

D. Acton: Landform information for a whole province would aid in interpretation and possibly eliminate some preliminary terrain analysis by engineers. Maybe this information could be supplied by pedologists.

Pawluk: I think this is a regional problem. In Alberta, there are good topographic maps available, especially in settled areas, and a terrain map may not be useful.

Penner: The idea of engineering interpretations of soil survey information is well accepted by me and I believe would be, and is, by soils engineers. These could tie in with the urban geology maps as depth of overburden is important.

Pawluk: We have suggested that this information be supplied i.e.: depth of overburden, when the information can be gathered by the use of hand tools.

Penner: This is a useful consideration as this information is important for the construction of piles, etc. where this information is not available from an urban geology map. Special formations such as Leda clays should also be included in overburden and engineering interpretation information. The Associate Committee on Geotechnical Information of the N.R.C. should be involved in this committee's (C.S.S.C. Engineering Subcommittee) deliberations. I believe this concept would be well received. If a committee could be struck heavily laced with both pedologists and engineers this would be most useful. As a point of interest, at first the idea of an urban geology map was not well accepted by engineers as most of the data from drill holes was in the hands of private engineering consultants. Now the urban geology maps are very well accepted and I believe that soil maps would be well accepted but often they are not available, or the engineer does not know how to use them or there is insufficient data for their purposes. I still maintain there would be no objection from engineers to use soil maps and soils interpretations if data are presented.

Rennie: Should representative data be presented on bench mark areas with no range in characteristics or should characteristics have ranges in properties defined?

Pawluk: It is difficult to give statistical error to soils data for engineering purposes, however, some variability or range in characteristics should be presented with soils data. Once again whether data are presented for all soils or only bench mark soils depends on scale of mapping, objectives of the survey, time and facilities available, etc., and thus becomes a regional problem. Data acquisition also depends on the cooperation and needs of the local region. Sometimes all that is required is that the pedologist carry out the sampling and engineering laboratories carry out the analyses, in other cases the pedologist must do as much as he can because there is no such cooperation. Therefore, I emphasize that many of these problems have to be dealt with at the local level.

Penner: Maybe Mr. Owen White would comment on how he cooperates with the Ontario Department of Highways.

White: In Waterloo County, I had a graduate student at Waterloo working closely with Mr. Presant at Guelph. The student sampled the soils and we undertook the analyses at the University of Waterloo. The costs of the tests involved were approximately 3 - 5% of the total cost of the survey. Tests carried out were grain size, standard Proctor and Atterberg limits on all horizons of 60 soils which is approximately 90% of the soils in the survey area.

In Brant County, essentially the same procedure will be followed. C. Acton selected the sites, I sampled and the Ontario Department of Highways will do the testing. A report will be written with co-authorship of the parties involved. We hope to continue this cooperative effort in the future as to date there have been very little real extra costs. I would suggest, however, that pedologists in carrying out their analysis take that extra reading of 5 μ on their hydrometers in grain size analysis.

Millette: In the Macdonald area, the University Department of Soils have a consulting firm that will take on contracts for analysis. This service is offered to everyone including government agencies. You are welcome to use our services as long as you are willing to pay for them.

Mailloux: In Quebec, the Highways Department requests soil survey information and reports. The use of soil reports by engineers is greater than by agricultural representatives. They use the information for site location for roads.

Recommendation

Pawluk: Various soil survey units get together with local soils engineers and work out the procedures best suited to local conditions.

REPORT OF THE SUBCOMMITTEE ON CROP YIELD ASSESSMENTS

R. A. Hedlin, Chairman

There is always difficulty in obtaining ideas and preparing a report on the basis of correspondence. The efforts of this committee proved to be no exception. Provision was made for a subcommittee meeting on Monday evening. However, out of nine members representing all provinces except Newfoundland and P.E.I. (2 from Quebec) - one was not in attendance at the meetings, two had not yet arrived and three were in attendance at other subcommittees meeting concurrently. I have tried to glean ideas from most of the members of the subcommittee and to incorporate them in this report. If their ideas are misrepresented or inadequately stated I hope they will feel free to correct them in the discussion.

In 1968 this committee directed its attention to three questions:

1. Can meaningful crop yield assessments be made?
2. Whose responsibility is it to make crop yield assessments?
3. Are soil survey reports the place to publish crop yield assessments?

With regard to the first question the conclusion was reached that crop yield assessments with "average" to "good" management are possible at least in the prairie provinces. There seemed to be some reservations insofar as the other provinces are concerned. The reason for the difference was stated as follows: "Wheat has been the dominant crop (in Western Canada) and has probably been grown on every soil". In addition, "Wheat yield data is relatively easy to obtain". By comparison in Eastern Canada and B. C. the respondents noted that difficulties were imposed by the variety of crops produced and by the problem of obtaining data from sufficient acreage to make yield assessments.

With regard to questions 2 and 3 it was agreed that pedologists had a responsibility, along with other agriculturists, to make crop yield assessments. There was not complete agreement concerning the desirability of publishing crop yield assessments in soil survey reports.

Part of the difficulty in making crop yield assessments is that of deciding who is going to do the work for a program which is time consuming and probably not very rewarding professionally and for which no one seems too anxious to provide financial support.

One problem has been raised which deserves discussion. A reply to my letter of March 16 stated, "Good yield assessments are not very meaningful even under good management due to the important part weather plays in producing the final yield".

This statement is true if a yield assessment is intended as a prediction of the yield which can be expected on one field in one year on a particular soil type. However, crop yield assessments have not generally been used in this way. Fenton et al. (2) in an article on soil yield potential give yield predictions which they consider attainable as a 10-year average. Rust and Odell (5) in an evaluation of productivity of corn yields in Illinois concluded that the standard error of the mean of yield estimates for one field for a 10-year period is approximately 10% of the mean yield, and the standard error of the estimated mean yield for 15 fields for 10 years is approximately 2.5% of the mean yield. They conclude that not much additional accuracy is obtained by using data from more than 150 fields.

If we accept the experience of the workers referred to above in making crop yield assessments we should be attempting to evaluate the average crop producing potential under a certain level of management. Such yield assessments should be valuable to farmers, to other agriculturists, and for many government programs such as crop insurance and land assessment.

In making crop yield assessments under different management levels we are then attempting to express the yield in terms of many factors affecting yields. This relationship can be expressed as follows:

yield = constant + f (soil type) + f (climatic variables) +
f (management factor A) + f (management factor B)

where

management factor A = soil + fertilizer N, P, K.
management factor B = tillage practices, weed control, etc.

A separation of management factors A and B seems desirable since the fertility status is more easily related to yields in a quantitative manner than are factors such as tillage.

Classification Units for Crop Yield Assessments

1. Soil and climate - Chapman and Brown (1) in their study of the climate of Canada recognized nine moisture classes ranging from no moisture deficiency on the average to an average deficiency in excess of twelve inches. They also established seven temperature classes on the basis of degree days and frost free period. The moisture and temperature classes were combined to give 40 climatic regions in the agricultural areas of Canada. These or other climatic groupings may serve as a basis for crop yield assessments when used in combination with soil classification units.

2. Various studies have been conducted based on soil classification units or interpretive groupings. Mackenzie (3) found that great soil groups and capability classes both showed some promise as a basis for predicting oat yields.

Moss (4) studied the relationship of soil and climate to wheat yields in Saskatchewan. He found both soil and climate to be important factors in determining wheat yields.

To be most useful assessments of crop yields should be made on the basis of soil units which are large enough that there will usually be only one or two units on the commonly used cropping units.

Last March I wrote to members of the subcommittee asking what had been done since 1968 regarding crop yield assessments. On the basis of information I have obtained in writing and in subsequent communication I would like to comment briefly.

In British Columbia some work is being done relating soil types and management practices to yields of cereals and forage in the Fraser Valley. One problem in this work has been that of getting farmers to keep adequate yield records. For specialty crops such as peas some yield information is provided by canneries.

In Alberta yield data has been collected by the Department of Municipal Affairs for wheat, oats and barley. This has been collected by shipping points for the years 1950 to 1964. Yield data is also available for the years 1960 to 1970 from a number of the better farmers in the province as well as from the substations formerly operated by the Experimental Farms. Some attempt has been made to relate these yields to soil capability units and to the climatic map units being prepared by Mr. Jack Clayton.

In Ontario there is now yield information available on maximum corn yields for about six years. Studies are under way to ascertain the soil properties and management practices which contribute to corn yields.

Professor Millette of Macdonald College offers a farm management service to farmers in which management practices and soil types are related to crop yields.

Methods of Obtaining Yield Information

1. Soil testing laboratories - In Saskatchewan and Manitoba farmers submitting samples for analysis fill out a questionnaire giving information on management practices including fertilizer use and yields obtained. Since the legal description is also provided by the farmer it is possible to determine the mapped soil unit although not always with a precision which might be desired.

In both provinces plans are in progress to relate yields to mapped soil units and to some management practices. In Manitoba, initially at least, the study will be limited to fields from which samples have been submitted for two or more successive years. In many such fields information will be available for the second and successive years with fertilizer applied at rates recommended by soil test.

2. Crop insurance statistics - In Manitoba a crop insurance plan has been in effect since 1960 when insurance coverage was offered on about 25% of the crop acreage of the province. This was gradually increased until insurance coverage was offered throughout the province in 1967. Presently about 50% of the farmers in the province insure at least a part of their land.

When this program was introduced productivity ratings were placed on a quarter section basis on all land in the province. The ratings were established on the basis of soil characteristics and were in effect an attempt to assign historic yields of wheat, oats and barley, which were available by crop reporting districts, to mapped soil units. For this purpose ten productivity ratings ranging from 100, 90, 80, etc. down to 10 were established (sometimes referred to as A, B, C, etc.). Needless to say, over the province as a whole each productivity rating includes a number of mapping and classification units.

As a part of the program, the Manitoba Crop Insurance Corporation (MCIC) is collecting a good deal of statistical information. This is done by obtaining annually, from every farmer insured in Manitoba, complete acreage and yield statistics for all crops produced. Information is obtained by the crop insurance agent who completes a research questionnaire with each of his insured farmers following each crop season. The statistics thus obtained provide MCIC with data on which to base the coverage and rate assigned to each productivity rating and to check the effects of fertilizer and cropping systems on yield. Over 12,000 usable questionnaires were obtained for the 1968 crop covering 1,700,000 acres of wheat, oats, barley and flax.

The questionnaires provide the acreage and yield, the amount and analysis of fertilizer applied, whether the crop was grown on fallow or stubble land and the productivity rating of the soil on which each crop was grown.

Some interesting results have been obtained regarding the relationship of yield to productivity rating with and without fertilizer. This is illustrated below.

Wheat Yield on Fallow and Stubble as Influenced by Productivity Rating and Fertilizer Use. (1964-68 average)

	Stubble				Fallow			
Soil	Yield - b.p.a.		Increase		Yield - b.p.a.		Increase	
rating	Unfert.	Fert. (1)	B.p.a.	%	Unfert.	Fert. (2)	B.p.a.	%
100 (A)	27.4	33.9	6.5	23.6	35 3	38.6	3.3	9.3
90 (B)	22.4	28.6	6.2	27.7	30.2	34.0	3.8	12.5
80 (C)	20.7	28.6	7.9	38.1	28.9	32.4	3.5	12.1
70 (D)	19.6	26.4	6.8	39.7	27.1	30.7	3.6	13.2
60 (E)	17.9	25.9	8.0	44.7	25.0	28.7	3.7	14.8
50 (F)	17.6	26.8 (3)	9.2	52.2	24.5	29.0	4.5	18.3
40 (G)	17.8	26.7 (3)	8.9	50.0	23.5	28.4	4.9	20.8
30 (H)	16.6	25.0 (3)	8.4	50.6	20.9	24.4	3.5	16.7
20 (I)					18.8	23.1	4.3	22.9
10 (J)					20.5	19.8 (3)		- 3.4
Average (weighted)	19.2	26.8	7.6	39.6	26.6	30.8	4.2	15.8

(1) At least 38 pounds N and 18 pounds P_2O_5 per acre.
(2) At least 18 pounds P_2O_5 per acre.
(3) 1966-68 data only.

The yield decreases in a fairly regular progression from the high to the lower rated soils on both fallow and stubble despite the substantially higher yield on fallow land. Yield increases due to fertilizer are greater on the less productive soils particularly when calculated on a percentage basis. Thus fertilizer application tends to decrease differences between soils.

3. Experimental plots - Since a large number of yields are necessary to characterize a particular soil, data from experimental plots appear to have limited value. They may provide information for some soils but certainly not for very many.

Summary and Recommendations

1. Relatively little work appears to have been done in assessing crop yields in relation to soil type and management level. This is probably due to a combination of factors. Crop yield assessments are difficult to make, require a good deal of time and statistical information as well as cooperative efforts of people with different types of training. Added to this is the difficulty of obtaining financial support for this type of work.

2. Despite the difficulties, in some provinces statistics are becoming available which are useful in making crop yield assessments. A good deal of work needs to be done to relate these statistics to soil mapping and classification units.

3. Work to date has been with annual crops. Crop yield assessments will probably be more difficult with perennial crops.

4. Crop yield assessments are of fundamental importance to many government programs and to resource planning. Therefore, continued efforts should be made to assess crop yields for different soils under different management practices. Where yield information is available soil type should be identified.

References

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2. Fenton, T.E., Hole, F.D., Odell, R.I. and Westin, F.C. 1970. Soil yield potential. Crops and Soils. Feb. 1970.

3. Mackenzie, A.F. 1970. Agronomic groupings of southern Quebec soils. Soil Sci. 109: 53-59.

4. Moss, H.C. 1962. The relationship between type of soil and yields of wheat in Saskatchewan. Dept. of Soil Sci., Univ. of Sask.

5. Rust, R.H. and Odell, R.I. 1957. Methods used in evaluating the productivity of some Illinois soils. Soil Sci. Soc. Amer. Proc. 21: 171-175.

Discussion

Baier - You emphasized that a crop yield assessment is an average yield for a soil type over a number of years. Do you have yield data for individual fields from which the effects of climate from year to year can be calculated? In addition to average for a soil type the yield variability is important.

Hedlin - The average yield data are calculated from individual yield estimates which are available.

Baier - Are these data published and if not where can they be obtained?

Hedlin - There is some published information as indicated in my report. Much of the data is in process of preparation. Les Henry has a table of data with him.

Henry - Our information from the soil testing laboratory includes yields for known legal locations for an individual year. Soil association and texture are coded from the soil survey maps and the data is all on computer tapes.

Millette - Under Quebec conditions management is more important than soils in determining yields. In comparing soils it should be done on an economic basis. The net return per acre is more important than the actual yield.

Hilchey - In the Maritimes the inputs required to obtain a particular yield also deserve major consideration.

Henry - Meaningful crop yield assessments must always include reference to level of management but extent to which you can quantify management inputs varies depending on the basic data available.

Pawluk - Did the subcommittee attempt to consider the effect of soil properties in contributing to crop yields?

Hedlin - No. The subcommittee considered only the use of yield data as a means of assessing yield.

Dumanski - Did the committee consider the relationship of soils to forest productivity?

Hedlin - No, the committee considered only agriculture. There is a classification of soils for forest productivity. I do not know if classification system has been supported by actual productivity data.

Clayton - Yes, measurements have been made. Foresters have a great deal easier opportunity to get this kind of information than agriculturists because they can get thirty or forty years' yield data from one yield assessment.

Millette - Fairly complete and accurate assessments of the forest productivity of a number of soils was made in New Brunswick when I worked there a number of years ago. This information is available.

Ehrlich - I think we are getting off the topic. Could we return to a consideration of the matters discussed in the report.

Peters - We have been looking at yields on a shipping point basis and relating them to soil capability classes. Some meaningful relationships have developed. We have been unable to relate yields to the soil-climatic map discussed yesterday.

Hoffman - In cooperation with the Soils and Crops Branch we have been obtaining yield information from corn yield competitions. We have yield data from 700 sites for 1964 to 1969 and are attempting to relate yields to a total of 26 soil and management factors. We hope to be able to determine which soil characteristics are most important in determining crop yields. Attempts are also being made to relate barley and hay yields to soil properties and management practices.

Henry - If we are serious about crop yield assessments we must obtain yield data on a continuing basis. It may be necessary to develop procedures for obtaining the data ourselves.

Ehrlich - It is important that our reports be relevant to the users. Crop yield assessments are valuable to many users.

Recommendation

Moved that we continue to obtain crop yield statistics and to relate them to soil mapping units. This motion was carried.

REPORT OF THE SUBCOMMITTEE ON SOIL CORRELATION, PRINCIPLES, PROCEDURES AND RULES

J. S. Clayton, Chairman

I was requested to act as Chairman of a Subcommittee on Soil Correlation, Principles, Procedures and Rules, and to prepare a preliminary report on these matters for the plenary session of the 1970 meetings. The subcommittee consisted of fifteen members representative of all regional soil survey units across Canada and of the Soil Research Institute in Ottawa.

A memorandum was circulated to all members in which the broad framework and background of our organization for soils work in Canada was outlined and an appraisal made of our past activities. On this basis some suggestions were made relative to the establishment and operation of a correlation function and a questionnaire included in order to get a compilation of our progress and future development of soil knowledge and interpretation in Canada. Subsequently I had the opportunity of discussing these matters with many of the members concerned and in addition received constructive written replies and comments from the majority of subcommittee members. In some instances these were personal replies, in others they represented a collective opinion from the organizations concerned. In this report I am presenting the gist of the memorandum and the questions circulated, and have tried to summarize the general reaction to them.

Memorandum on Soil Correlation

I am not going to review the history and development of soil survey and the build-up of soil knowledge in Canada. Others have done this before. Let me say, however, that I think if we look back and take a broad and long view, we will acknowledge that since the first surveys began in the twenties at local provincial levels and with local concepts, we have progressed to the point where we have at the taxonomic or conceptional level a large measure of national agreement. At the same time we have been able to go forward in developing concepts which closely relate to those which are being developed on a continental and world basis, and in so doing have been able to make a significant international contribution. For much of this we must thank our predecessors at both the provincial and national levels, and I think particularly those who played such a significant part through the progress of the National Soil Survey Committee in working towards common goals.

We now have a Canadian System of Taxonomy at the conceptional levels of Order, Great Groups and Subgroups. We have established acceptable criteria for horizon and profile identification and correlated these closely to equivalents in the American Comprehensive System and to the FAO/UNESCO World Soil Units. We have adopted standards for textural, structural and other physical identifications and guidelines for chemical and mineralogical recognition. It is inevitable that in this developing process we have made some errors, abandoned what to many have been cherished concepts, and on occasions have reversed decisions to find ourselves riding around the same old roundabout of argumentation. I am sure we have not yet seen a final perfection of concepts for soil identification but at least we have made a good start in arriving at common understanding.

The next major step in correlation is the nitty-gritty one of taking our common concepts, bringing them down to earth, and recognizing their place in the landscapes we survey, and grouping these into soil map units at varying degrees of detail or abstraction. We have been doing this of course for many years at our local soil survey levels, and of course it is here that such processes are initiated. Within provincial levels and jurisdiction we have established a variety of series, associations, catenas, or complexes and have associated these with textural, topographic, land forms or other phases considered significant. Our interpretations of these map units have also been largely at the local provincial level, and this of course is where it should be done first. In most instances adequate correlation between mappers within the provincial or regional units has been accomplished. In any case at this level such correlation is and should be the responsibility of delegated authority within the provincial units.

Some progress has been made in correlation of map units between provinces and regions but except in local areas this has not been a systematic operation. Some named map units are common across provinces in the Maritimes; whether they are always recognized at the same level of abstraction is another matter. Some recognition of common map units has been made in the British Columbia and Alberta Peace River blocks, and to a minor degree between Manitoba and Saskatchewan. These correlations have mostly been made during the course of cooperative soil tours across and adjacent to provincial borders and these have been most helpful as a start. Some correlation of capability mapping and interpretation particularly in the agricultural sector has also been done on provincial borders.

From time to time the provincial units have sent to Ottawa lists of names of series or other map units and these have been compiled. Very little information on the type or modal concept of these map units has been systematically prepared or made available for correlation, except what can be gleaned from scanty soil survey reports.

I think we all realize that with the present stage of development of soil survey data in Canada, the increasing demands for its use and interpretation at the regional and national levels can no longer be entirely accommodated by individual provincial approaches.

Another increasingly significant factor is the development of many soil interpretation programs by other agencies including university geography departments, various provincial or federal governmental services, and other organizations or individuals in the private sector.

These programs have been performed at varying levels of relevance, but unfortunately with little guidance or assistance available to them in correlation or in arriving at uniform approaches. Because of these factors their usefulness is frequently limited. These organizations and individuals should be made aware that there is a national approach to the professional recognition and interpretation of soils in Canada and they should be assured of receiving assistance in correlating their work to the national concepts.

With these goals in mind I have prepared two charts. Fig. 1 suggests the lines of communication and correlation that do or should exist within Canada and with regard to our international relationships. Fig. 2 gives some ideas on the function and levels of operation which might be desirable if effective correlation is to be reached. I might at this point make the obvious statement that correlation is and must be a mutual relationship, a two-way game, and should not be an imposition by one to another without common consent, or if relating between a number of individual units should be by a common consensus. In this regard I would like to quote from statements of Dr. Kellogg on correlation given to the 1963 National Work Planning Conference of the United States Cooperative Soil Survey. They are equally relevant to our own Canadian situation.

"We have some real problems in soil correlation. Emphasis on interpretations and the work on the 7th Approximation have forced us to look more carefully at the soils than we had formerly and as we do that, we find soil characteristics that were not previously noted and recorded accurately. We find that the limits of our soil series and of the phases within them have not always been in the proper places. We discover this not only through the official correlation route but also through the interpretation route. It becomes clear that many of the older soil series are either vague or wrong.

Also we find that some of us have been using quite different concepts in soil classification; and even different combinations of characteristics are included under the same series name. Such differences must be resolved. I think all of you have had the problem of soil series that need testing and do not have adequate descriptions.

Because we have about 1500 people working in the Soil Survey, we've got to give weight primarily to evidence rather than unsupported judgment; and I mean evidence that is written down. Because so many people are involved they must be able to look at the soil descriptions and interpret them alike. All 1500 of us cannot go out and look at the soils together. Getting together in the field used to be the standard way to handle a soil correlation dispute. But, gentlemen, this is now impossible; we've got to handle soil correlation largely through the written evidence."

In Canada we haven't got 1500 people working in the Soil Survey, but we undoubtedly have the same kind of problems and they will have to be handled systematically. You know that we have limited staff to cover a big country. Perhaps at this stage of the game this is no insurmountable handicap. You will note by Fig. 1 I am suggesting the establishment of a National Soil Correlation and Interpretation Service at Ottawa with an enlarged staff and function, over and above what is presently inadequately provided. I think such an establishment would enable better correlation not only taxonomically for the benefit of ourselves as pedologists, but also in the fields of Agronomic, Biophysical, Forestry and Engineering Interpretations. I believe this would go far to remove some of the justifiable criticisms, to the effect that we have frequently been too narrowly oriented or agriculturally biassed in our approach to soils.

I have not tried to be too specific regarding functions at this stage; we have to know what we want to do first, the machinery can come afterwards.

I hope you will study these proposals carefully and reply with constructive criticisms or suggestions. I would specifically ask for your opinions on the following questions:

(1) Do you believe that the present or suggested lines of operation and communication are adequate? If not, what would you suggest?

(2) Do you believe that the conceptional criteria and standards of taxonomy and classification should be:

(a) Developed by common consensus through the national committees to arrive at a common and uniform approach for Canada?

(b) Developed for Canada in such a way that they will closely relate or identify with concepts developed for
1. The United States of America?
2. The FAO/UNESCO World Map Units?
3. Both?

(3) Do you believe that the individual provincial survey units should adhere to the national approach to taxonomic classification or be free to follow independent action in conceptual standards? (This does not refer to map units.)

(4) Do you believe that the primary authority for the establishment of map units at the local level, of whatever abstraction, should reside in the individual survey establishments?

(5) Do you believe there should be a standing committee of the Canada Soil Survey on matters of disagreement in correlation either at taxonomic or mapping levels?

(6) Do you believe a National Soil Correlation and Interpretation Service should be established at Ottawa with adequate staff for correlation and data processing?

Summary of opinions

With regard to the questionnaire there was a broad agreement in most of the replies with some variation in emphasis between units.

Response to Question 1

The general opinion was that the present lines of operation and communication are not adequate or are barely adequate. Most felt that the suggested lines of operation, cf. Figs. 1 and 2, with modifications would improve the correlative operation.

Response to Question 2

2a. All replies expressed belief that the conceptual criteria and standards of taxonomy and classification should be developed by common consensus through the Canada Soil Survey Committee, to arrive at a common and uniform approach for Canada. One comment suggested that such common consensus should not prevent development or promotion of new criteria by regional units, but that these should be agreed upon by the national committee before use.

Another reply, while agreeing in principle, suggested that in the past there had often been an undue influence exerted by one or other sector of the national body in establishing criteria for taxonomy based on specialized studies of soils in regional areas not necessarily representative of a broader Canada-wide distribution.

2b. All replies suggested that concepts should be developed so that they would closely relate if not identify with concepts developed for both the U.S.A. and the FAO/UNESCO systems. Several replies while agreeing in principle emphasized that the need for a viable, workable and acceptable system for Canada was paramount, and that we should be prepared to follow an independent path if concepts and criteria established for other systems prove unsuitable to our needs.

One or two replies tended to favor relating to the FAO/UNESCO concepts rather than those of the American system, but all suggested the desirability for close relationship with both.

Response to Question 3

All replies agreed that the regional units should adhere to the national approach to taxonomic classification with a majority reiterating the right of the regional units to initiate and develop new concepts, techniques and guidelines. They felt that these should be accepted at the national level before being used. One reply suggested that while adherence to national taxonomic classification was necessary and logical, local groups may have to indicate local terminology which has been used in the past and which is serving a local need.

Response to Question 4

All groups agreed emphatically that the primary authority for establishment of map units of whatever abstraction resides at the local level, with a significant number indicating that these should be correlated at the regional or interprovincial level, so that they can fit into a national framework. One reply suggested that the local authority for establishment of map units should not be above the subgroup category. Another suggested that map units should not be recognized officially until they have been correlated interprovincially.

Response to Question 5

There was no firm majority opinion regarding the desirability of a Standing Committee of the Canada Soil Survey on matters of disagreement in correlation either at taxonomic or mapping levels. A few felt there should be such a committee but others suggested that this was a function of correlation and could be handled by an adequate correlation service. One opinion suggested that such disagreements are best resolved in the field with the assistance of resident correlators in the regions.

Response to Question 6

All replies agreed on the necessity of a National Soil Correlation and Interpretation Service at Ottawa, following the general lines suggested in Fig. 1. A number felt that correlators should reside within the different regions or at the very least should be in a position to spend a significant portion of time in the areas concerned.

A few replies suggested the need for provincial correlators, particularly where adequate provision for such correlation had not been officially established between operating units. It was emphasized, however, that in such instances there was usually a reasonable correlation at the local working level. One well-considered reply suggested concurrence in the establishment of a National Correlation and Interpretation Service providing priority was given to research both at the national and local regional levels and with particular regard to interpretative soil research at the regional level.

As might be expected a number of other suggestions were brought to the attention of the chairman. These included the following:

(a) The necessity of adequate data on all mapped soils being made available to a central service was considered essential to adequate correlation and also to the establishment of a national Data Bank. It was suggested that the responsibility of providing this information rest with the provincial units under whose authority such map units were established.

(b) A suggestion was made that responsibility for obtaining soils data for the Arctic Islands and Northern Territories reside at Ottawa.

(c) The need was emphasized for better communications between all levels of soil operations, not only between survey units but also with the many users of soil data.

Figure 1 SOIL CORRELATION. Suggested lines of Communication & Correlation.

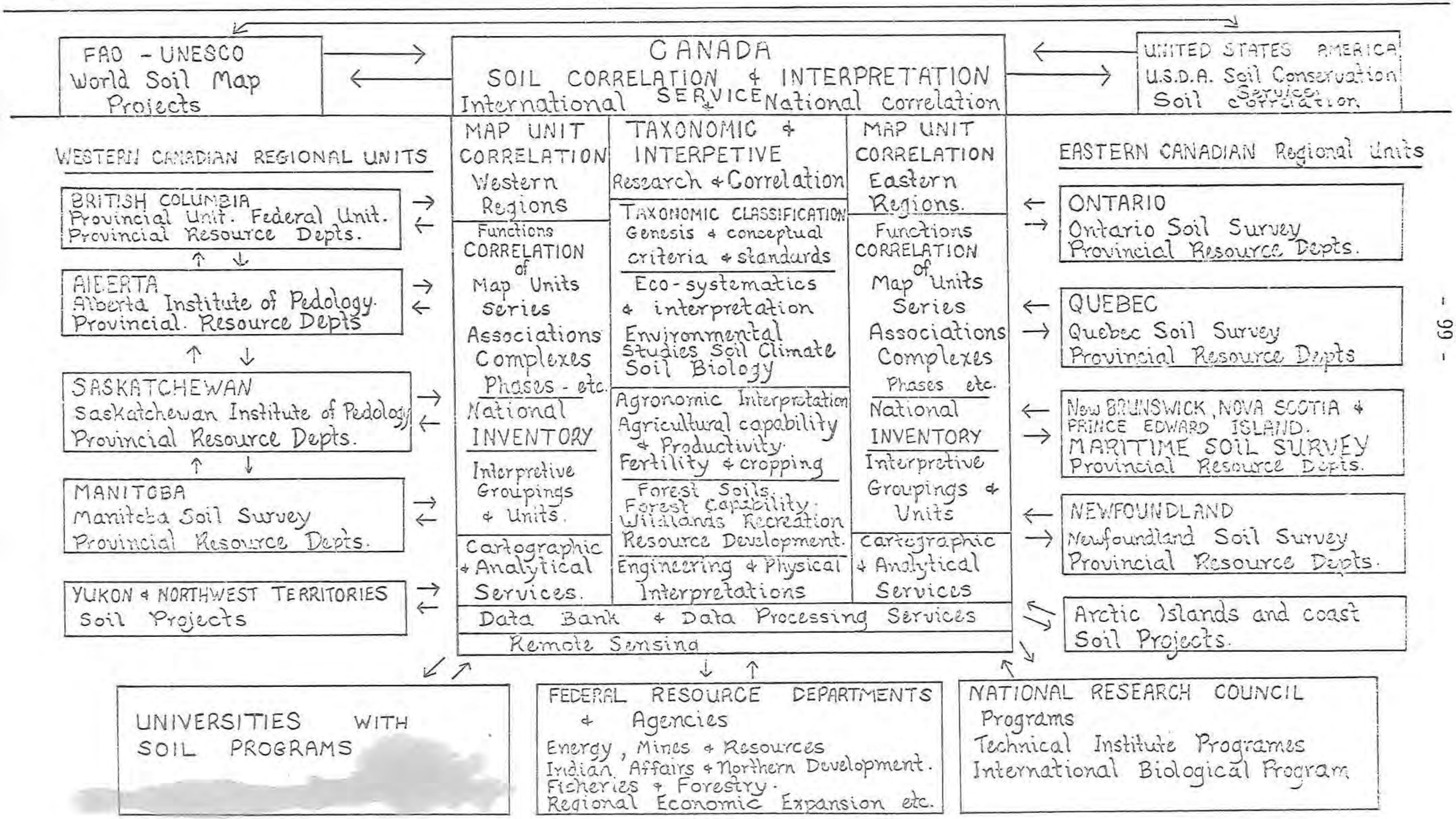

Figure 2. SOIL CORRELATION Suggested levels of function & correlation of functions.

TYPE of FUNCTION	Levels of initiation, establishment, data recording & correlation of soils			
	Provincial or territorial level	Regional or Interprovincial level.	National Canadian level.	International level USA (SCS) & FAO/UNESCO
Conceptual Development Taxonomy. Nomenclature Criteria Horizon identification etc.	a. initiation by research b. establishment by agreement & acceptance. National Soil Survey c. Correlation. d. data recording.	b. establishment & c. correlation with adherence to National Guide lines	a. Initiation by research b. establishment by agreement & acceptance by National Soil Survey c. correlation d. data recording & Bank	c. correlation with SCS and FAO/UNESCO services. by National Unit.
MAP UNIT ESTABLISHMENT Initiation Establishment Characterization Descriptive Analytical Interpretive Data recording Map Units include Series, Variants Phases Associations catenas, complexes & families.	a initiation b establishment characterization Description analytical Interpretation Data Recording. c Correlation within province or territory	c. correlation of map unit, map boundaries across Provincial areas correlation trips Inter provincial Interpretations	a. initiation through research & guidance. c. correlation through development of standards & guide lines c. correlation across Canada-U.S. border and with FAO/UNESCO concepts. d. Data Bank	c. correlation at level of continental and world Map Projects Border correlation.
Soil Survey & Mapping Reports Maps & legend.	a. initiate b. establishment Prepare reports & initial maps	Review of Reports. Maps & legends Guidance	Review & Guidance Production of Maps & Reports	Cooperate in Publication of Continental or World Maps & Reports
Interpretations. Agronomic Forest Wildlands Engineering etc.	development & establishment data recording Identification with Provincial standards	Correlation at level of regional concepts & standards Interprovincial or regional interpretations	National Correlation & Interpretation. National Guidelines	Correlation at Continental or World Unit level.

REPORT OF THE SUBCOMMITTEE ON STORAGE AND RETRIEVAL OF SOIL SURVEY DATA

R. Protz, Chairman

This subcommittee was formed in 1970. From a February, 1970, questionnaire it was apparent that all provinces needed the computer as an aid to handle soil survey data. From a September questionnaire sent to all subcommittee members it was apparent that some provinces were well advanced in using the computer whereas others were just exploring what steps were required. Everyone agreed that a Canadian Soil Survey Data Bank should be established.

During the October, 1970, Canada Soil Survey Committee meetings the subcommittee held its first meeting. From this meeting it was agreed that the following points were essential for the development of the Data Bank.

1. The system must be modular. All information now available should be put into storage. As new and revised data become available the bank will be updated. The Data Bank can be developed one module at a time. This would also allow for testing of the data system early in its development.

2. All available information should be circulated to all members (provinces) before a final format is established for any module.

3. The modules should be comprehensive so that the different data required by each province are included.

4. Research is required before a uniform coding system for all soil profile morphological data can be accepted.

5. Each province is responsible for adjusting the data collected earlier into present methods of reporting. Where data have been adjusted a record must be kept of the formulae used.

6. A very necessary requirement is the design of an effective printout system for users who wish to relate soil profile data to soil maps and to the Canada Land Inventory maps.

In the light of the discussion held by the subcommittee the following recommendations were made to the C.S.S.C. All recommendations were accepted.

1. That Canada should develop a soil data bank so that
   a) soil profile data would be more accessible to all users;
   b) interpretive work would be facilitated;
   c) further research on present data would be possible.

2. That the Master Data Bank be at the Soil Research Institute in Ottawa. That the coordination of the data bank be the

responsibility of the Soil Correlation Staff of Canada. If necessary new positions should be created at the S.R.I. to do this work or several positions should be transferred from the provinces to Ottawa.

3. That the Soil Data Bank be accessible to provincial and university personnel for research purposes. That a request for funds via an Extramural Research grant be initiated by the Head of the S.R.I. or the Chairman of the C.S.S.C. to establish close research association with personnel at the universities. This request for funds should be made in the next year.

4. That the subcommittee be given the responsibility to coordinate and disseminate data on handling soil profile data until a sufficient staff is operating in the S.R.I. Subsequently this subcommittee could operate as an advisory group to the S.R.I. correlation staff.

Discussion

M. Jurdant: A coding system for ecological and pedological data has been developed in Quebec and will be published shortly. We would like to make this information available to the subcommittee.

R. Protz: We would like to draw as much as possible on the experiences of groups engaged in this type of work.

E. Presant: In the interpretation module, the only reference to engineering interpretations is waste disposal.

R. Protz: The entire section entitled Organization for Consideration was included in this report only for purposes of illustrating the module or card(s) concept.

A. Mailloux: I cannot conceive how you propose to develop a system of this nature including all the modules.

R. Protz: We don't have to. Due to variability and availability of data we have come up with a modular concept so that data that is available and easy to code can be incorporated in order that the program can get under way as soon as possible. In other words, as modules are completed they can be incorporated and used.

A. Mailloux: We in Quebec have developed a coding module and consequently we would wish to cooperate with the rest of Canada.

R. Protz: It is hoped that this subcommittee and other interested individuals and groups work together on this program.

E. DeJong: With reference to item 6.3, do you propose that the series designations of older reports be changed according to the present classification?

R. Protz: Yes. But as was indicated in item 6.3, that this be the responsibility of the provincial units on the condition that a record of adjustments be kept.

B. Cann: This type of system should have been initiated long ago. The problem has been and still is a question of time, staff and funds. However, this program should be given our most serious consideration.

R. Protz: This essentially is why we have proposed it in the way we have.

G. Millette: To my way of thinking, once the coding system has been worked out, it is a relatively simple matter to give the information to a computer programmer and let him set it up.

W. Ehrlich: Dr. Douglass, what approach has the U. S. taken?

J. Douglass: Essentially this same modular approach has been taken. Our system is being built in stages as well. Very generally we have 3 stages.

1. Classification
2. Laboratory and morphological data
3. Interpretations

Currently we are working on laboratory and morphological data.

A. Mailloux: I feel that morphological data cannot be contained on one card.

R. Protz: Each module will be composed of as many cards as is necessary to contain the data.

A. Ballantyne: If we agree to a standard format, this should be developed as quickly as possible.

G. Millette: The subcommittee should investigate the various attempts that have been made to establish a soil data bank before a national code is agreed upon.

R. Protz: This is precisely what we propose to do. As was indicated in the report, programs have progressed to various stages. Also we intend to draw on work done in the U. S. and elsewhere.

E. DeJong: Do you propose to put all soil descriptions in the bank even if laboratory and other data does not exist for some of these soils?

R. Protz: Yes. This is why we have come up with the modular approach in that we do not have to wait for the whole system to be completed before it can become operative.

E. DeJong: Do you expect to get the field descriptions for every pit that is dug?

R. Protz: These decisions should be worked out by the individual provinces.

A. Mailloux: The usefulness of any system is entirely dependant on the character and accuracy of the data that is used.

R. Protz: This is certainly true.

REPORT OF THE SUBCOMMITTEE ON SOIL SURVEY REPORTS

D. B. Cann, Chairman

Terms of Reference. "To determine (a) the specific needs and interest of the various groups who use soil survey data and (b) to recommend methods of reporting that would best suit these needs."

General Discussion. With respect to item (a) of the terms of reference, the subcommittee relied mostly on the opinion and experience of soil survey organizations that had dealt with disciplines using soil survey information. A previous survey of users in Alberta and a more recent one conducted by the Saskatchewan Institute of Pedology indicated that the soil section of the report was considered most important to nearly all readers. The kind of information which these users indicated they would like to see in reports include the following - fertility data; N, P and K levels of soils; expanded yield data; research information on soils (which soils are most productive, have the greatest potential for increased yield, or give the most economic returns from fertilizers); soil moisture data (moisture holding capacity, effect of slope on moisture distribution, effect of organic matter on moisture storage); expanded physical analyses (relationship of physical properties to plant growth); engineering data and interpretation (analyses useful to highway engineers, foresters, city planners and others); recreation and wildlife data; special reports (land use planning engineering, forestry, etc.).

Other soil survey organizations mentioned the inclusion of more information on drainage, soil stability, available fertility, best use indicators, more detailed physical analyses and the use of single purpose maps. Those who teach soils would like more information on the variability and limitations of the mapping units and on the the geographical distribution of soils. Class definitions of interpretive classes need to be more meaningful.

In the opinion of many pedologists current soil survey reports are not sufficiently oriented to the general user and should contain more interpretive material. It is apparent that the primary users of soil survey reports are, and will continue to be, agriculture, forestry, engineering and educational institutions. Others include urban planning and recreation development agencies. Present reports are not adequately filling the needs of these disciplines. Some of the criticisms cited are that the soils are not adequately described, the distinction between taxonomic and mapping units is not clear, and the kinds of data and their interpretation vary widely in different reports. More emphasis is needed on the relationship of the soil to the landscape.

The Multi-discipline Approach. The basic data of the soil survey include an accurate description of the soils, a map showing their distribution and an analysis of their physical and chemical properties. Regardless of the needs of various disciplines, this is the data from which interpretations must be made in relation to the soil environment. It is possible to increase the detail of soil descriptions and to expand the scope of the analyses. If multi-discipline interpretations are to be included in the soil survey report, a team effort is required. Such an approach would broaden the scope of the report and attract more users.

There are problems in implementing a multi-discipline approach to soil survey reports. Pertinent data or expert interpretation for certain disciplines may not be available in some areas. Time is also a factor. Engineers, for example, could interpret the basic data without visiting the field. Foresters, urban planners or recreation specialists would require field observations, preferably at the time the survey was being made. Unless experts are attached to soil survey staffs or work as a team with the soil survey, the writing of interpretive sections may be delayed. The subcommittee discussed the question of having individuals from other disciplines write parts of the report. It was agreed that these reports could take the form of a separate section under individual authorship or be written by the principal author after consultation with the expert involved, and properly acknowledged. Separate sections under different authors make it essential that someone accept responsibility for the whole report, since it is difficult for the editor to deal with a number of authors without delaying publication. Undoubtedly there will be considerable variation from province to province in the extent of interpretive material presented in reports. The report cannot be expected to meet the requirements of all disciplines to the same degree. Conditions in a given region as well as the survey detail may determine the kind and extent of interpretation necessary. The collaboration of the various disciplines during the mapping stage is the best approach.

Some pedologists feel that there should be a basic, well documented soil survey report giving complete profile descriptions, analytical data, a discussion of the taxonomic and mapping units and the relationship of the soils to geology, vegetation and landscape. Separate reports and maps would be published for various disciplines. This type of approach does not appear feasible at present because soil survey staffs lack the time and physical and financial resources necessary to investigate soil properties in sufficient depth to be able to make interpretations except for agriculture. Nevertheless, future reports should contain more interpretive material, possibly up to 75 percent of the report. The user is looking for easily digested information that involves a minimum of searching. Subcommittee agreed that many of the older reports either lack information or require considerable reading to find it.

A suggestion was made that consideration should be given to replacing the present system of soil survey reports with a computerized system capable of serving national, provincial and local needs - similar to the Canada Land Inventory data system. It seems evident that we are progressing toward some form of such a system, but there are many problems to be solved.

Format of Published Reports. It was suggested that an effort be made to make soil survey reports more attractive to the reader, by improving the type of cover or inclusion of more colored photographs. Cost is one of the limiting factors that must be considered. The subcommittee considered a change in page size to 8 1/2 x 11 inches. The advantages of this size include better accommodation for profile descriptions and foldout maps, particularly where detailed mosaic maps are used. The disadvantages are that it requires more paper and takes up more shelf space. Each province should decide what size they prefer.

The format outlined below is intended to provide guidelines toward the type of report that the subcommittee feels would better meet the needs of users. The report has two parts - one including information designed to meet the needs of the general user, the other containing a detailed discussion of the taxonomic aspects of the soils for information of pedologists. The outline allows considerable flexibility in planning the report. It should be made clear that neither the titles of the sections, nor the content of each section is intended to be restrictive. The details outlined for each section are intended only as guidelines. It is evident that, at present, each province will follow a format best suited to its needs. Nevertheless, it seems essential that some similarity of format in our publications should be maintained. The outline is a rearrangement of the format proposed by the 1965 subcommittee, with some additions.

Suggested General Format for Soil Survey Reports

1. TABLE OF CONTENTS

If the soils are not treated in alphabetical order, an additional alphabetical listing is most useful to the reader, particularly if he is not familiar with soil survey reports. Make it easy for the user to find information. Include a list of figures and tables.

2. PREFACE OR FORWORD

Give purpose of report and outline the content. This section may be used in place of an introduction.

3. ACKNOWLEDGMENTS

Indicate exactly what the person or persons did.

4. SUMMARY

State size of area, basic information on climate, main physiographic features, main vegetation, great groups and subgroups, and other information pertinent to land use.

5. INTRODUCTION

Not needed if a preface is used. This might be replaced by a brief section explaining the use of the map legend and soil report.

Part I

6. GENERAL DESCRIPTION OF THE AREA

Keep all sections as brief as possible; use map illustrations and diagrams where possible.

Some authors would place this section in Part II, but a majority feel that it should come here to acquaint the reader with the area.

a. Location and Extent

b. Climate - Most authors feel that this section should be brief. Append climatic tables or diagrams. Data on degree days and any information on climatic capability and soil climatic groupings could be added.

c. Physiography - Many feel that this section should be expanded. Use Bostock's classification of physiography to describe broad areas, supplemented by local terms. Give relief, aspect, topography, landforms and drainage of the physiographic divisions delineated. For landforms give the type and relation to geology; state the significance of topography and drainage. Include pictures.

d. Geology - Discuss surficial geology, types of deposits in the area and relationships to soils. Briefly describe bedrock geology. Block diagrams could be used here.

e. Vegetation - Keep general; put technical site-type descriptions later. Use the common names of all plants and trees followed by the scientific name including the name of the author. If much vegetation is mentioned, use common names in the text. In the Appendix, include an alphabetical list of common names and a parallel list of scientific names.

f. Population, Towns, Transportation; History of Development; Economic Aspects; Industries) There is divided opinion whether these sections should be optional. Some think that they provide a geographical environment for the soils. Keep very brief and include a number of headings together.

Note: The sections of Physiography, Geology and Vegetation might be replaced by a section on Terrain System.

7. HOW THE SOILS WERE MAPPED AND CLASSIFIED

Written in a general way and aimed at the user. How soil information is obtained. Briefly outline the significance of color, texture, structure, consistence and other characteristics, the basis for recognizing great groups, subgroups, families, associations, series and phases. Clarify the distinction between the mapping unit and the taxonomic unit. Emphasize the problems of scale and type of mapping; reliability of mapping. This section should lead logically to the description of associations or catenas.

8. PROPERTIES OF THE SOIL UNITS

The soils may be described in alphabetical or taxonomic order. A brief description of the soil orders, great groups, subgroups, families and associations or catenas and map units, and their relationships may be given here. These could be related to vegetation site-types.

Description of soil association, catena or complex

1. Location and extent (acreage)
2. Parent material - type, color, reaction, etc.
3. Range in texture
4. Topography and landform
5. Drainage
6. Included series and associated soils
7. Irrigation rating if applicable
8. Land use - a paragraph on general land use and broad management considerations not covered in the interpretive sections below.

Try to stress how the ecosystem components (subgroups, vegetation, drainage, landscape position) fit together. Give information on alkalinity, salinity, permeability and other important characteristics as they apply.

Block diagrams could be used here to show landform, parent material, drainage, vegetation, site-types and subgroups for each catena or association.

Conclude this section with a table showing the relationships between the map units <u>or</u> a short paragraph on the map units and map complexes, if it would add additional useful information.

9. USE AND MANAGEMENT OF SOILS

The emphasis given to the following sections will depend on the area and its importance and the amount of information available. If little information is available, the section should be omitted.

<u>Capability for agriculture</u> - Give interpretations of climate and the limits imposed on agriculture by climate. If possible, give climatic zone map; discuss crop suitability and crop yields; present tables of long time yields; give acreages, management groupings and discuss management problems such as effects of wind and water erosion, soil

moisture, soil fertility, salinity and drainage. Soil analysis pertinent to interpretation could be presented here. Try to avoid repeating information given on Canada Land Inventory maps. Rather attempt to further refine or supply additional data such as rating of organic soils or subdivisions of Class 6 soils.

A paragraph on moisture holding capacity, effect of slope on moisture distribution, effect of organic matter on moisture storage, structure and bulk density could be presented here if useful in defining the capability of the soils.

Capability for forestry - Give M.A.I. for each suitable species. Provide as many silvicultural interpretations and recommendations as possible, e.g., seedling mortality and plant competition, windthrow hazard, brush hazard, fertilization and species adaptability in relation to soil properties.

Factors oriented toward physical features, such as ratings for trafficability, erosion hazard, slump hazard and species adaptability could go here or under engineering uses, depending on where it best fits.

Engineering uses of soils - This section needs to be developed, but is of increasing importance. The range of interpretations will depend on amount of physical data that can be assembled. A good guide has been developed by U.S.D.A. Supporting soil analyses could be presented here. The data used in this section could also be applied to recreation, hydrology and other uses of soils. The interpretation may be presented according to soil family groupings. Consult report of Subcommittee on Engineering Applications.

Wildlife management - This section needs to be developed in cooperation with wildlife specialists. One objective would be to develop criteria for habitat suitability as related to soils. Vegetation and successional trends are important. Ungulate capability maps may indicate correlation between soils and big game. Upland game bird predictions could be developed.

Capability for recreation - This section needs to be developed. It would be a very generalized section. Engineering data would give some indication of soils best suited for camp sites, sewage disposal, playgrounds, roads, etc.

Hydrology - This section also needs to be developed. Engineering data would be necessary as well as information on the vegetation. Hydrologic groupings might be developed (S.C.S. Engineering Handbook on Watershed Planning). Characterize and classify water bodies. These groups of water bodies may be used as a classification entity in defining land systems.

Other sections that might be included here are:

Fisheries
Suitability for Industrial or Urban Development
Ratings for Irrigation

Note: The above sections are not necessarily in order of importance. They can be changed to suit the area being described and the information available on any particular discipline.

Single purpose interpretive maps might be presented here if they would serve a useful purpose.

Part II

10. SOIL DEVELOPMENT AND CLASSIFICATION

(a) Soil Formation - Discuss the factors of soil formation in relation to soil development.

(b) Soil Development and Classification - Discuss the kinds of soils at the great group, subgroup, and family levels. Give descriptions and analysis of each dominant subgroup. Describe profiles of most minor subgroups. This description of subgroups is most useful for teaching purposes. Present pictures if possible. Describe how the soils were classified and present a soil key showing relationship between the soils. If appropriate, show the corresponding classification of the soils in the American Comprehensive System of Classification.

11. DESCRIPTIONS OF THE SOILS

Description of Soils. In describing soils, it is essential that adequate analyses are presented for each soil, that most of the soils are analyzed, that the data are correct and that the profile descriptions are carefully and fully prepared.

(a) Describe series profiles under catena or association headings. These may be in alphabetical order or grouped according to parent material.

(b) Use tabular or text form for profile descriptions and place analytical data on same page if possible or on opposite page. The analyses may also be reported together in an appendix. Some object to the tabular form because it restricts the space needed to describe some horizons.

(c) For each profile give:

1. Location, extent, parent materials, topography, drainage, vegetation, great soil group and subgroup.

2. A generalized and detailed profile description. Use standard terms and sequence of horizon description as in

the "System of Soil Classification for Canada", pages 217-235.

3. Range in soil characteristics; differentiation from competing series.

4. Major uses.

Analytical Methods. Outline the methods of physical and chemical analyses that were used to obtain the data in the report. (This section might be preferred in an appendix).

Discussion of Analytical Data. Discuss chemical and physical characteristics of the soils in relation to classification and use. The relation between soil physical properties and plant growth might be discussed here.

12. VEGETATION CLASSIFICATION

This section would include site-type descriptions and successional relationships, as well as a table giving common and scientific names of the plants commonly found in the area. This section could be placed in an appendix if desired.

13. REFERENCES

List authors in alphabetical order and number the citation. The citation may be mentioned in the text by inserting the number in parenthesis.

14. APPENDIX

There may be several appendices. They will include tables of acreages, analytical data, if desired, climatic data, etc.

15. GLOSSARY

Use official glossary of Canada Department of Agriculture 1970.

RECOMMENDATIONS

The subcommittee recommends that:

1. Future soil survey reports have two main parts - one part which brings together general information on the soils and interpretations of their capability for use; the other part describing the morphology and classification of the soils.

2. The interpretations for use be written by or in consultation with persons qualified in the particular discipline.

3. The "Style Manual for Biological Journals" be the standard followed in editing soil survey reports.

DISCUSSION

Dumanski: How can computers be used in the situation described? Suggested that they cannot perform the work needed by soil survey.

Raad: What about scale of maps published in reports?

Baril: Do not repeat the information given on C.L.I. maps, in the report. This should be unnecessary if each soil class has a capability rating which can be tabulated in the report. No need to publish two maps at the same scale.

Millette: If you have a soil map, all that is needed is to catalogue its information in the C.L.I. system, from which it could be retrieved at any time. Eventually you could dispense with published soil maps. The same applies to the data in Part 2 of the suggested format for reports.

McKeague: The style of report suggested is ideal. Wanted to know if any reports using the style are at present in preparation, and what are the possibilities of ensuring its use in the future.

Ellis: The Rosetown report follows the suggested scheme quite closely.

Toogood: Why suggest a uniform size of report across the country, since a smaller size is a better fit on a library shelf.

Cann: There are some advantages in using the 8 1/2 x 11 size for detailed reports where mosaic maps are included in the report. The choice of size will depend on the province and local situation.

Mills: Should consider putting 7th Approximation correlation at the subgroup level into the soil report. Reasoned that in the context of our international image, as referred to by the chairman, more people are familiar with the American system than with the Canadian system.

Cann: Agreed to include this item in the guidelines for reports.

Tardif: Concerned that many pedologists, especially those in universities, have little knowledge of or interest in such subjects as recreation and wildlife capability. He felt that the interpretive section, as outlined, is asking too much of these people.

Cann: Pointed out that there was considerable freedom of choice left to individual units to do as they see fit in this area. The guidelines stress that such sections should be written by people with knowledge of the particular discipline.

deJong: Questioned the need for long profile descriptions in Part 2, if this information can be made instantly available on computer tape. He felt that there was a lot of irrelevant detail in descriptions.

Protz: Pointed out that it was neither economical nor efficient to set up a system so that anyone can use it to retrieve single profile descriptions. However, it is economical to put descriptions into a computer if they are needed for other purposes.

In the Waterloo County survey, a geologist and an engineer are involved in producing a report fairly close to the recommended format.

Smith: Data storage in its present form is archaic. It is a costly business to go through four soil reports to find a soil with certain qualities. Why not eliminate Part 2 and put all effort into Part 1 and interpretations? Why put information into Part 2 if it is so difficult to retrieve?

Protz: Data must be set down in some form that will enable a key puncher to put it into the computer in the first place.

deJong: A brief summary of the information could be published for those who might have some use for it in that form.

Protz: The two approaches are not contradictory, but complementary. Printing and computerizing of data should exist side by side.

Stobbe: It is desirable to have rapid production of soil survey reports. He stressed the significance of rapid publication, since a demand exists and we have an obligation to supply it as quickly as possible. He suggested that if a report is not available within 5 years after field work is completed, all other work should be abandoned until it is finished.

Mailloux: The soil map is in demand and is a most important document. Its legend should be simple, yet comprehensive and easily read. Agricultural representatives in Quebec take the map out to farmers and frequently leave the report at home. The legend might contain simple profile descriptions (suggested by Millette) and be very comprehensive, with all other detail put into the computer.

The recommendations of the subcommittee were passed unanimously.

REPORT OF THE SUBCOMMITTEE ON SOIL FAMILIES

R. Baril, Chairman

Introduction

The concept of soil families as set forth at the seventh meeting of the National Soil Survey Committee*(1) "seeks to define the mineralogical, the organo-mineral fabrics, and the pedoclimate of soil series in general terms. From these viewpoints, interesting and new relationships can be seen amongst 3,000 Canadian soil series. Furthermore, the soil families may enable us to examine critically the limits set forth in the study of soil series or soil individuals".

The terms of reference of our Subcommittee on Soil Families for this eighth Canada Soil Survey Committee meeting in 1970 was to make a progress report on soil family groupings across all Canadian provinces. Since the Edmonton 1968 meeting we must confess that very limited progress was made by any province. Why was this? It may be that we took too seriously the word of our national chairman: "Do not make any major change in the Canadian Soil Classification Scheme unless you have strong evidence for a change". Could it be that this lack of effort in testing by the "trial and error" method the concept of soil families is due to complacency? As we look at the architecture of our Soil Classification Scheme we have to realize that there is an empty story ... the 3rd floor ... the family, an intermediate level between the higher category: the subgroup and the lower one: the soil series.

Some provinces feel, as in 1965 and 1968 meetings, that family classes could be an interpretative grouping for applied objectives in order to show in a better way soil-plant relationships. This attitude is, in a general way, in line with the ARDA program which has drawn from soil survey data land capability classes and soil capability maps for Canada at the scale of 1:250,000.

Without denying the necessity of immediate interpretative groupings for a better use of land at a time where agriculture has a serious problem of adjustment, it seems nontheless imperative that a serious effort should be made for grouping soil series. The soil series, called the polypedons or the soil individuals, are, according to Cline (3), "the real thing that is classified from which our concepts of soil genesis and soil classification have been drawn". Family grouping becomes a yardstick for checking and establishing proper limits to soil series.

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*The category of Soil Families was adopted in 1968.

Questionnaire and Answers

With the aim of finding if a consensus of opinions existed amongst representative subcommittee members, a questionnaire was sent to each of them. The three rather simple questions were as follows:

1. Do you agree or find the soil family groupings useful and necessary?

2. Are there any soil family groupings made in your province?

3. Would it be feasible to draw a map showing soil families?

At the outset, the third question was ruled out. All provinces do not see the necessity, at this time, of a family map. Hoffman et al (4) has published a type of Family Map with their Soil Association Map at a scale of 1:633,600. The units are named after the dominant Family; for example, Guelph was used as a family name for a group of related soil families and associated series. This map together with the legend would be, according to Orvedal (5), a categorically detailed and cartographically generalized soil map. Quebec (2), like Ontario, has a Soil Association Map at a scale of 1:3,000,000. The names of the map units are the dominant series and great groups. Alberta (6) has distributed a colored map that is both categorically and taxonomically generalized, e.g. great groups and at a scale of 1:6,000,000. Other provinces, like Nova Scotia for example, have manuscript maps but most of these have not been for general distribution.

To the first question regarding the usefulness and necessity of having the family grouping, we must report that all provinces are far from being unanimous. Saskatchewan feels that this category is neither useful nor necessary for the classification of their soils, although they would accept the family category if other provinces think it is needed in the Canadian Scheme. Manitoba has started to group soils on a family basis but is uncertain about the usefulness of the groupings. Newfoundland feels that: "without knowing what the answer is to the question, we do know that if we do not have families we will not be lacking in our knowledge of soils or soil genesis".

On the other side of the picture we have had favorable comments from the Maritime provinces, Ontario, Quebec and the Central Office in Ottawa. The Maritime provinces contemplate a joint project and more progress in family groupings in the next few years. Quebec pedologists of the Provincial Department of Agriculture are still busy with ARDA land capability inventory but foresee more time devoted to this matter. The Department of Soils of the Faculty of Agriculture is engaged in some research for the characterization of benchmark soils and others. Ontario, as previously mentioned, is engaged along these soil studies. To complete these expressions of opinion, I would like to mention the statements of John Day from Ottawa (I will try to be faithful in translating some of his comments sent in French): "I agree that the subcommittee is really useful and necessary ... it would be more useful if all members would put their efforts to use the proposals for family groupings and to direct this experience to the chairman. This is the only way which would assure an ultimate success".

Modifications and Additions of Family Criteria

The criteria proposed in 1968 (7th Meeting) are proposed again for adoption with the following amendments and guidelines.

Amendments

1. That the ortstein development in some horizons of the Humic, Ferro-Humic and Humo-Ferric podzols should be eliminated as part of the definition of the orthic classes of same but should be defined as new classes at the subgroup category, e.g. Ortstein Humic podzols, Ortstein Ferro-Humic and Ortstein Humo-Ferric podzols. The vast areas covered by these various Ortstein podzols in northern and eastern Canada (probably more important than in the U.S.A.) and other genetic considerations are the main reasons which are advanced for this change. Note: suffix "c" in the horizon nomenclature.

2. That the fragipan (suffix "x") development in some horizons of various great groups of podzols given above be specifically identified at the subgroup category and eliminated in the definition of great groups, e.g. Fragic Humic podzols, Fragic Ferro-Humic podzols and Fragic Humo-Ferric podzols.

3. That the 18 inches limit as a criterion for the identification of bisequa profiles be removed and all like soils having a podzol B (Bf, Bfh, Bhf) that is evident under the plow layer be placed only in the Podzolic Order. Luvic would replace the term bisequa. As a consequence the Bisequa Gray Brown Luvisol (3.13), the Bisequa Gray Wooded (Bisequa Gray Luvisol) (3.2-/4) and the various bisequal profiles of the Podzolic Order would be called Luvic Humo-Ferric podzols (4.3-/5). The Bisequa Gray Brown Luvisol (3.13) on account of the Ah diagnostic horizon could be distinguished from the Bisequa Gray Wooded (3.2-/4) but using the additional adjective (intergrade name), namely: Sombric and Luvic Humo-Ferric podzols (3.13). The depth limits would be considered at the family and series categorical levels.

4. Possible amendments might come from revisions, if deemed necessary, of the changes proposed in other subcommittees, e.g. the subcommittee on climate, drainage and/or moisture classes, etc. These could be supplements to the published handbook on Canadian Soil Classification Scheme.

5. Guideline for applying family textural classes or groups to the soil control section and additions as proposed by John Day.

   (Unfortunately the section on this subject, presented in the 1968 NSSC proceedings on page 96, does not explain how this can be done and thus some explanation is needed.)

   a) In applying texture classes use the weighted average texture of the control section or of the horizons listed below, unless there are strongly contrasting textures within the control section. If there are strongly contrasting textures, both textures are used, e.g. fine over coarse.

b) For lithic and cryic subgroups of mineral soils the texture classes are applied from the surface down to the contact.

c) For all other mineral soils that lack Bt or Bn horizons the texture classes are applied only to the mineral soil from a depth of 10 inches to a depth of 40 inches.

d) For mineral soils that have Bt or Bn horizons the texture classes are applied to that portion of the Bt or Bn below any Ap, or from the top of the Bt or Bn to the whole of the Bt or Bn if less than 20 inches thick or to the upper 20 inches if it is more than 20 inches thick, or if there are horizons or layers of strongly contrasting textures within or below the Bt or Bn and within 40 inches, texture classes are applied from the top of the Bt or Bn to 40 inches, or to a lithic contact if shallower than 40 inches.

6. It was proposed that the reaction class limits (based on the pH in 0.01 M $CaCl_2$) be reworded as follows:

   a) Acid: pH lower than 5.5 in all parts of the control section.
   b) Neutral: pH 5.5-7.5 in at least some part of the control section.
   c) Alkaline: pH higher than 7.5 in at least some part of the control section.

Note: A more constant communication could be done between subcommittee members each year or at any time as suggested by Dr. Alex McKeague. In this manner we would avoid the rush of the late hours.

References

(1) Baril, R. 1968. Proceedings of the Seventh Meeting of the National Soil Survey Committee of Canada. Mimeographed report of the Canada Department of Agriculture, Ottawa, pp. 95-106.

(2) Baril, R. 1967. Carte des associations de sols du Québec. Présentée au Congrès de l'Institut agricole du Canada au Collège MacDonald. Revision de la carte déjà parue dans Revue Agriculture, vol. XXII, no. 1, mars 1965.

(3) Cline, M.G. 1963. Logic of the New System of Soil Classification. Soil Science, Vol. 96, No. 1, pp. 17-23.

(4) Hoffman, D.W. et al. 1964. Soil Associations of Southern Ontario. Report No. 30 of the Ontario Soil Survey.

(5) Orvedal, A.C. and Edwards, Max J. 1941. General Principles of Technical Grouping of Soils, SSSA Proceedings, Vol. 6, pp. 386-391.

(6) Odynsky, Wm. 1962. Soil Zones of Alberta. Research Council of Alberta, 3rd ed. Map at 1:6,500,000 scale. Distributed by the Department of Extension, University of Alberta, Edmonton, Alta.

REPORT OF THE SUBCOMMITTEE ON ORGANIC SOILS

J. H. Day, Chairman

The additions and changes recommended for the classification of organic soils and the decisions taken by the members of the CSSC are as follows:

A. Define Folisol great group and subgroups.

8.4 Folisol Great Group - These organic soils are not usually saturated with water for more than a few days, and consist of 4 inches (10 cm) or more of L-H horizons derived from leaf litter, twigs, branches and mosses. A lithic contact occurs at a depth of less than 52 inches (130 cm), or the organic layers rest on fragmental material with interstices filled or partially filled with organic material. A lithic contact may occur below the fragmental material. Mineral layers thinner than 4 inches (10 cm) may be above the lithic contact and the organic materials are more than twice the thickness of the mineral layer.

8.41 Typic Folisol - These soils consist of organic layers underlain by fragmental materials (rock debris) with interstices filled or partially filled with organic materials, i.e. more than half of each pedon. A lithic contact may occur below the fragmental material.

8.42 Lithic Folisol - These soils consist of organic layers underlain by a lithic contact within 52 inches (130 cm) of the soil surface.

It was agreed that L-F-H designations be used in this great group of soils to imply the origin and drainage of the organic material.

This proposal was adopted (11 for, 7 against) for trial during the next two or three years.

B. Alter the definition of the control section by deleting paragraph d) The System of Soil Classification for Canada (SSCC), p. 149.

This proposal was adopted unanimously.

C. Redefine 8.11b

8.11b Silvo-Fibrisol - These soils consist of uniform fibric organic material derived dominantly from mixtures of wood, moss (less than 75% of the volume consisting of Sphagnum spp.) and other herbaceous plants, throughout the middle and bottom tiers. They lack mesic or humic subdominant layers. The control section is 52 or 64 inches (130 or 160 cm) thick and lacks any terric, lithic, hydric, cryic, cumulo or limno layers.

This proposal was adopted unanimously.

D. Establish an order of importance among the subgroups with the objective of limiting the number of combinations of subgroups to those deemed to have special significance. Some pedologists are concerned by the number of possible combinations of subgroups and all that the terms imply at lower categories. However, some characteristics are more important than others because of implications to interpretations and should be recognized as subgroups.

The following principles were proposed:

a. Typic, Fenno-, Silvo- or Sphagno are used singly with a great group name.

b. Hydric is used alone.

c. Cumulo is used alone and is given precedence over Fibric, Mesic or Humic.

d. Limno is used alone and is given precedence over Fibric, Mesic, Humic or Cumulo.

e. Lithic is used alone and is given precedence over Fibric, Mesic, Humic, Limno, Cumulo or Terric.

f. Fibric, Mesic or Humic are used alone or in combination only with Terric. Terric Fibric, Terric Mesic or Terric Humic is given precedence over Cumulo.

g. Terric is used alone or in combination only with Fibric, Mesic or Humic. It is given precedence over Limno or Cumulo.

h. Cryic is used alone and is given precedence over Cumulo, Terric, Fibric, Mesic, Humic, Limno.

This proposal would fix the permissible combination of subgroups as follows:

Typic Mesisol, Humisol or Folisol
Fenno-Fibrisol
Silvo-Fibrisol
Sphagno-Fibrisol
Hydric Fibrisol, Mesisol, Humisol
Cumulo Fibrisol, Mesisol, Humisol
Fibric Mesisol, Humisol
Mesic Fibrisol, Humisol
Humic Fibrisol, Mesisol
Terric Fibric Mesisol, Humisol
Terric Mesic Fibrisol, Humisol
Terric Humic Fibrisol, Mesisol
Limno Fibrisol, Mesisol, Humisol
Lithic Fibrisol, Mesisol, Humisol, Folisol
Terric Fibrisol, Mesisol, Humisol
Cryic Fibrisol, Mesisol, Humisol

This proposal is intended to apply to reconnaissance and detailed soil surveys. For genesis studies pedologists should name the subgroup as they see fit. If this proposal is accepted the subgroup definitions and numbering systems should be changed, e.g.

8.1-/6 Terric Fibrisol - These soils have a terric layer beneath the surface tier but within the control section. Used only with subgroups 8.12/6, 8.13/6, or alone when the organic material is uniform.

This proposal was adopted unanimously.

E. Institute the requirement that in Terric Fibric, Terric Mesic and Terric Humic subgroups the thickness of the subdominant organic layer is 10 inches (25 cm) or more.

This proposal was adopted unanimously.

F. Amend definition of hydric layer to read as follows:

Hydric: This consists of a fluid layer that extends from a depth of not less than 16 inches (40 cm) or 24 inches (60 cm) to a depth of more than 52 inches (130 cm) or 64 inches (160 cm).

The current definition should be amended to make it agree with the requirements stated under the hydric subgroups.

This proposal was adopted unanimously.

G. Amend paragraph c) under Control Section (p. 149 SSCC) to read as follows:

c) to any lithic contact that occurs below a depth of 4 inches (10 cm) but shallower than either a) or b) or, to any hydric contact that occurs below a depth of 16 inches (40 cm) but shallower than either a) or b) or,

This correction is necessary because as presently worded it implies that 4 inches of organic material over a hydric layer is an organic soil.

This proposal was adopted unanimously.

H. Consider adopting officially the criteria proposed in 1968 for the soil family and soil series levels.

Discussion of this proposal centered around the absence of climatic class criteria and the desirability of restricting the textural classes of terric layers to three. It was agreed that these criteria should be further developed and tested in the next three years.

I. Revise the order definition to read as follows:

8. Organic Order

These are soils that have developed dominantly from organic deposits. The majority of them are saturated for most of the year, or are artificially drained, but some of them are not usually saturated for more than a few days. They contain 30% or more of organic matter and must meet the following specifications:

a) If the surface layer consists dominantly (more than 75%) of fibric Sphagnum moss the organic materials must extend to a depth of at least 24 inches (60 cm).

b) If the surface layer consists of other kinds or mixed kinds of organic materials the organic materials must extend to a depth of at least 16 inches (40 cm).

c) If a lithic contact occurs at a depth shallower than stated in a) or b) above, the organic material must extend to a depth of at least 4 inches (10 cm). Mineral material less than 4 inches (10 cm) thick may overlie the lithic contact but the organic materials must be more than twice the thickness of the mineral layer.

d) The organic layer may have a mineral layer thinner than 16 inches (40 cm) on the profile surface. If covered with less than 16 inches of mineral soil the organic layer or layers taken singly or cumulatively must be at least 16 inches (40 cm) thick.

e) Mineral layers thinner than 16 inches (40 cm), beginning within a depth of 16 inches from the surface, may occur within the organic deposit. A mineral layer, or layers taken cumulatively, thinner than 16 inches (40 cm) may occur within the upper 32 inches (80 cm).

This revision was adopted unanimously.

The subcommittee recommends that it continue to function. Several members proposed that further study be conducted on the thickness of the surface tier and of the control section.

REPORT ON SOLONETZIC SOILS

T. W. Peters, Chairman

It is proposed to reintroduce the following subgroups into the Solonetzic Order:

1. A Dark Brown Solonetz in the Solonetz Great Group.
2. A Dark Brown Solod in the Solod Great Group.

This has been found necessary to handle those soils of this Order which fail to meet the criteria as established for the Brown and Black subgroups. They reflect a more humid climate than the Brown subgroups and yet not as humid as the Black subgroups. Also, agronomically, they are superior to the Brown Solonetz or Solod.

The introduction of these new subgroups involves re-numbering within the order. The proposed numbering is as follows:

2. Solonetzic Order		
2.1 Solonetz	2.11	Brown Solonetz
	2.12	Dark Brown Solonetz
	2.13	Black Solonetz
	2.14	Gray Solonetz
	2.15	Alkaline Solonetz
	2.1-/8	Gleyed Solonetz
	2.1-/9	Lithic Solonetz
2.2 Solod	2.21	Brown Solod
	2.22	Dark Brown Solod
	2.23	Black Solod
	2.24	Gray Solod
	2.2-/8	Gleyed Solod
	2.2-/9	Lithic Solod

The following are the proposed descriptions of these subgroups:

2.12 Dark Brown Solonetz

Profile type: Ah or Ahe or both, (Ae), an intact Bnt, (Bts), (Btk), Csa or Cs, (Cca), (Ck).

These soils are associated with a grass, forb, and shrub vegetation and a semiarid to subhumid climate. The mixed A subhorizons have a color value darker than 3.5 moist and 4.5 dry and a chroma of more than 1.5. In many cases there are several inches of an Ah with a color value of 3.5 moist or dry.

Areas of this subgroup are often characterized by a patchy microrelief due to differential erosion of the A horizon. These eroded pits usually have steep sides and support a sparse vegetative growth. These pits are not as common in the Dark Brown as in the Brown soil zone and may be fairly well grassed over.

2.22 Dark Brown Solod

Profile type: Ah or Ahe or both, Ae, AB, Bnt, (Cca), (Ck), Csa or Cs.

These soils are associated with a grass, forb, and shrub vegetation and a semiarid to subhumid climate. The mixed Ah and Ahe has a color value darker than 3.5 moist and 4.5 dry and a chroma of more than 1.5. The upper several inches of the Ah horizon may have a color value darker than 3.5 moist and dry.

The Cs or Csa horizon is usually below the Ck or Cca horizon.

In areas of these soils there is often evidence of previously eroded pits. They are quite well grassed over and usually quite shallow.

The introduction of these two subgroups means that the color criteria of the Brown Solonetz and Brown Solod will have to be modified. They should now read: "The mixed Ah and Ahe has a color value of more than 3.5 moist and greater than 4.5 dry and a chroma of more than 1.5."

The color criteria for the Black Solonetz and Black Solod should read as follows: "The mixed A subhorizons have color value of less than 4.5 (dry), usually 3.5 or less (dry), and chromas of less than 2.5.

In the meantime these soils are being handled at the soil series level.

REPORT ON LUVISOLIC SOILS

D. B. Cann, Chairman

Recommended Changes

Luvisolic Order - SSSC page 79, line 8, reads:

"Slight accumulations of $CaCO_3$ may occur under a B horizon, but these seldom meet the requirements of a Cca horizon."

Suggested change: "Slight accumulations of $CaCO_3$ may occur under the B horizon which meet the requirements of a Cca horizon."

Reason: Such conditions are known to occur.

3.1 Gray Brown Luvisols - SSSC page 80, line 15, reads:

"Although the Bt horizon is generally immediately underlain by calcareous materials, a transition BC horizon, free of lime, may be present."

Suggested change: "Although the Bt horizon is generally immediately underlain by calcareous materials, a transition BC horizon may be present."

Reason: Since these soils are developed from calcareous or basic parent materials, the designation BC is misleading if it is a lime free horizon.

3.2 Gray Wooded (Gray Luvisol) - SSSC page 82

Change: illuvial (Ae) horizons to eluvial (Ae) horizons.

REPORT ON PODZOLIC SOILS

D. B. Cann, Chairman

Recommended Changes

Podzolic Order - SSSC page 97, last sentence reads:

> "If the Ae and podzolic B horizons are incorporated in the Ap, the Ap must have (a) more than 3% organic matter (1.7% C), (b) (Fe + Al) greater than 0.8%, and hues redder than 10YR and moist color values less than 3.0, or chromas of 3.0 or more in hues of 10YR or redder."

Suggested change: Delete.

Reason: No longer a requirement for a spodic horizon.

4.21 Orthic Ferro-Humic Podzol - SSSC page 103, first paragraph reads:

> "--- in the upper part, --- and contain more than 10% organic matter---."

Suggested change: "These soils have dark colored (moist values and chromas 3.0 or less) Bhf horizons 4 inches (10 cm) or more thick that contain more than 10% organic matter, and in which Δ (Fe + Al) is greater than 0.8% and the ratio of organic matter to oxalate-extractable Fe is less than 20. Usually the Bhf is the uppermost B horizon, but in some soils the Bhf may be overlain by Bfh or Bf horizons."

Reason: As presently written the Bhf must be the uppermost B horizon and the whole B horizon must have more than 10% organic matter.

4.32 Mini Humo-Ferric Podzol - SSSC page 109, last sentence:

Suggested change: Delete.

Reason: No longer a requirement for a spodic horizon. It is also automatically excluded by the definition of the Great Group.

4.3-/5 Bisequa Humo-Ferric Podzol - SSSC page 110

Suggested change: Delete second paragraph.

Reason: Error in printing. Does not belong here.

In the diagrams of the Humo-Ferric Podzol great group, and Orthic and Mini subgroups, SSSC pages 94 and 95, the BC horizon should be pinched off. Otherwise it indicates that a BC horizon is always present.

It seems evident that some major changes will be required in the Podzolic Order. Members of this subcommittee will be asked to express their views on this matter in an attempt to reach a satisfactory classification scheme for these soils before the next national meeting.

It is recommended that the subcommittees on the Podzolic and Luvisolic Orders continue to seek improvement in the definitions of these orders.

REPORT ON BRUNISOLIC SOILS

P. J. Lajoie, Chairman

Although it is not the intention of the Canada Soil Survey Committee to make any major changes in the classification of mineral soils at this time, the following suggestions of some members are presented to be placed on record for future consideration.

1) It is suggested that the adjectives used to qualify the subgroups be connotative as much as possible, for example that Podzolic Eutric Brunisol be used instead of Degraded Eutric Brunisol to indicate the podzolic development in a Brunisol. Such suggestion applies not only to Brunisols but also to other groups.

2) In order to arrive at a more precise definition of the Brunisols, it is suggested that, in about 3 or 4 years, the Committee consider the modification of the definitions along the following lines:
Melanic and Eutric: having a pH (0.01M $CaCl_2$) of 5.5 or more in some parts of the control section.
Sombric and Dystric: having a pH (0.01M $CaCl_2$) less than 5.5 in all parts of the control section.

Data already available would support such a possible delimitation, but many more analyses are needed before they could be used as valid support for such definitions.

3) It is suggested that provision be made to include in the Brunisolic Order all soils that meet the requirements of the Brunisolic Order and occur in alpine environment and that the Sombric Great Group be redefined to correspond to the Sombric Subgroup definition of the Podzolic Order.

Note: Two words are missing on page 123 of "System of Soil Classification for Canada": in line 6 of paragraph 2 the text should read (M.A.A.T. less than 42F [5.5C]).

RAPPORT SUR LES BRUNISOLS

Même s'il est entendu que la Commission de Pédologie du Canada ne désire faire présentement aucun changement majeur dans la classification des sols minéraux, les suggestions de quelques membres sont présentées pour qu'elles soient retenues et examinées plus tard.

1) On a suggéré que les adjectifs utilisés dans les sous-groupes soient connotatifs autant que faire se peut, par example, dire Brunisol eutrique podzolique au lieu de Brunisol eutrique dégradé pour indiquer que des critères aberrants rapprochent ce sol des podzols. La suggestion s'applique également à d'autres groupes.

2) Pour en arriver à une définition plus précise des brunisols, il est suggéré que, dans 3 ou 4 ans, la Commission étudie la possibilité de modifier les définitions comme suit:
Melanique et Eutrique: ayant un pH (0.01M $CaCl_2$) de plus de 5.5 dans une partie de la section réglementaire.
Sombrique et Dystrique: ayant un pH (0.01M $CaCl_2$) de moins que 5.5 dans toutes les parties de la section réglementaire.

Des données déjà disponibles suggèrent qu'une telle délimitation est possible, mais il en faudrait encore beaucoup d'autres pour donner un appui convenable à de telles définitions.

3) Il est suggéré que provision soit faite pour accommoder dans l'ordre brunisolique tous les sols de milieu alpin qui rencontrent les exigences de l'ordre brunisolique et que le grand groupe des sombriques soit redéfini pour correspondre à la définition du sous-groupe sombrique de l'ordre podzolique.

A noter: À la page 123 du "System of Soil Classification for Canada" il manque deux mots: à la ligne 6 du 2ème paragraphe il faut lire (M.A.A.T. less than 42F [5.5C]).

REPORT ON GLEYSOLIC SOILS

J. A. McKeague, Chairman

Most of the survey units sent comments or suggestions regarding the Gleysolic Order. The majority seemed to favor leaving it unchanged but the following changes were suggested:

1. John Nowland suggested the addition of a Pseudogleysol Great Group for soils having strongly leached Ae horizons overlying dense, mottled B horizons that do not meet the limits for Bf or Bt. Distinct or prominent mottling does not extend more than 30 cm into the B horizon and the C horizon is not gleyed. Some of these soils in Nova Scotia are classified at present as Gleyed Degraded Dystric Brunisols and others as Orthic Gleysols. John is studying water table fluctuations, moisture contents, etc. of some of these soils.

I sent a copy of the proposed definition of the suggested Pseudogleysol Great Group to each survey unit. Several of those who replied thought that the suggestion had merit although most wondered how they would separate these soils from some Gleyed Subgroups of other orders. Others considered the proposed change to be unnecessary. Auguste Mailloux suggested the establishment of "paragleyic" subgroups to classify the soils in question.

2. Roger Baril presented a case for a new subgroup, "Humic Maxi Ferra Eluviated Gleysol" for Gleysolic soils in which the solum is impoverished in free and total Fe. He suggested a new horizon Bge as diagnostic of this subgroup. It would be useful to know if others have studied Gleysolic soils in which extractable and total Fe increase with depth.

This proposal, if accepted, would involve a change in the definition of the Eluviated Gleysol Great Group as the new subgroup does not have a Bt horizon.

3. Ian Sneddon suggested that provision be made in the Gleysolic Order, and others, to include the Gleysolic soils that occur in alpine environments (above timberline). This would involve the addition of various Alpine Subgroups.

4. Jack Clayton suggested changing the name "Eluviated Gleysol" to "Luvic Gleysol". This change would:

(a) Result in shorter names for the great group and its subgroups;
(b) Perhaps avoid the confusion due to the term "Eluviated" in the name of the Great Group. Eluviated Gleysols have Aeg and Btg horizons. Eluviation refers to clay. Gleysolic soils eluviated of Fe are not Eluviated Gleysols and this has caused some confusion. Perhaps Low Humic Eluviated Gleysol could be changed to Ochric Luvic Gleysol.

I would recommend that these proposals be considered for a year or two and that they be decided upon at the next C.S.S.C. meeting. In the meantime, proposals 1, 2 and 3 should be supported by documented information and this should be sent to all survey units. The information required to support a proposal for a change in the classification should, in my opinion, include:

(1) A statement of the problems in classification that could be resolved best by a change in the classification system.
(2) Detailed descriptions of the soils concerned and some information on the extent of occurrence of the "new" soil.
(3) Analytical data for 2 or 3 of the soils concerned.
(4) A detailed statement showing how the proposed change would affect the definitions of other soil classes, and suggested new definitions or criteria for the classes affected.
(5) A statement on methods of distingushing the proposed new class from similar soils of other classes. Criteria to use, both in the field and in the lab, should be indicated.

I would suggest that proposed changes in the Gleysolic Order and in other orders should be handled in the way indicated. The formal proposal should be sent to the chairman of the order concerned at least 2 months before the next C.S.S.C. meeting. The chairman should send copies of these proposals to the head of each survey unit and to the correlators at least a month before the meeting.

Several comments were made regarding the report on the Gleysolic Order.

(1) Several remarked that the criteria for distinguishing Gleysolic soils from Gleyed Subgroups of other orders are not specific. Criteria that seem adequate in some areas are not of much use in others. Work on this problem is needed in all regions and some useful data have been obtained recently by Michalyna, Nowland, Crown and Hoffman and probably others.

I would suggest that people concerned with this problem set up criteria for distinguishing Gleysolic soils from gleyed subgroups in their areas and that these suggested criteria be sent to the Gleysolic Order chairman. It should be possible in this way to develop generally applicable criteria.

(2) Cliff Acton would prefer to have straight lines separating the horizons in the diagrams of Gleysolic and other soils. I agree as the present diagrams seem to imply that we know what are the average thickness of horizons of the soils. He also questioned including horizons that are not diagnostic of the subgroup in the diagrams, e.g., Aeg in Humic Gleysol. These points should be considered and a definite recommendation will be made at the next meeting.

(3) Bruce Cann suggested that the last sentence in the definition of the Gleysolic Order should be changed by deleting "a horizon or horizons at least 4 inches (10 cm) thick with". I would like to have other opinions on this.

(4) Daws Lindsay observed that the differentiation of Gleysols and Rego Gleysols is not consistent because people have varying concepts of a Bg horizon. Suggestions are needed on how to sharpen the definition of Bg. As in '1' above, it would be useful if people in different regions would outline their concepts of a Bg horizon and set up criteria that would be adequate in their area.

(5) Gleysolic soils having Ah, Btg, Cg profiles are not described in the classification system. Are they Humic Gleysols or Humic Eluviated Gleysols?

(6) Don Acton noted that "Carbonated" Gleysolic Subgroups may have primary or secondary carbonates in the Ah horizon, whereas "Carbonated" Chernozemic soils have secondary carbonates in the A or B horizons. The lack of consistency in the use of "Carbonated" is undesirable.

(7) Bill Odynsky considers that field trips are necessary to aid in resolving some of the problems in classifying Gleysolic soils.

In summary, I recommend that the Gleysolic Order be left unchanged at present and that the proposals for change indicated in this report as well as any others be considered as indicated before the next C.S.S.C. meeting and decided upon at this time. I think that is important that there be continuous exchange of ideas about classification problems between the order chairmen and other people using the system. Thus, do not wait until C.S.S.C. meetings to send suggestions or comments on problems in classifying Gleysolic soils. I also recommend the appointment of a new chairman for the Gleysolic Order as it's time for some different concepts.

Discussion

St. Arnaud supported the general procedure outlined for initiating a change in the soil classification system. He recommended that the proposal for a change be submitted at one C.S.S.C. meeting and voted on at the following meeting. None dissented and thus this procedure was agreed upon.

REPORT ON SOILS ABOVE TIMBERLINE

J. I. Sneddon

a) All soils occurring above the timberline should be classified into the appropriate subgroups of the order whose criteria they meet in the Canada System of Soil Classification and not be excluded because of geographic location.

b) In addition, where soils above the timberline meet the requirements of classes where they rest unconformably because of the encompassing nature of the class definition; more precise definitions of such classes will have to be made to exclude these soils and new classes should be defined to accommodate them.

REPORT ON SANDY PODZOLIZED SOILS IN SASKATCHEWAN

H. B. Stonehouse

In the northern provincial forest region of Saskatchewan there are extensive areas of sandy soils. From the beginning of soil classification in Saskatchewan these soils have been considered to belong to the "podzol group" of world soils (2). Podzolic soils (1, 3) are characteristically formed in moist, cool climates under forest or heath vegetation. This climate and biological conditions result in a soil characterized by an organic surface layer, underlain by a light-colored eluvial horizon which has lost relatively more sesquioxides than silica. This eluvial horizon is in turn underlain by a darker colored illuvial horizon in which the major products of accumulation are sesquioxides and organic matter. More specifically, in 1965 the Canada Soil Survey Committee (then the National Soil Survey Committee) adopted chemical criteria for an f horizon, (Bf or Bh horizon are diagnostic for Podzolic soils) such that for any horizon to be termed an f horizon it must "contain a minimum of 0.8% more oxalate extractable iron plus aluminum than the C horizon".

Recent analysis of soil samples collected during soil surveys of the forested areas have shown that these soils do not have Bf horizons as described above. Thus, according to the present criteria, they cannot be classified as Podzolic soils but must be classified as Brunisolic soils.

The world concept of Brunisolic soils is that these are soils which are characterized by a brownish colored B horizon which has no accumulation of clay and only slight accumulation of sesquioxides. These soils have very little or no Ae (4). Since many of the sandy forested soils in Saskatchewan do not fit this concept of Brunisolic soils a project was initiated whereby soil samples were collected over a wide area in northern Saskatchewan representing soils developed on sandy parent materials under forest vegetation and exhibiting a varying range of morphological characteristics. It is some of the results of this study which are being presented here.

It should be made clear at the outset that no attempt is being made at this time to suggest new criteria for classifying Podzolic soils developed on sandy parent materials. Our immediate purpose is to establish whether the difficulty in classifying these soils is unique to Saskatchewan and if not, to establish whether those involved with classifying these soils in other areas are satisfied with existing classification criteria.

For purposes of soil sampling and reporting of the data the soils were classified according to morphological characteristics observable in the field and were designated as Podzols, Brunisols or Intergrades between Podzols and Brunisols. General characteristics for each of these were:

1. Podzols - Strong development of an Ae underlain by a strongly developed high chroma B.

2. Brunisols - Very weak development of Ae underlain by very weak Bm or no discernible B horizon.

3. Intergrades - Weak development of Ae underlain by a weakly discernible low chroma B or moderate development of Ae underlain by weakly developed low chroma B.

Thirty-three profiles were sampled. Nine were classified as Brunisols, four as Intergrades and twenty as Podzols. Of the twenty profiles classified as Podzols twelve were sampled in such a manner that analysis was carried out on the entire horizon. The other eight profiles were sampled in such a manner that analysis was carried out on only that portion of the horizon which exhibited maximum expression of that horizon. These were compared to see if sampling technique had any effect on ultimate classification by chemical criteria. The results of oxalate extraction of Fe (Fe_o) and Al (Al_o) as well as total iron (Fe_t) analysis are summarized in Table 1.

Table 1. Summary of oxalate extractable Fe and Al, and total Fe in parent materials for sandy Podzolized soils in Saskatchewan

Soil	No. of Profiles	% Fe_o in B	% Al_o in B	% Fe_t in C	$\Delta(Fe + Al)_o$
Brunisols	9	.01 to .19	.06 to .20	.21 to .98	.03 to .19
Intergrades	4	.09 to .26 one at .45	.07 to .21	.47 to .97 one at 1.35	-0.17 to .24 one at .42
Podzols	12	.11 to .47	.08 to .36 one at .85*	.11 to .93 one at 1.36	.13 to .69 one at 1.18
	8	(.21 to .45 one at .95)**	(.15 to .48)	(.97 to 2.03)	(.23 to .62 one at .80)

*P15.2 - Fe_o = .47%, Al_o = .85%, $\Delta(Fe + Al)_o$ = 1.18%

**5224 - Fe_o = .95%, Al_o = .31%, $\Delta(Fe + Al)_o$ = 0.80%

The results for the soils classified as Podzols are divided into two groups. Firstly, those in which analysis was carried out on the entire horizon (shown without brackets), and secondly, those in which analysis was carried out on only a portion of the horizon (shown in brackets).

The results show that oxalate extractable iron, in the Brunisols and Intergrades, is very low, generally below 0.26%. The same is true for oxalate extractable aluminum, which ranges from 0.06 to 0.21%. Total iron values in the parent material for the two groups of soils is in all but one case less than 1.00%. Differences in the total of oxalate extractable iron and aluminum between the B and C horizons $\Delta(Fe + Al)_0$ are very low.

Results for the Podzolic soils are somewhat higher than for the other two groups but still do not give $\Delta(Fe + Al)_0$ values high enough to meet the criteria for Podzolic soils, with the exception of two soils. One of these soils was high in Fe_0, the other high in Al_0. The specific results for these two soils are given at the bottom of Table 1. Sampling of only that part of the horizon which showed maximum expression gave slightly higher results for individual horizons but did not increase $\Delta(Fe + Al)_0$ values.

The results indicate that, with the exception of a very few soils, the iron and aluminum content of these soils are too low to meet the present criteria for f horizons. The probable reason for this is that the parent materials are sufficiently low in iron-bearing minerals that a difference of 0.8% between the B and C horizons is not possible without weathering occurring throughout a much greater depth of soil than that presently taking place.

If it is desirable to keep sandy podzolized soils which have the morphological characteristics of Podzols in the Podzol Order, and we in Saskatchewan think it is, it would seem that for these soils a ratio of iron or aluminum or both between certain horizons might be more suitable, rather than an absolute difference. This would be similar to criteria for a Bt horizon. Thus some ratios, shown in Table 2, were calculated, and certainly many others could be.

Table 2. Summary of graphical representations of some ratios of Fe and Al in the A to that in the B horizons

	Fe_t B/A	Chroma B	Value A/B	Al_o B/A	Extr'y Fe^o/Fe^t	Fe_o B/A	A.FeR Fe^o/Fe^d
Podzols							
21.1	X	X	X	X	X	X	X
17.1	X	X	X	X	X	X	0
P13.1	X	X	X	X	X	X	X
P12.1	X	X	X	X	X	X	X
P11.1	X	X	X	X	X	X	X
P10.2	0	0	0	X	0	0	0
P8.1	X	X	X	X	X	X	0
P7.1	X	X	0	X	X	X	X
P3.1	0	0	X	0	X	X	X
P4.2	0	X	0	0	0	X	0
P15.2	X	X	X	X	X	X	X
Intergrades							
P14.1	0	0	0	0	X	0	X
P9.1	X	X	X	X	X	X	X
P6.1	0	0	0	X	0	0	0
P2.1	X	0	X	X	0	0	X
Brunisols							
P17.2	0	X	0	0	0	0	X
P17.1	0	0	0	0	0	0	0
P13.2	0	0	0	X	X	X	X
P10.1	0	0	0	0	0	0	0
P5.1	X	X	0	X	0	0	0
P4.1	0	0	0	0	0	0	X
P1.1	0	0	0	0	0	0	0
P16.1	X	0	0	X	0	0	0
P18.1	0	0	0	0	0	0	0
X Podzol	2.5 or >	4 or >	1 or >	4 or >	28 or >	3 or >	5 or >
0 Brunisol	< 2.5	< 4	< 1	< 4	< 28	< 3	< 5

The values for the ratios calculated were then plotted graphically using the value of the unit calculated on the vertical axis and a spacing of values on the horizontal axis. After all points had been plotted a grouping quite often became apparent. The higher values were usually the soils classified as Podzols while the lower values were usually the soils classified as Brunisols. A line was then drawn separating the two groups and for our purposes the soils which had values above the line were called Podzols and marked with an X, the soils which had values below the line were called Brunisols and marked with an O. The results of these graphical representations are shown in Table 2 with the value used to separate Brunisols from Podzols shown at the bottom. The soils as they were classified morphologically in the field are shown on the left hand side and their position on the graph for each ratio calculated shown in the appropriate column to the left.

It can readily be seen that no one ratio calculated gave a separation of soils as they were classified morphologically, however, some ratios were better than others. They did, however, show that generally soils classified morphologically as Podzols fell in the Podzol range as calculated and that soils classified morphologically as Brunisols and Intergrades fell in the Brunisol range as calculated, with certain exceptions. These were soil profile P10.2 which was classified morphologically as a Podzol and almost always fell in the range of Brunisols, and soil profile P9.1 which was classified morphologically as an Intergrade but which always fell in the range of the Podzols.

As previously mentioned some ratios gave a separation of soils which more closely resembled the separations made morphologically. The most notable one was the ratio of oxalate extractable Fe in the B to that of the Ae. The separation used was that if the Fe_o in the B exceeded that in the Ae by a factor of 3, it should be classified as a Podzol. The exceptions to this were the two soils previously mentioned and soil profile P13.2 which was classified morphologically as a Brunisol, yet fell in the range of the Podzols.

The results are not conclusive and more work must be done. However, the consensus of opinion, after the above presentation and the viewing of a number of slides of these soils, and eastern soils which meet the criteria for Podzolic soils, was that it would be desirable to keep the soils which have all the morphological characteristics of Podzols in the Podzolic Order. One suggestion as to how this may be accomplished was to apply the U. S. formula for a Spodic horizon in sandy soils. That is, to have a Spodic horizon a soil must have one or more horizons which meet all of the following criteria:

a) $\dfrac{\%\ \text{pyrophosphate Ext Fe + Al}}{\%\ \text{clay}} = > 0.2$

where $\dfrac{\%\ \text{pyrophosphate Ext Fe + Al}}{\%\ \text{dithionite Ext Fe + Al}} = > 0.5$

b) loses 25% or more of its C.E.C. (at pH 8.2) upon shaking overnight in dithionite-citrate solution

c) is thick and developed enough that the index of accumulation of amorphous material, [(C.E.C. (pH 8.2) - 1/2% clay) x thickness in cm], in the horizons that met the preceding requirements is > 90

From the discussion that followed it was apparent that British Columbia, Alberta and probably Manitoba also have soils similar to those found in Saskatchewan. It is hoped that the meeting will have pointed out a need for more research on these soils, and that other provinces will be encouraged to conduct research on these types of soils with the results that definite decisions can be made at a future meeting.

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BIOPHYSICAL LAND CLASSIFICATION SYSTEM AND SURVEY

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The National Committee on Forest Land established a subcommittee in 1966 on Wildland Classification to (1) review the existing land classification systems, and (2) to present recommendations to the parent body regarding a national approach to a physical land classification system suitable for the evaluation of the capability of the land for various renewable natural resources. The work of this subcommittee under the chairmanship of D. S. Lacate eventually resulted in the Biophysical Land Classification system. In the following the philosophy and practice of this system will be outlined. Being the product of a committee, much of the thinking behind the system has not been expressed on paper, although the lines of thought are clearly evident. In such cases the following account is colored by my own understanding of this land classification system.

It is important to differentiate between the Biophysical Land Classification system with its theoretical and philosophical background, and the Biophysical Land Survey which is the application of this classification system. While the basic concepts of the land classification system are uniform throughout the nation, the application of the system is flexible to allow adjustment to local circumstances.

The Biophysical Land Classification system has been influenced to a greater or lesser degree by various ideologies. The Australian system, the Ontario system of Hills can both claim parental rights, but the influence of many other workers is forcefully evident. The task of the subcommittee was to extract the best features of other systems, modify them as needed and fashion them into a coherent whole.

The philosophy of the classification system rests on the recognition of primary physical characteristics of the land as the most important feature of the environment. In the natural environment all factors are interrelated and tend to influence each other to various degrees. One may enumerate the main environmental factors as: landform (material as well as form), climate, organisms, soil, groundwater and time (Fig. 1). Among these main factors landform, climate and time influence others to a far greater degree than they influence each other or are influenced by other features. Thus landform, climate and time may be considered as the most important factors influencing and controlling the living environment.

Time is the duration of the period between the present and the formation of the land surfaces. Fortunately, in Canada this is relatively uniform for most lands: the disappearance of glacier ice 15-10,000 years ago signals the beginning of this time period. There are minor exceptions (alluvial plains, emerging shorelines, dunes, landslides, etc.); the major exceptions are organic terrains which are still being formed.

Climate must be evaluated in terms of its significance to the living and non-living environment. Data, if available, must be interpreted in terms of effect on the environment. In the absence of such data the effects of the climate may be examined and evaluated. Climatic zones or regions can be recognized on the basis of their effect on the living organisms and on the processes of the non-living environment.

This leaves the landform as the remaining main environmental factor. By landform is meant not only the surface shape, but also the materials which give substance to that shape. Each landform can be characterized by description of the composition of its parent material (with various strata if any), the texture and thickness of this material, its mode of deposition, and its topography. Specific landforms occurring within a climatic zone will have specific influence on the vegetation, fauna, soil and groundwater. This influence can be detected, described, and in some cases, measured.

The landforms can be further divided into segments which appear to exert similar influence on organisms, soil and groundwater occurring on these segments. Ecologic criteria are generally used to recognize these segments. Thus a certain portion of a landform may be recognized as an ecologically significant section of that landform. These subdivisions of the landforms are identified not merely because they are there, but because they offer significantly different environments.

During the work of the subcommittee it was repeatedly stressed that the proposed land classification system is in no way duplicating the soil survey, nor is it a rival system. It was felt that, because the landform (within defined climatic zones) is basic to the environment, a classification system based on landform can accommodate many different factors as soils, vegetation, groundwater. Because of this broad base, this classification system should be more useful to resource disciplines than a system based on a more restricted base. Soil and vegetation information can be used to form an integral part of the Biophysical classification, but not to form its basis.

The subcommittee then considered the application of this classification system to the inventory of land. It was felt that a hierarchical system is needed which would allow to choose the level of detail required by the purpose of the particular survey. It was recognized that broad surveys result in small scale maps, showing the land at a high level of abstraction. Such maps may be useful to provide generalized information suitable for regional planning. More detailed surveys would result in large scale maps that show the terrain in less abstracted form. It was realized from the outset that the information will serve as a background store of knowledge and will not replace the need for firsthand investigation by resource managers.

The following units of classification were established (Lacate, 1969), listed from the broadest to the more specific:

<u>Land Region</u> - defined as an area of land characterized by a distinctive regional climate as expressed by vegetation. Direct and indirect

indicators of climate are used to characterize the regions: climatic data, vegetation, permafrost, etc. can be utilized.

Land District - defined as area of land characterized by a distinctive pattern of relief, geology, geomorphology, and associated regional vegetation.

Land System - defined as an area of land throughout which there is a recurring pattern of landforms, soils and vegetation. The land systems are defined by the landform pattern and further characterized by soils and vegetation patterns.

Land Type - defined as an area of land on a particular parent material, having a fairly homogeneous combination of soils and a chronosequence of vegetation. Thus the Land Type is truly a basic ecological unit.

The subcommittee chose to test this classification system at a reconnaissance level. The aim was to differentiate and classify ecologically significant segments of the land surface, rapidly and at a small scale, mainly to serve as the ecological basis for land use planning.

The mapping unit selected for the pilot projects was the land system which would permit the delineation of areas at a relatively small scale (1:125,000). The main working group of investigators would in each case form a team consisting of a land ecologist, geomorphologist, pedologist and plant ecologist. Workers of other disciplines, as wildlife biologists, hydrologists, meteorologists, etc. were to be drawn into the team if available, either during the initial investigation or during a later, evaluation phase.

Four pilot projects were established: one each in British Columbia (380 sq. mi.), Newfoundland (about 500 sq. mi.), Quebec (800 sq. mi.) and Manitoba (5,500 sq. mi.). The resulting reports (Kowall, 1967; Bajzak, 1969; Jurdant et al, 1969; Zoltai et al, 1969) show considerable variation of approach within the framework of the Biophysical system. This variation is due to the character of the terrain, the availability of expert participation, and the background and experience of the individual workers. In spite of these variations all pilot projects showed a successful application of the proposed system. Several trends in the methodology became universally apparent:

1. There was a great need for cooperation by outside experts. Forest land ecologists worked hand in hand with pedologists, geomorphologists, foresters, wildlife biologists and recreationalists.

2. Because of the large areas involved, extensive use was made of aerial photographs. The mapping units (landforms and their patterns) are readily recognizable on aerial photographs, and ecologically significant combinations of landforms could be made by a trained land ecologist after suitable field checking. Significantly, in no case was photointerpretation entrusted to a person without professional training in the land sciences.

3. The proposed system proved itself workable under widely different physiographic and climatic conditions. The flexibility of local application permitted modifications that made the system more meaningful under the given circumstances, while retaining the basic mapping units. Complete uniformity across the nation may not yield satisfactory results in all cases.

A case history: the Manitoba pilot project

In Manitoba a complete NTS map sheet (63 K) was selected as the pilot project area. It is relatively inaccessible, having only about 120 miles of roads and trails of any kind. It straddles the contact between the Canadian Shield and the Manitoba Lowlands, providing good physiographic contrast. The initial resource team was composed of three persons, none of whom has been within 200 miles of the area prior to the field work for the pilot project. They consisted of a land ecologist-geomorphologist, a pedologist and a plant ecologist.

During the initial field investigation the land systems were established. This was done by gaining an understanding of the processes that influenced the shaping of the land: glaciation in three different stages, affecting different parts of the area and producing tills of widely differing quality. Inundation by Lake Agassiz depositing lacustrine material in certain positions on the landscape. By gaining an understanding of the glacial events, the broad distribution pattern of soil materials became evident. This distribution pattern was then refined and the anticipated soil material distribution could be defined. This was checked in inaccessible areas and a land system map was prepared showing the repeating pattern of ecologically significant land types.

It became evident that certain modifications of the proposed Biophysical guidelines were necessary. The guidelines recommended that genetic landforms should be recognized. On the Shield, however, about 95% of the area is irregular bedrock plain covered by discontinuous sandy till; hence a more meaningful expression of landform had to be found. Finally the landform was expressed as the soil material and ranges in relative elevation, slope percent and number of slopes per mile.

Other modifications were necessary because of the presence of a large number of lakes. It was realized that water bodies cannot be ignored when making a resource survey. An attempt was made to integrate the land and water portions of the landscape into broad units. This was done on the basis of the distribution pattern of land and water within a watershed or a portion of a watershed. These 'Landscape Units' were described in terms of broad physiographic features, lake distribution and morphological features.

During this phase of field investigation contact was maintained with the various members of the resource team to ensure that the Land Systems, with their Land Types, were ecologically significant separations. This cooperation made certain that all members had the same concept of the building blocks, the Land Types, and that their work was related to this framework.

During the field work it became evident that the mapsheet did not lie in the same eco-climatic Land Region. Similar materials and moisture conditions supported different vegetation sequence in the western part of the area than in the east. Later, when permafrost was found in some organic deposits, it was found that permafrost is far more widespread in the east than in the west. On the basis of these observations, supported by the scant meteorological data, the mapsheet was divided into different Land Regions.

The report was prepared on the basis of the field work and photo interpretation based on reference points established in the field. Each Land System was mapped and described in terms of the component Land Types of the particular Land System. The soil and vegetation associated with each Land Type was included in the description. On the final map the Land Systems were grouped into Landscape Units on the basis of the combined characteristics of the land and water within larger watershed areas.

In the report a large section is devoted to soils, prepared by the pedologist member of the team. The soil series were established on the basis of physical and chemical characteristics of the soil and related to Land Types. It was found that there was a high degree of correlation between soil profile development and topography, parent material and drainage. The pedologist prepared his report as he would have done it for a reconnaissance soil survey, except he did not remap the area. Instead, it was decided that the Biophysical map is adequate and more detailed mapping is necessary only in areas of deeper soils where more detail was needed.

The sequence of investigation may be summarized as follows:

1. Investigation of available information of the area. The only relevant reports concerned the bedrock geology.

2. One week field work by the land ecologist, working along existing roads.

3. Three days of flying with fixed wing aircraft, with spot checking on ground.

4. Two days in the field, correlating geomorphology with plant succession.

5. Produce maps by air photo interpretation.

6. One week in the field, correlating plant succession with soils and physiography.

7. Two days of spot checking by helicopter.

8. Produce final map.

9. Produce preliminary report.

10. Map checked by evaluators of natural resources.

Steps 1, 2, 3, 5, 8 were carried out by the land ecologist; steps 4, 6, 7, 9 jointly with the team. The work was initiated in September, 1967 and the initial map (step 5) was in the hands of the potential users by May, 1968. Steps 8 and 9 were completed by the winter of 1968-69. Step 10 was carried out at different times in 1968-69 as the evaluators in agriculture, forestry, upland game, waterfowl and recreation became available. The total working time for steps 1-9 was as follows:

Field work	- along road	27 man-days
	- aircraft	13 man-days
Office work*		100 man-days
		140 man-days

*Office work includes photo interpretation, reporting, drafting and soil testing.

Summary

The Biophysical Land Classification recognizes the importance of landform within a climatic framework as a major determining factor of the environment. A hierarchical system of land survey was built on this premise, permitting the examination of lands at any desired level. This land survey system was successfully applied to widely different physiographic and climatic areas. The application showed that important features of the system are adaptability to different conditions; cooperative participation of different disciplines, always including pedologists; speed with which reconnaissance surveys can be carried out.

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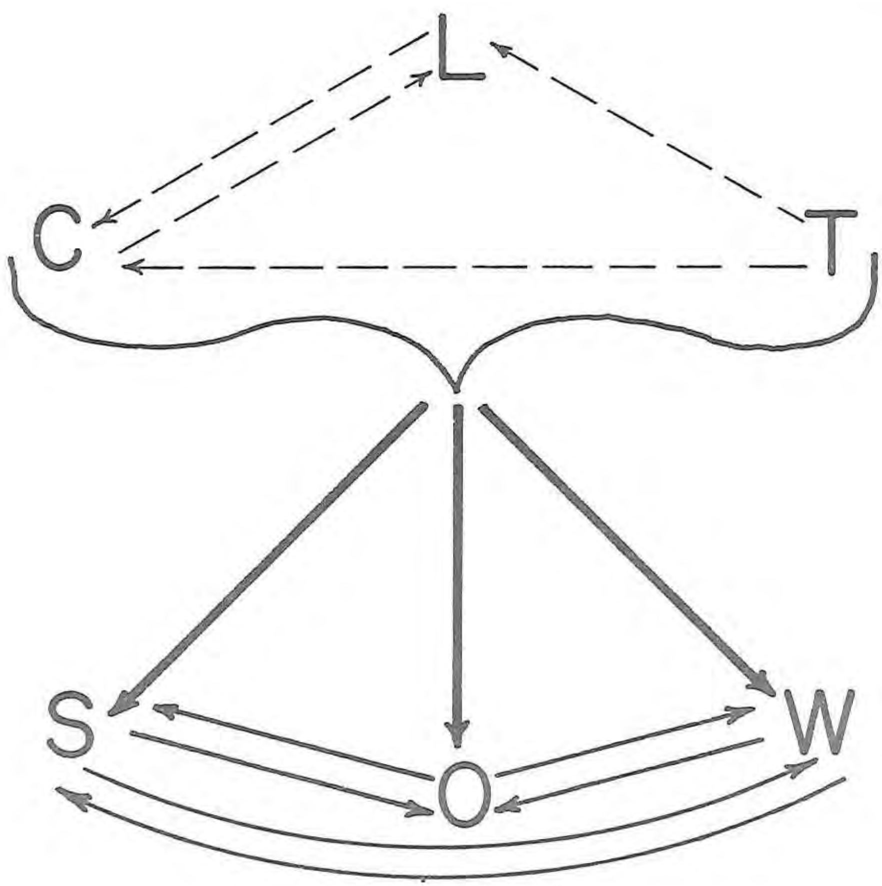

Figure 1. Diagram of complex interrelationships between major environmental factors of climate (C), landform (L), time (T), and soil (S), living organisms (O), groundwater (W).

LAND CAPABILITY ANALYSIS

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Introduction

In this era of talk about ecological land use planning, quality of the environment, pollution, and land use conflict, there is increasing concern about the land and its performance characteristics; however, there are few direct comparisons of the various potentials or best land uses as a guide for administrators, planners, etc. Land Capability Analysis is one of the tools which should start us in the right direction.

Land Capability Analysis (L.C.A.) if it means anything, probably means many different things to a wide variety of people. Often it is a generalization and is done at the risk of losing sight of the complexity of reality. No generalization on such a subject as land capability can fit all conditions. At the same time the excuse that not enough is known and that much more research is needed, amounts to a withdrawal from responsibility.

We have to face it. The race for space is on. Everyone wants the most desirable land. With the demand for land for all purposes steadily growing, we are faced with the necessity for broad, large-scale environmental planning and detailed planning at the local level.

I should like to emphasize at this point that planning for a meaningful life style, if you like, will call for an examination of the total landscape for its inherent natural values.

In many areas land uses have competed with one another, often to their mutual detriment, so that progressive communities or regions had to give more thought to integrated planning in such a way that the best use is made of the land available. Essential to this planning is an ability to assess the value of land for a particular use. Given the powers of hindsight, it is clear now that it would have been better if an evaluation of our land resources had been made some 100 years ago - and this had been incorporated into the development of the country.

Thus we come to such things as soil survey interpretations, biophysical land classification and land inventory to provide basic data for making decisions on land use. As was suggested earlier, a once over land classification to save time, money, etc., is the most desirable. With these data there are many alternatives for grouping data and expressing these groupings cartographically. The crucial problem in constructing an interpretation such as a Land Capability Analysis is deciding what information is irrelevant, or, conversely, what should be emphasized for the particular purposes in mind. This, of course, depends on the problems, objectives, etc. that are considered - the nature of the problems and the ideas that various specialists have for solving these problems.

Turning directly to L.C.A. systems, there are many different types in existence in North America at the present time. The majority are based on the use of computer grid systems and sieve mapping techniques. With the inclusion of various physical, social, economic and present land use characteristics - all of these have one thing in common - they are used as tools in land-use planning. Example - Holling (U.B.C.), U.S. (N.Y. & Penn.), Ontario Reg. Dev. Branch, McHarg (Design with Nature), and the British Columbia Land Capability Analysis (B.C.L.C.A.) with which I am most familiar. All have different purposes, requirements, scales, objectives, etc.

Almost all L.C.A. types (a vast and complicated field about which a great deal remains to be learned) are included. Thus:

(1) the resource base - the actual physical landscape, including as much information on the ecosystem and various land capabilities as is available.

(2) the infinite variations within that base.
- in each case it is recognized that each region is a combination of structural, physical and cultural characteristics.
- standards vary with region and purpose of analysis, i.e. East Kootenay of British Columbia crown lands vs McHarg's Greater Philadelphia study.

(3) all recognize an interrelationship between all forms of land use.

(4) all recognize man as a part of, rather than dominant to, the natural elements about him.

(5) all have weighting systems of some sort, but few agree.

The basic data are thus interpreted and reconstituted within a value system, which varies with purpose, scale, data limitations.

The British Columbia Land Capability Analysis System

In addition to the individual Canada Land Inventory (C.L.I.) sector studies in British Columbia, we are carrying out an analysis which for want of a better term is called a land capability analysis. This brings all sectors together within specific study areas. An overlay process (which will be described later) combined with a team approach to best use rather than multiple use, has revealed that conflicts can be resolved. We don't pretend to have answers to all the problems nor do we pretend that our cartographic representation is a land use plan - only the first step. We are educating ourselves as we go along.

In any event, we try at all times to let the land indicate what its inherent capability for development might be. For example, in some cases - particularly with recreation and wildlife - it may be best left alone. This is a matter not always satisfactory with the other sectors.

This system, utilizing C.L.I. base data, has been described as a technique whereby several disciplines effectively integrate their activities in map form, i.e. East Kootenay. We are enthused about the technique because it is believed that this results in a better analysis than when the basic capability data are turned over to a planning team. This team may not have enough professional disciplines and it may not be aware of the implications and limitations of the data. This approach seems to be satisfactory in British Columbia because of the particular set of objectives, problems, etc. The emphasis here is being placed on administration and allocation of crown lands.

This is a method whereby the nature of the land area may be learned by a number of disciplines. The land has been inventoried (C.L.I.) and from this information a simple sequential examination of the land resource by a group of professionals assigned the task of coming up with best typical land use is presented cartographically (the L.C.A. maps). I emphasize best typical land use, but often we are talking of associations of uses (i.e. Native Range or Highland categories). Might I suggest we are attempting to write a "land-use prescription" or at least are starting in that direction.

History

Capability analysis is undertaken in British Columbia at the request of the ARDA Ministerial Committee.

We have gone through several stages of development to bring us to the present techniques and ways of thinking - (following is summary of a presentation to the 3rd Annual Meeting of the Provincial Canada Land Inventory Coordinators, Regina).

Stage 1

In May, 1967, a small working committee which had been set up previously for technical coordination was asked to show proof of performance for two years' inventory work. The area chosen was the Prince George Special Sales Area. In order to ensure that the work was done quickly, with as little interference as possible with the current field program, each sector was given a 1:50,000 autopositive of the area and asked to plot its own high capability areas. Agriculture and waterfowl chose to show classes 1-4 as its high capability while the other sectors showed classes 1-3. There were a number of problems: (a) a large part of the area was not mapped, (b) this unmapped area varied from sector to sector, and (c) the degree of generalization varied between sectors.

The map produced had what is now recognized as an agricultural bias, in that the few assumptions that were made were pro-agriculture. Conflicts were resolved mainly in agriculture's favor as it "generally yields a higher return than the same class in any other sector". At the same time, problem and low capability areas were assigned to the convenient title of "multiple uses".

Stage 2

The Deputy Ministers Committee's response on viewing the Prince George map was a request for more detail. A new and more sophisticated analysis to evaluate the development potential of the Prince George area was started. The initial overlays were to provide a direct comparison between physical capability and present use, emphasizing such things as (a) farmland available for improvement, (b) areas suitable for mechanical reforestation. The initial overlays were then to be superimposed on others to highlight the area of unrealized potential. The initial overlay work was undertaken by a class of 40 geography students at the University of Victoria. The resulting maps and acreage tabulations were disappointingly poor and represented 40 different measurement standards. Supported by an unenthusiastic response from the Deputy Minister to the presentation of some of the better maps, the work was abandoned.

Stage 3

In February 1968 the Intersector Committee was reconvened to undertake a simple analysis of "single typical use" or prime use. This finally resulted in the published Land Capability Analysis for the Prince George Special Sales Area. Table 1 shows some bias towards agriculture and to some extent towards forestry. There were three groups for agriculture, two for forestry and one each for recreation, ungulates and waterfowl. In addition the resolution of some conflicts was influenced by present land use.

Table I. Data Grouping (Prince George Special Sales Area)

	Agriculture	Forestry	Recreation	Ungulates	Waterfowl
Prime Group	1-3	1-3	1-3	1-3	1-3
Moderage Group	4	4	-	-	-
Limited Group	5	-	-	-	-
Low Potential	6&7	5-7	4-7	4-7	4-7

Stage 4

When work commenced on the East Kootenay area, an attempt was made to correct the apparent deficiencies in the analysis of the Prince George area. The analysis was extended to include the moderate groups for ungulates and waterfowl, the moderate and limited groups for recreation, and the limited group for forestry. Two new categories of "Native Range" and "Highland" were introduced, permitting the elimination of the low potential category. Also, conflicts were resolved without recourse to present land use.

Table II. Data Grouping (East Kootenay)

	Agriculture	Forestry	Recreation	Ungulates	Waterfowl
Prime Group	1-3	1-3	1-3	1W & 2W	1-3 & 3M
Moderate Group	4	4	4	3 & 3W	4
Limited Group	5	5	5	-	-
Low Group*	6&7	6&7	6&7	4-7	5-7
Special Categories:					
Native Range	5&6	5&6	6&7	3&4	6&6
Highland	6&6	6&7	5&6	3-6	5-7

*not shown

The East Kootenay analysis set the pattern for the Bulkley analysis which is now complete and the Peace River analysis is under way. I think it can be assumed that the guidelines will be changed regularly as the group involved continues to educate itself as new problems appear.

The Mechanics

At the risk of boring you with the mechanics of the British Columbia Land Capability Analysis, I will attempt to outline what is being done now and what could or might be done in the future as experience is gained, using Canada Land Inventory biophysical land classification, soil survey and other land resource data.

Assumptions

1. Our terms of reference suggest that a "single typical use" be shown to restrict ourselves to the physical capability analysis and to resolve all conflicts through the committee. The economic and social inputs are left out as it is felt that it is dangerous to introduce an incomplete input.

2. All conflicts have to be resolved as only prime use is mapped. We do, however, have the facility to mention compatible uses in the narrative, and some exceptional cases integrated use categories.

3. It is assumed all classes are equal unless proven otherwise. In other words, classes 1, 2, or 3 in any one sector are considered as good as classes 1, 2, or 3 in the other four sectors. This rather simplified approach is open to much argument but it is difficult to make value judgments and attach weights to different sectors.

4. Good management to current standards is assumed for all sectors, with the individual sectors setting their own management guidelines subject to intersector review.

5. Most sectors, particulary agriculture, assume a minimum unit size

that is compatible with proper management of the land. Isolation of units is also given consideration.

6. The highest rating is used. For example - in agriculture the irrigated rating is used where it is better than the dry farm rating.

7. The first class in a complex is considered to be representative of that unit. It is only in situations in conflict that a total complex is referred to.

8. No consideration is given to land resource users other than those included in the C.L.I. program, except perhaps in the narrative.

The preparation of materials using colored overlays and an overhead projector rather than manual overlay involves a number of steps. Sector capability maps at 1:50,000 are photographically reduced to a common scale of 1:126,720. These are joined together into two-mile map sheets and ozalid prints are produced. A planimetric base map of the area is printed on clear film at the same scale. This base is normally a photographic enlargement of the 1:250,000 publication base. The second step requires coloring the 1:126,000 prints for each sector according to a color scheme devised for the analysis. Only those classes to be considered in the exercise need be colored for each sector. From these colored sector prints, the required information is placed on clear acetate overlays that cover the area under consideration. With the fourth step, the drafted overlays and planimetric base are photographically reduced to a scale of approximately 1:1,000,000 suitable for projection on an overhead projector. Next, clear contact positives are made from the reduced sector negatives. Once these are obtained the lines delineating moderate and low class areas are opaqued on the negative. This leaves only prime areas. Clear contact positives are then made from these. In step six transparent color overlays are produced at the same scale using GAF projecto-viewfoil film. This is an ozalid process. Two copies are made of each sector for both sets of overlays. The color transparencies are then fastened so that they may be overlaid in any combination when mounted on the projector.

The overlay process involves four steps. A white paper base is mounted on the wall. Using white paper as a projection screen, one of the overlays is projected and coordinate reference points are marked on the paper screen. The prime capability group of transparencies are then projected and using the analysis color system the areas of single no-conflict capabilities are colored.

In step three all conflicts that occur within primary areas are resolved. The overlay of all groups is projected and the same procedure as in steps two and three is repeated.

In preparing a preliminary map the five sector overlays at 1:126,720 are overlaid and a single matte autopositive is made. This shows all sector boundaries that are considered in producing the capability analysis. From here it is relatively simple to color the autopositive according to the boundaries established on the preliminary map obtained in the above four steps.

Sector considerations involving conflicts and resolving of these conflicts becomes quite involved. Examples follow:

Agriculture

- Irrigated capability ratings are applied where irrigation is the accepted practice.

- The size of the agricultural unit is considered in that no small isolated blocks are allocated to agriculture.

- Compatibility between agriculture and other sectors is not good when considering agriculture classes 1 to 5 because it is difficult to have complementary uses in cultivated areas.

- Waterfowl and agriculture often are complementary where drainage of potholes, etc. has not destroyed prime waterfowl habitat.

- Recreation conflicts are usually site specific and involve small acreages of land. Agriculture is complementary where the management of agricultural lands provides a pleasing pastoral setting.

- Conflict areas resolved in favor of agriculture are most often made on the basis of adjacency and contiguity with other units allocated to agriculture.

Forestry

- Considerations vary with region but in general most extensive recreation and ungulate uses are compatible with forestry as long as they are given management consideration.

- To date little conflict has arisen between agriculture and forestry but problems may occur.

- Recreation is the main contender for good forest lands (stream corridors most often).

- In conflict situations decisions for or against forestry are most often influenced by lower or higher complex components.

Recreation

- Often conflicts are resolved by the "significance of features" rather than by the class capability.

- Often are awarded conflict lands because of site specific nature of recreation unit.

Ungulates

- Are highly compatible in general with the others except at the 1W and 2W levels.
- Are basically incompatible with intensive agriculture and this is one of the most difficult problems to resolve.

Waterfowl

- See agriculture note; otherwise little conflict to date.

Summary

(1) The most important advantage of the B.C.L.C.A. system is the personal interdisciplinary contact where dialogue is set up among the various disciplines and a common base is set for constructive discussion and land use decision making far beyond the L.C.A. itself. In other words a base for interdisciplinary communication.

(2) The land capability analysis is not a land use plan, but an indicator of capability patterns based on a comparison of C.L.I. physical data. The analysis of physical capability is only the first step towards land use planning.

(3) Our main objective is to provide physical land resource information to land administrators in the various line departments of government who are asked to make land use decisions of one form or another.

(4) No consideration was given to provincial and regional demand patterns for particular uses, nor to socio-economic needs.

(5) L.C.A. cannot substitute for on-site and regional planning which would consider site and land use factors.

(6) The ideal is seldom a choice of either one land use or another, rather it is a choice of a combination of two or more uses.

(7) The tendency is to oversimplify - land is very complex - we are unaccustomed to noting all of the variabilities in the environment and responding to these.

(8) Results are qualified if the factors (inputs) are of disproportionate weights. Many value judgments are involved here.

(9) There are limits in the photographic resolution of different input maps.

(10) It must be recognized that certain areas are highly suitable for several land uses and can be seen either as a conflict or as an opportunity to combine uses that are socially and economically desirable.

(11) To date the L.C.A. has been used to delineate the administrative boundaries of government land agencies and to determine policy for agriculture, forestry and recreation. The analysis has also resulted directly or indirectly in a Cabinet and Deputy Minister's Committee on Land Use in British Columbia.

The Provincial Deputy Minister's Land Use Subcommittee made up of senior administrators in the natural resource departments in conjunction with C.L.I. staff are using the analysis as a base in conjunction with other pertinent land use information (see example) such as highways, mining claims, water resource information, present tenure, etc., as a base for land use policy and decision making. Atlas type overlays of analysis and other pertinent information are being prepared for line department fieldmen who are confronted with land use problems within their regions each day.

The question arises, what are some of the other things that could be done with the available land resource data on land capability analysis to assist ecological land use planning?

Perhaps an attempt should be made to optimize multiple compatible land uses rather than a single use. Each land use might be tested against all others to determine compatibility, incompatibility, and to what degree. Then an examination could be made of the single optimum or best typical land use and determine the degree of compatibility with other land uses. This may be somewhat unrealistic, nevertheless it may be possible or necessary.

Let's turn to the land resource information that has been or will be collected, Canada Land Inventory and others, and indicate some of the land data that are available; that is, on the landform base there is a prediction of geomorphology and soil parent material, topography, slope (moisture shedding and receiving), drainage, depth to bedrock, soil texture and other morphology, permeability, etc.; on climate are such factors as precipitation, frost-free period, growing season, soil temperature heat units (degree days), etc., expressed cartographically; on vegetation are macro cover and in most cases micro vegetation in terms of site types or range of site types, successional trends or predictions. The result of the above data provides a picture of the total physical environment.

Then how can these data be regrouped to provide new measures or tools for the land use planning team? Perhaps the L.C.A. techniques with computer help might be useful for further comparisons.

Some of the following suggested groupings are dependent on the scale of mapping but all are possible predictions that likely will result in land use conflicts. These conflicts could perhaps result in better long range planning.

(1) Agriculture:

(a) Productivity ratings for the range of crops (possible climatically) on each soil.

(b) Irrigation and drainage groupings.

(c) Conservation of agricultural land through rural zoning of those soils of high capability and high productivity occurring near markets.

(d) Range management (productivity-palatability groupings), stocking rates, range rehabilitation.

(e) Economic land capability (production unit classification); economic inputs are necessary for this grouping.

(f) Tax assessment.

(g) Management groupings a la Soil Conservation Service - fertilization, recreation, etc.

(2) Forestry:

(a) Forest management and silviculture

- seedling mortality and scarification possibilities
- plant competition
- equipment limitations
- erosion and slump hazard
- trafficability ratings, forest soil fertility groupings
- windthrow hazard, yield classes
- species suitability - rehabilitation of decadent forests.

(3) Urban Location and Zoning:

- flooding hazard, susceptibility to erosion, depth to bedrock, sector capabilities, pipeline corrosion, sewage effluent disposal, drainage, topsoil possibilities, sedimentation during construction, runoff, landscaping, subdivision planning, housing density, green belts, parks, transportation route location, aggregate sources.
- predicting or determining the direction and extent of urban expansion is a perplexing problem for the land use planner in British Columbia with formation of the new regional districts as local planning units in British Columbia - information may be used in defense of zoning.

(4) Other Engineering and Hydrology:

- prediction of water recharge and discharge areas (ground water conditions)

- runoff and sedimentation and turbidity, infiltration rates

- foundation problems.

Note I have indicated prediction because this is not intended to replace on-site drilling and inspection to solve particular problems.

(5) Wildlife:

The key here in the case of most wildlife is the vegetation, its successional trends and the manipulation of the vegetation to provide the desired habitat.

- an interpretation of the soils, climate, water bodies and vegetation necessary for wildlife habitat elements should be possible.

- the wildlife manager could thus be directed to the best areas for cover manipulation in relation to other land uses.

- location of wildlife sanctuaries, refuges, nature study areas.

- sedimentation, siltation of streams, erosion and silting of spawning beds, turbidity.

- coarse fish. - waterfowl and drainage of potholes, etc. - prediction of nutritional deficiency in habitat.	) essential to have some form of comparison with other resource users because of non-market values

(6) Recreation:

- many of the considerations mentioned for other uses.

- prediction of features and quality of recreation.

- i.e., duned area near lakeshore or sandy outwash likely to have high quality beaches.

- sedimentation.

- landscape description for classification of scenic resources (land form, climate, vegetation combinations) - probability of these staying, i.e., moderate and low capability agriculture areas associated with moderate forest capability lands are likely to remain with a dispersed pattern of cultivated and forested lands.

- parks, green belts, high intensity recreation areas:- golf courses, playing fields.

- camping, tenting, cottaging, winter sports areas.

- alpine recreation use and prediction of soil and vegetation damage (use control).

The intersector capability analysis is one exercise in using land inventory data as a first step in land use planning. I have indicated other inputs that could be useful in land use planning if attacked by a multi-disciplinary group using the base data on the ecosystem - keeping in mind that the physical data interpretation is only one tool in the planning process. The limitation is time - these interpretations were needed yesterday.

I think we can do a lot more in terms of practical use of our land inventory data than has been done in terms of ecological considerations, on a man-land language, and eventually in land-use planning.

ORGANIC SOIL CAPABILITY SYSTEM FOR AGRICULTURE

D. W. Hoffman

Canada with an estimated 500,000 square miles of organic terrain has probably been the least active of any country in the world with respect to development of organic soils. Ontario has done little better than the rest of Canada. With almost 1.5 million acres (23,125 square miles) in Southern Ontario alone only a small proportion is developed and in Northern Ontario where there are millions more acres there is no development of any significance.

The reasons for this situation are manifold. Little is known of the hydrology, morphology and soil characteristics of a bog and perhaps even less is known of the production potential of organic soils for vegetables, wildlife, recreation, forestry and energy. When dealing with mineral soils in Canada land use decisions can be assisted by using soil survey reports and the interpretive information supplied by the Canada Land Inventory. Soil survey reports describe fertility, structure, morphology and the physical properties of soils. This information can be used to assess the potential of soils for agriculture, forestry, recreation, wildlife and urban uses in terms of soil capability. Employed in making land use decisions it becomes an effective planning instrument. Soil capability also provides a means for evaluating a piece of land for a specific use. No such system has been applied to the organic soils of Canada.

Until recently Canadian soil survey reports classified organic soils into two main classes, peat or muck. Peats are fibric, poorly decomposed and acidic while mucks are well decomposed, humic and slightly acid to alkaline. Such a classification provides too little information to be useful in land use planning. However, in 1968, a taxonomic system of organic soil classification developed by the Canada Soil Survey Committee was adopted for use. This provided the means of recording the characteristics of organic soils in much the same way as those for mineral soils are recorded and made the development of an organic soil capability classification for agriculture possible.

Capability Classification of Organic Soils for Agriculture

The organic soil capability classification for agriculture is an interpretation of the agricultural potential of organic soils from information gained by studying the morphology and physical and chemical characteristics of organic soils. The capability classification consists of 7 classes which indicate the potential of the soil for vegetable production. In addition to rating soils on their potential for vegetable production an additional rating system has been introduced to indicate the relative amount of reclamation which is necessary before the full potential of an area for agriculture can be realized. It is called a "development difficulty rating".

Development Difficulty Classification

Undeveloped organic soils are given a development difficulty rating from one to seven. Such a rating is necessary because reclamation may be more difficult on one site than on another even though their agricultural capability is the same.

Minimum difficulty is encountered in overcoming hazards present in soils rated 1, 2, or 3. Only minor reclamation is required. Minor reclamation includes those operations which can be carried out by a single operator and which do not require cooperation among several adjoining operators. Such operations would include land clearing, levelling rough surfaces, removal of surface woody layers and the installation of certain features of water control.

Soils rated as four require major reclamation but when the agricultural capability is high (class 1, 2, or 3) reclamation is usually warranted. Major reclamation is considered to be those operations that require cooperation between adjoining operators and that may require outside financial assistance. Such operations could be construction of dams or levees and other major water control features and correction of very low or very high soil reaction (pH).

Hazards present in class 5 soils require major reclamation schemes that are only warranted where agricultural capability is class 1, 2 or 3 and where high value crops can be produced. Class 6 soils can be developed only with very large reclamation projects but reclamation is seldom warranted because the hazards are so serious they constitute a continuing limitation and a reduction in capability. The most serious hazards occur in class 7 soils. These are overcome only by intensive development on a major scale and in such cases development is likely uneconomical.

Capability Classification

Like other A.R.D.A. capability classification this permits the rating of soils in classes from one to seven according to the degree of continuing limitations that particular hazards may have on crop production. The capability class is a group of soils with the same potential for the production of agricultural crops. The degree of limitation becomes progressively greater from class 1 to 7 and the potential for crop production becomes correspondingly less from class 1 to class 7.

Classes 1, 2 and 3 are capable of sustained production of vegetable crops, class 4 soils are marginal for sustained production of vegetable crops and class 5 soils are not suited to vegetable production. However, class 5 soils may be used for forage and pasture production. Class 6 soils are not suited to the establishment of crops other than indigenous species and class 7 soils are non-agricultural. Organic soils that have been reclaimed are classified according to their continuing limitations only.

The capability classes and the development difficulty classes are subdivided into subclasses. A subclass is a group of soils with the same limitation or hazard. The ten subclasses and the letter used to designate them are as follows:

1. Inundation and Excess Water

   Inundation - I
   Excess Water - W

   Drainage is needed to control wetness and dikes, levees or other installations may be required to prevent flooding.

2. Degree of Decomposition - Permeability - P

   The degree of decomposition is important because it has a continuing effect on drainage, capillary rise of water and rate of subsidence.

3. Depth of Profile and Underlying Mineral Materials - D

   Some minimum depth of organic soil must be available before vegetable production is justified. Ease of drainage is related to the kind of underlying mineral soil if it is within 6 feet of the surface.

4. Fertility - F

   The most important aspect of soil fertility to capability is soil reaction since this varies markedly from site to site and other elements such as phosphorus and potassium remain the same; commonly low.

5. Climate - C

   Temperature has an effect on crop production.

6. Wood in Profile - L

   Woody layers within 20 inches of the surface will interfere with cultivation.

7. Surface Roughness - T

   Uneven surface due to fire, erosion, wildlife, etc. may interfere with land clearing.

8. Permafrost - G

   Permafrost presents an obvious limitation to crop production.

9. Salinity - N

   Salt concentrations can affect both productivity and the kinds of crops grown.

The classification system is not an indicator of the most profitable use of organic soils. It is, however, an indicator of the potential of organic soil resources for crop production. In order to arrive at a means of estimating the potential of organic soils for agriculture certain assumptions were made. These are as follows:

1. The organic soils capability classification is interpretive and is designed to evaluate the limitation of individual organic soils to development for and production of vegetable crops.

2. Good soil management practices are assumed.

3. Location, transportation, market condition and the skill and resources of individual operators do not constitute criteria for capability groupings.

4. Capability groupings and definitions are subject to change as new information and methods concerning the manipulation of organic soils become available.

Uses of Organic Soils for Other Purposes

Forestry, recreation and wildlife habitat are other uses of organic soil areas and they may be left in the natural state to act as water reservoirs.

In most cases the capability of organic soils for commercial forest production is low. Limitations such as very poor drainage, low fertility and flooding limit the growth of many tree species. Organic soil areas also have a low capability for recreation. Indeed, since bogs are soft and easily compressed the roots of trees and shrubs can readily be exposed by foot pressure resulting in possible death of the plants. Perhaps human traffic should be kept to a minimum.

Organic soils provide a valuable habitat for certain types of wildlife. White-tailed deer, muskrat, beaver and grouse inhabit many of the bog areas as do many other species. A capability classification of organic soils for wildlife purposes should be developed.

Future Developments

The capability classification of organic soils for vegetable crops would be more useful if the definitions of the classes carried some indication of yield. In addition research is needed to determine the costs of production on organic soils of various capabilities. Such inputs would permit more precise definition of each class and would give some estimate of the value of the land to horticulture.

Research is also needed to determine the costs of reclamation for different bogs and work is needed to assess the value of organic soil areas for flood control and water storage.

A GUIDE FOR CAPABILITY CLASSIFICATION OF ORGANIC SOILS

Prepared by Department of Soil Science
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A. Physical Features used to determine Organic Soil Class (check one description under each heading)

DECOMPOSITION

50 Fibric

0 Mesic

35 Humic

REACTION

50 pH < 3.5 in H_2O

35 pH 3.5 to 4.0

20 pH 4.1 to 4.5

10 pH 4.6 to 5.5

0 pH 5.6 to 6.5

10 pH 6.6 to 7.0

35 pH 7.1 to 7.5

50 pH 7.6 to 8.0

65 pH > 8.0

SURFACE ROUGHNESS

0 Level

20 Holes and Mounds > 1 ft.

35 Holes and Mounds 1 to 2 ft.

50 Holes and Mounds < 2 ft. deep

EXCESS WATER and FLOODING

0 None

20 Occasional Flooding

35 Frequent

50 Fairly Frequent

65 Very Frequent

80 Extreme

CLIMATE

0 Climatic category i

20 Climatic category ii

35 Climatic category iii

WOODY LAYERS

0 None

20 Softwood Layer < 3" thick

35 Softwood > 3" thick

50 Hardwood > 2" thick

DEPTH

0 Deep (over 6 ft.)

20 Mod. Deep (6-5 ft.)

35 Shallow (5-4 ft.)

50 Very Shallow (4-3 ft.)

B. ORGANIC SOIL CLASSES

The seven characteristics under A above have numbers to the left of each description. As a guide to the proper land class, add up the numbers which are opposite the descriptions selected and subtract this figure from 100 (circle the land class below that approximates the value which you have now obtained).

1	2	3	4	5	6	7
100 - 85	80 - 70	65 - 55	50 - 40	35 - 25	20 - 10	less than 10

ORGANIC SOIL CLASSES

CLASS 1 (100-85) - Organic soils of this class have no water, topographical or pH limitations and are deep and level. They are located in climate category 1 and are at an intermediate stage of decomposition.

CLASS 2 (80-70) - Organic soils in class 2 have one limitation which restricts their use in a minor way. The limitation may be woodyness, reaction, flooding, topography, depth or climate.

CLASS 3 (65-55) - Organic soils in this class have moderately severe limitations that restrict the range of crops or that require special management practices.

CLASS 4 (50-40) - Soils in this class have limitations which severely restrict the range of crops or which require special development and management practices. Reclamation and management costs will be high.

CLASS 5 (30-20) - Soils of this class have such severe limitations that they are restricted to the production of perennial forage or other specially adapted crops. Large scale reclamation is not feasible.

CLASS 6 (20-10) - Class 6 organic soils are capable of producing only indigenous crops and improvement practices are not feasible.

CLASS 7 (less than 10) - Organic soils of this class have no capability for agriculture.

C. HOW TO RATE ORGANIC SOILS

The rating of organic soils is a relatively simple procedure when the guide is closely followed. First, classify the stage of decomposition, water conditions, reaction, climate, woodyness, surface roughness and depth in the appropriate classes as defined below. Next classify the capability as outlined on this and preceding page.

DECOMPOSITION - refers to the stage of decomposition of the organic materials.

Fibric - the least decomposed of all organic soil materials. There are large amounts of well-preserved fiber that are readily identifiable as to botanical origin. An unrubbed fiber content of more than 2/3 of the organic volume.

Mesic - the intermediate stage of decomposition. Has an unrubbed fiber content between 1/3 and 2/3 of the organic volume.

Humic - the most highly decomposed. Has an unrubbed fiber content less than 1/3 of the organic volume.

EXCESS WATER and FLOODING - refers to excess water either underground or overflow.

Occasional flooding - excess water causes slight crop damage.

Frequent flooding - excess water causes minor crop damage but no crop loss.

Fairly frequent flooding - excess water causes moderate crop damage and possibility of one crop loss.

Very frequent flooding - excess water causes crop loss.

Extreme flooding - excess water causes crop loss 2 or more times.

CLIMATE - refers to climatic zones defined in

Climatic category i - includes the following climatic types 1G, 2G, 2H, 2F, 3F, 3G, 3H.

Climatic category ii - includes the following climatic types 3G, 4H, 4K, 4L, 5L.

Climatic category iii - includes the following climatic types 5H, 5K, 6K, 6L.

WOODY LAYERS - wood located within 20 inches of the surface will probably interfere with cultivation practices. The limitations posed by woody layers are noted on page 162.

SURFACE ROUGHNESS - refers to mounds, hummocks, plateaus, ridges and holes causing uneven surfaces on some bog soils.

DEPTH - refers to the depth of organic material over sand, silt, loam, clay, marl or bedrock. Limitations occur when any of these materials occur within 6 feet of the surface.

REACTION - refers to the acidity or alkalinity of the soil.

D. DEVELOPMENT DIFFICULTY CLASSIFICATION

It is possible that two separate soils may have similar agriculture but one may be more difficult to reclaim than the other A development difficulty rating from 1 to 7 is proposed for all organic soils in an unreclaimed state. Brief definitions of the development difficulty classes follow.

Classes 1, 2 and 3 - only minor reclamation is required. Minor reclamation is considered to be those operations which can be carried out by a single operator.

Class 4 - major reclamation is required but is warranted when soil capability is high. Major reclamation is that requiring cooperation between adjoining operators and/or outside financial assistance.

Classes 5 and 6 - major reclamation is required and seldom warranted.

Class 7 - hazards to development are so serious that they can be overcome only by major scale projects. Such development is unwarranted.

INTRODUCTION TO REMOTE SENSING

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Remote Sensing is the measurement of environmental conditions at or near the surface of the earth that is performed primarily with sensors on airborne and space vehicles. Such measurements are usually the measurement of Electro-Magnetic radiation either emitted naturally from the surface of the earth (a so-called passive system), or reflected by the surface of the earth from a source--such as the sun, or a source adjacent to the sensor--(a so-called active system).

Intervening atmosphere and weather conditions allow measurements to be made in some parts of the electro-magnetic spectrum, but not in others.

Sensors may produce an image (e.g. cameras, scanners, radars), or a "point" measurement (e.g. radiometers, spectrometers). Active systems which employ the sun as the illuminating source can only operate in daytime; other systems can operate in any part of the diurnal cycle which is appropriate to the mission. (Indeed operations at several times in the diurnal cycle may be of interest.)

One of the most interesting sensing systems is that of multispectral scanning, whereby a raster picture is produced line by line at several parts of the electro-magnetic spectrum simultaneously. Computer processing and interpretation has achieved some results in "target recognition", principally of crops, using the principle that each different crop should (and indeed does) have a different reflectance spectrum. However, variations in the spectrum of a particular crop can occur from place to place, and from season to season. This makes the computer identification of the crops difficult even in the presence of considerable "ground truth" verification.

ORGANIZING A CANADIAN PROGRAM IN REMOTE SENSING

A. F. Gregory
Program Planning Office, Dept. of Energy, Mines and Resources, Ottawa

Canadians have made major contributions to the successful collection of resource information by means of aerial surveys in many countries. The opportunity for similar leadership with remote sensors in aircraft and spacecraft is closer than many people realize. Accordingly, the Canadian Government, in cooperation with industry, universities, and provincial governments, is planning for a national program in remote sensing. The objective of such planning is to identify the common interests of many user agencies across Canada and to consider the means of focussing the research effort, centralizing major flight, sensor and processing facilities and minimizing the overall cost of essential but expensive experiments.

Such a broad study was initiated by the Cabinet Committee on Science Policy and Technology when it instructed the Department of Energy, Mines and Resources to convene an Interdepartmental Committee on Resource Satellites and Remote Airborne Sensing. This committee, chaired by Dr. J. M. Harrison, has the primary goals of:

(1) coordinating and funding federal government plans for advancing remote-sensing technology in Canada;

(2) recognizing applications of remote sensing in the assessment of Canada's natural resources, in the monitoring of ecological conditions and pollution, in the inventorying of farm and forest productivity and in the planning and monitoring of land use;

(3) extending remote sensing technology to assist developing nations;

(4) planning and recommending a pertinent organization to carry out a national program as warranted by the study.

Supporting the interagency committee is a Program Planning Office (PPO) directed by Dr. L. W. Morley. This interim organization will phase out of existence upon submission of its final report for inclusion in the 1972-73 estimates. This report is to contain recommendations for the organization and support of a national program. The PPO will also manage certain urgent projects until such time as permanent management is established.

In order to assure a broad technical input, the PPO set up working groups with representation from appropriate disciplines in governments, universities and industries (see organizational chart, Appendix A). Such working groups will function for about one year, presenting their final reports on March 1, 1971.

CF-100 HIGH ALTITUDE REMOTE SENSING PROJECT

E. A. Godby
Program Planning Office, Dept. of Energy, Mines and Resources, Ottawa

1.0 Introduction

This project was initiated by the Program Planning Office, Resource Satellites and Remote Airborne Sensing for the purposes of:

(a) Investigating the potential of high altitude, small scale imagery for mapping and natural resources application.

(b) Obtaining simulated spacecraft imagery.

The vehicle being used is a CF-100 aircraft belonging to the Aerospace Engineering Test Establishment (AETE) at Canadian Forces Base, Uplands. This aircraft had been outfitted as a versatile camera platform by AETE to meet the experimental and test requirements of the Department of National Defence. It is being used in this project under a two year cooperative agreement between DND and DEMR. AETE are responsible for the entire flight operations under the direction of their own photographic section.

At present, six federal government branches or departments are involved in the project. The first flight was conducted on May 19, 1970, over Lake Ontario on behalf of the Inland Waters Branch of DEMR.

Although the present agreement covers a two year period, it is anticipated that there will be a continuing requirement in Canada for experimental high altitude remote sensing. Part of this requirement will be in support of satellite programs (e.g. ERTS) and part in developing and testing new sensors and data analysis and interpretation technique.

Present plans are to review the program after it has been in operation for approximately one year and in light of the experience which has been accumulated, consider the possible extension of the program beyond the termination of the existing agreement in April 1972.

2.0 CF-100 Aircraft (#18767)

2.1 Performance

Operational Ceiling: 40,000 feet (stable platform)
Flight Duration at Altitude: 2.5 hours
Range: 1,000 miles at altitude
True Airspeed: 240 knots to 400 knots

2.2 Sensor Locations

Sensors can be located in three positions on the aircraft:

(a) Rocket Bay. The space available for sensors measures approximately 4' long x 3' wide x 35" high.

The bay is readily detachable from the aircraft. Since six of these bays are available, different sensor packages can be fitted on the aircraft with a minimum of aircraft down time.

Packages available:

(1) 4 Vintens
(2) RC10, 1 Vinten
(3) Reconofax IV, Radiometer

(b) Nose Section. Two separate nose sections are available allowing two separate instrumentation packages to be available for fast interchange.

Normally, this section carries an oscillograph recorder and two 70mm Vinten cameras.

(c) Radome Section. This is the forward part of the aircraft which originally housed the radar antenna. A 70mm Vinten camera will operate in this position.

2.3 Support Systems

Radio Compass
R Theta Computer
Tacan
Closed Circuit Television
Radar Altimeter (after fall 1970)
Oscillograph

3.0 Sensors

The following sensors are now scheduled to be fitted in the CF-100 aircraft.

3.1 Vinten F95 Camera

3.1.1 Description: Seven cameras, multispectral possibilities, 70mm, Type 2 Military Sprocket Format, 1 3/4-inch, 3-inch, and 6-inch focal length lenses. One special Leitz Elcan 3-inch lens with camera and magazine assembly calibrated for infrared.

3.1.2 Physical Parameter Measured:

Reflected energy of earth features.

3.1.3 Internal Design Features:

Shutter Speeds:	1/2000 and 1/3000 second	
Cycle Rate:	0.5 second to 120 seconds	
f-stops:	1 3/4" lens	22, 16, 11, 8, 5.6, 4, 2.8
	3" lens	22, 16, 11, 8, 5.6, 4, 2.8, 2
	6" lens	22, 16, 11, 8, 5.6, 4, 2.8

3.1.4 Special Characteristics:

Film: All acetate and estar base films 4.0 to 6.0 mils

Filters: Glass - W12 (4)
25A (2)
29F (1)
39 (1)

Gelatin - HF3
HF4
HF5
8
11
12
23A
25A
32
34
36
38A
47
58
64
80B
85
89B

3.1.5 Data Characteristics:

Film: 100-foot rolls - 460 exposures

3.1.6 Spatial Characteristics:

20 lines/mm - low contrast target

3.2 Wild Heerbrugg RC10 Camera

3.2.1 Description: Aerial Survey Camera, 9-inch x 9-inch format, 3 1/2-inch focal length (88mm)

3.2.2 Physical Parameter Measured:

Reflected Energy of Earth Features

3.2.3 Internal Design Features:

Shutter Speeds: 1/100 to 1/700 second
Cycle Rate: 0.7 second
f-stops: 5.6, 6.8, 8, 11, 16, 22
22, 16, 11, 8, 6.8, 5.6

3.2.4 Spectral Characteristics:

Filters: Glass - 2 minus blue anti-vignetting filters with cut-off at:
1. 500 nanometers
2. 700 nanometers
- 1 clear glass anti-vignetting filter
- 1 sandwich filter

Gelatin - HF3
HF4
HF5
36
47
58
89B

3.2.5 Data Characteristics:

Film: 400-foot magazine - 450 exposures

3.3 <u>HRB Singer Reconofax IV</u>

3.3.1 Description: A single channel line-scan imaging system that quantifies infrared radiant energy emitted from the viewed scene.

3.3.2 Physical Parameter Measured:

Infrared radiant energy.

3.3.3 Internal Design Features:

Cooled, mercury doped germanium detector 8-14 micron, 16 milliradian resolution (16 ft. resolution for an aircraft altitude of 1,000 ft.)

Cooled, indium antimonide detector 3-5 micron 3 milliradian resolution, (3 ft. resolution for an aircraft altitude of 1,000 ft.)

3.3.4 Spectral Characteristics:

Records in either the 8-14 micron or the 3-5 micron spectral band depending on the detector used.

3.3.5 Data Characteristics:

Image produced on 70 mm film.

3.3.6 Spatial Characteristics:

Viewing Angle = 120°
Mirror Speed = 120 rps.

3.4 Hulcher 109

This camera is not yet available.

4.0 Participating Agencies

The agencies participating in the program are listed below along with the names, addresses and phone numbers of the individuals concerned.

4.1 Canadian Department of Agriculture

Mr. L. E. Philpotts 4-9507
Farm Management Division
Economics Branch
Sir John Carling Bldg.
930 Carling Avenue
Ottawa

4.2 The Department of National Defence

Maj. E. J. McLaren 5-3013 - DND Project Officer
OC Photographic Development
Aerospace Engineering Test Establishment
Hangar 10
CFB Uplands, Ottawa

4.3 Forest Management Institute, Department of Fisheries and Forestry
Majestic Bldg., 396 Cooper Street, Ottawa

Mr. A. Bickerstaff, Director 6-1674

Dr. L. Sayn-Wittgenstein, Associate Director 6-1675

Dr. P. A. Murtha, Project Officer 5-6413

4.4 Geological Survey of Canada, DEMR

Mr. V. R. Slaney 4-5697
Exploration Geophysics Division
601 Booth Street
Ottawa 1, Ontario

4.5 Inland Waters Branch, DEMR

Dr. J. Kruus 4-9802
Groundwater Subdivision
Hydrologic Sciences Division
No. 8 Temporary Building
Carling Avenue, Ottawa

Dr. R. K. Lane 164-9632-1940
Head, Physical Limnology Section
867 Lakeshore Road
P. O. Box 5050
Burlington, Ontario

4.6 Surveys and Mapping Branch, DEMR

Mr. J. F. Fleming 4-9029 (PPO Project Officer)

Mr. J.R.R. Gauthier 4-5216

615 Booth Street, Ottawa

5.0 <u>Organization</u>

The organization of the project is shown in Fig. 1.

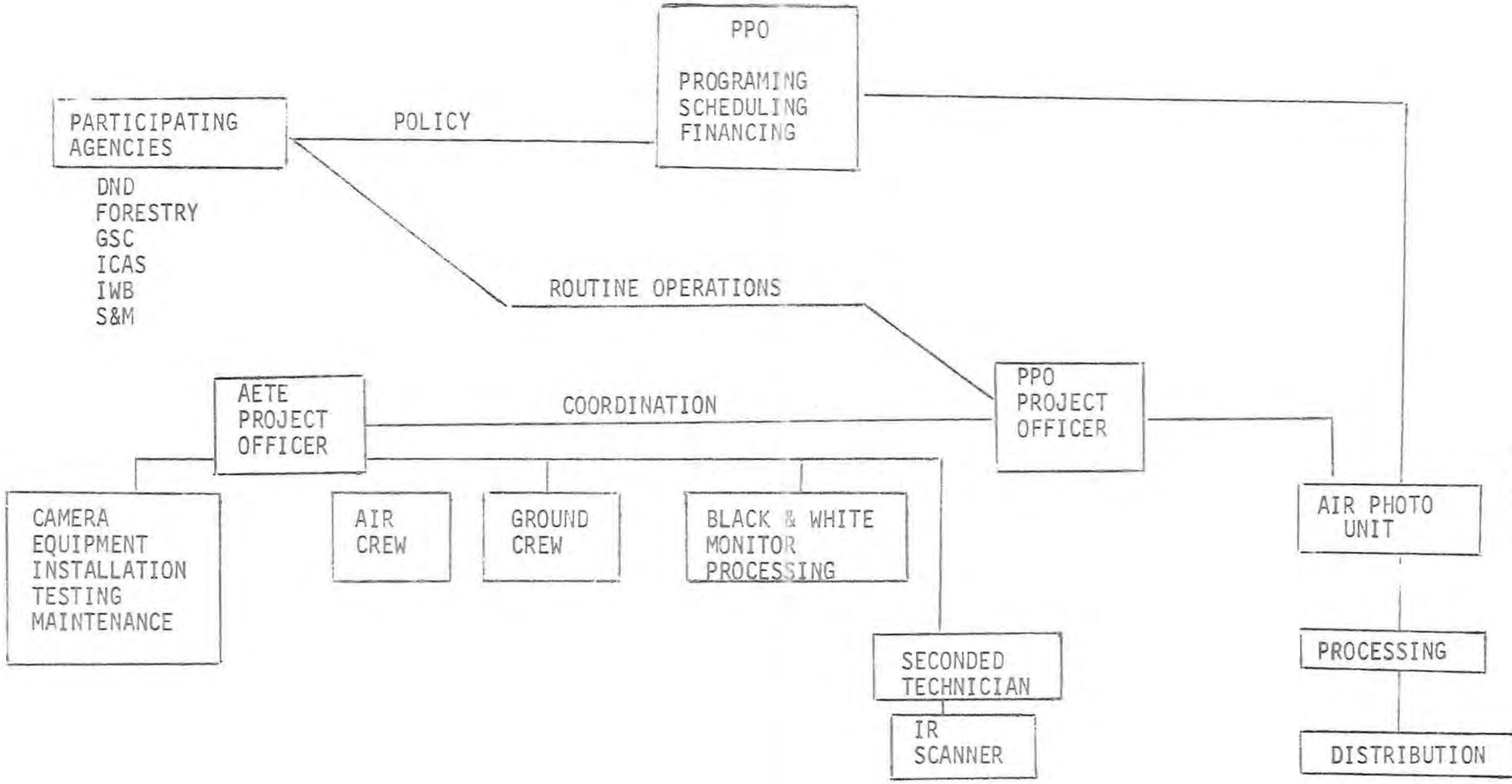

FIGURE 1 - Organization Structure
High Altitude Photographic Project

THE NASA ERTS SYSTEM AND POTENTIAL COVERAGE OF CANADA

R. O. Chipman
Program Planning Office, Dept. of Energy, Mines and Resources, Ottawa

Introduction

The U. S. National Aeronautics and Space Administration has announced plans to orbit an Earth Resources Technology Satellite (ERTS) to provide high resolution images of the earth on a repetitive basis. The launching of the first satellite, ERTS-A, is scheduled for March of 1972, to be followed about 1 year later by an almost identical ERTS-B[1].

The satellite will be placed in a circular, near polar sun-synchronous orbit at an altitude of 910 km and will carry 4 sensors, 3 return beam vidicon (RBV) cameras, identical except for spectral filters, and a 4-channel multispectral scanner, all of which will cover the same 185 km wide swath along the ground track, the vidicons taking a series of snapshots and the scanner scanning continuously. The ground resolution is expected to be 80 - 150 m. per line pair. The imagery can be recorded in the satellite for later transmission or transmitted directly to a ground receiving station where it will be recorded and sent to a central data handling centre to be transformed into hard copy (photography). Corrections to make the imagery conform geometrically with existing maps will then be made and the images, in color or black and white, will be sent either directly to users or to specialized data interpretation centres.

The satellite will also have the capability of relaying data from remote automatic ground platforms such as stream or tide gauges, etc. to the receiving station on a daily basis.

The Sensors

The 3 RBV's will be sensitive in the blue green (475-575 nm.), the red (580-680 nm.), and the near I.R. (690-830 nm.), and will make simultaneous exposures of the same ground area 185 km on a side. A spectral filter, a 2" lens, and a shutter, produce an image 1" square on a photoconductor during an exposure of 8-16 msec. The image is then scanned in 4200 lines by an electron gun, and the intensity of the reflected beam, modulated by the image, is measured and transmitted in analogue mode to the ground station. The picture-taking cycle consists of: simultaneous exposure of the three cameras, sequential readout requiring 3.5 secs. for each camera, and erasure of the photoconductor and preparation for the next image. The total cycle takes 25 sec. during which the satellite

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[1]The satellites are expected to have a lifetime of about 1 year. General Electric has been named prime contractor for the system, assisted by Bendix Aerospace and Wolf Research and Development.

advances 160 km along the ground track giving an overlap of 13% between pictures. The resolution is expected to be about 80 m per line pair in the visible, and slightly poorer in the infra-red. Distortion due to inhomogenities in the beam focusing and deflecting fields and deflection of the beam by the image should be no more than 1%. The photoconductor will have a grid of marks which will appear on the image and can be used to determine the form of the distortion and the correction. Whether or not such corrections can be done routinely is not yet known. If part of the distortion is systematic, it will probably be possible to apply the same correction to all images. If the distortion varies, however, it will probably be quite time-consuming and expensive to correct.

The multispectral scanner will cover the same 185 km wide ground swath as the vidicons, but will image continuously rather than as snapshots. The scan across the swath, i.e. perpendicular to the motion of the satellite, is provided by a mirror rocking at 15 hz, and the progression of the scan along the track is provided by the orbital motion. The radiation reflected by the mirror is focused by a pair of curved mirrors onto a 6 element by 4 element array of fiber optic bundles, each bundle looking at a ground element 70 m square. Each of these elements is passed through a spectral filter and into a photomultiplier. The 6 elements along the track provide 6 scan lines per mirror cycle and the four elements across the track look at four spectral bands, 500-600 nm. (nanometer), 600-700 nm., 700-800 nm., and 800-1100 nm. The 24 measurements require about 15 micro-second during which the mirror moves a distance corresponding to 70 m on the ground. Each cycle of the mirror therefore produces 6 scan lines of about 2500 elements in each of 4 spectral bands, the data being transmitted continuously in cycles of the 24 elements. To reproduce the imagery, the 4 spectral bands must be separated, and each must be reorganized into individual scan lines.

Spacecraft Orientation

The spacecraft will be the Nimbus platform and will probably be launched by the Delta-M rocket. The spacecraft must have the ability to obtain the precise orbit required and to maintain that orbit using gas propulsion for corrections, with enough gas to last for at least 1 year.

The orientation of the satellite, with the sensors directed at the nadir, is maintained by horizon sensors on the horizontal axes, and by a gyro on the vertical axis. When the attitude error reaches .7°, a brief impulse is given to a momentum wheel on the appropriate axis by compressed gas. Such corrections are expected every 20-25 seconds for each axis, every 130-160 km along the ground track.

For the vidicons, which take snapshots, a .7° error simply means that the centre of the area viewed will be displaced by about 10 km from the subsatellite point, an error that can easily be determined by comparison with maps.

For the scanner, which images continuously, however, relative displacements of up to 20 km can occur within a 185 km square frame. Since the horizon sensors are not accurate to much better than 0.5°, there is no way of correcting these errors on the basis of information from the satellite unless more accurate orientation sensors are included. Correction using maps, however, may be practical. Since the displacements occur due to the pitch, roll and yaw of the spacecraft relatively slowly, there will be negligible distortion within a scan line and very little between closely-spaced scan lines. Since the reaction of the satellite to the momentum wheels will be known, it should be possible to compare a limited number of image points with the corresponding points on a map, determine the correction transformation and apply it to the entire image. By this means, it may be possible to correct the scanner imagery to within a few resolution elements, but how difficult, expensive, or time-consuming this may be has not yet been determined.

Thus, ERTS-A will produce two sorts of imagery, return-beam vidicon snapshots in 3 colors with possibly uncorrectable errors of up to 2 km, and continuous scanner imagery in 4 colors with errors of up to 20 km but correctable to within several hundred metres. The scanner also has the very significant advantage that the four spectral images, corrected or uncorrected, when superimposed, will align exactly since the spectral separation occurs after imaging. Since the distortions in the three vidicon tubes will be independent, it will be impossible to produce good color pictures from the RBV imagery.

Image Reproduction

Two devices with the necessary printing speed and resolution have been proposed for producing master images from which copies will be made for distribution. A laser beam image recorder consisting of a continuous wave laser, an electrically-controlled modulation cell, a lens system, a rotating multifaceted mirror to provide the cross track scan, and a moving film carrier to provide the progression along the track, can produce positive or negative images in a 9" by 9" format. Also proposed is an electron beam recorder using an electrically deflected magnetically focused electron beam to expose 70 mm film from which 9" by 9" copies can be made.

Since both of these devices are still being developed, their speed and resolution are not known, but both appear capable of matching the speed, resolution and dynamic range of the sensors. The black and white images can be superimposed with appropriate filters to provide true or false color imagery.

The satellite will also serve as part of a data relay system. Inexpensive automatic remote ground platforms will collect, record and transmit to the satellite for relay to the ground, data such as temperature, pressure, precipitation, or stream flow. The platforms are designed to be as simple and inexpensive as possible and are therefore equipped for transmission only. They cannot be commanded or interrogated. Roughly every 2 minutes, each platform will transmit an 80 bit message burst lasting .1 sec. In order for this to be relayed to the ground station, both the platform and the ground station must be in contact with the satellite. This will occur from 1 to 3 times every 12 hours depending on the location of the platform and the contacts will have an average duration of about 5 minutes. During this period of contact, the message can be read if no other platform within range of the satellite is transmitting simultaneously at the same frequency. The inherent frequency differences of the inexpensive crystal oscillators, combined with thermal variations and doppler shift will often allow simultaneous transmissions to be separated by fourier analysis and appropriate filtering. With 1000 platforms across the U. S. there would be less than a 50% probability of reading any given transmission but with three ground stations, the probability of reading at least one message every twelve hours would be 95%. In general, Canadian platforms would have somewhat less interference than the U. S. platforms, but with only one ground station, the probability of one clear transmission every 12 hours would be about 90%. If Canada were to use only a small number of platforms, it might be more economical to use a more expensive, more accurate platform, which would make transmissions more reliable and decoding more economical.

The message consists of 80 bits, 11 bits for identification allowing a maximum of 2048 platforms, 5 bits for synchronization, and 64 bits for the message. The maximum information that can be obtained from a platform is therefore 64 bits every 12 hours.

Telemetry

The telemetry will use the Manned Space Flight Network Unified S Band (USB) system around 2.2 Ghz with a narrow band backup in the Satellite Tracking and Data Acquisition Network (STADAN) around 150 Mhz.

The command uplink has one channel in each network, of bandwidth 3.6 Mhz in the USB and 30 Khz in STADAN. These commands may be effected immediately or stored for later action.

The housekeeping, attitude, sensor performance, and data relay information are transmitted on 2 channels, one in each network with bandwidths of 5 Mhz in USB and 90 Khz in STADAN. The data relay uplink at about 400 Mhz has a 100 Khz bandwidth which allows up to 5 simultaneous transmissions of 20 Khz bandwidth to be separated.

The vidicon and scanner imagery will be transmitted separately on two USB channels around 2.3 Ghz with bandwidths of 20 Mhz. The vidicon images are squares with 4200 resolution elements on a side and are transmitted in 3.5 seconds giving a data rate of about 5 million elements per second. The scanner data, transmitted continuously, with each element split into 4 or 5 spectral signals in 8 bit digital format will come down at 15 million bits per second.

The Canadian receiving station is to be located at Prince Albert, Saskatchewan which has an unused 80 ft antenna, which can be converted to the ERTS system. Prince Albert will be able to receive data from all of Canada except the Atlantic Provinces. Data from this area could be obtained from the station at the Goddard Space Flight Centre.

The Orbit

At an altitude of 900 Km, a satellite would have a frequency of exactly 14 orbits per day and would cover the same 14 ground swaths every day. At 912 Km, the frequency becomes slightly less than 14 and the ground tracks progress westward at 1.4° of longitude per day, 160 Km per day at the equator. Since the ERTS sensors cover a 185 Km wide swath, successive days will provide overlapping coverage, and after 18 days the orbits will have progressed westward through 25.7°, the separation of consecutive orbits, and coverage of the world will be complete and will begin again.

Since the separation between any two orbits decreases as the cosine of the latitude, orbits which are 160 Km apart at the equator will be 113 Km apart at 45°, 80 Km apart at 60° and 40 Km apart at 75°. The overlap between coverage of consecutive days will be 14% at the equator, 40% at 45°, 68% at 60° and 78% at 75°. With no overlap, complete coverage of Canada would require about 500 pictures. On the descending side of the orbit, the day side, ERTS will produce about 1500 pictures over Canada every 18 days, about 500 from the provinces, 500 from the mainland districts of the territories, and 500 from the Arctic Islands. In mid-winter, however, the sun will be below the horizon north of about 65° and the number of pictures will be reduced by almost 50%. In midsummer, north of about 65°, the sun will be above the horizon for the ascending as well as the descending orbit and output will increase by almost 50%.

To simplify interpretation and comparison of imagery, it is desirable to keep subsatellite illumination conditions as constant as possible. A retrograde orbit inclined at 81° to the equator will precess about the earth's axis counterclockwise with a period of one year. This precession exactly compensates for the motion of the earth around the sun so that the orbit will always maintain the same orientation with respect to the earth-sun line. As the earth rotates, every point will pass under the satellite orbit twice a day, once on the day side and once on the night side, and these will occur at the same time every day. Since the orbit is not quite a polar orbit, the times will vary with latitude, but will be independent of longitude and season. The orientation chosen is such that, on the descending orbit, the satellite will cross the equator at 9:30 a.m. Since, in a retrograde orbit, the satellite is moving east to west, it will be moving to progressively earlier subsatellite local time as it moves south across Canada, the change of time with latitude being greatest in the north. Thus at the northernmost point of the orbit it will be 3:30 p.m. on the ground. As the satellite passes over 80°N it will be 2 p.m., at 75° 12 noon, at 70° 11:15 a.m., at 60° 10:30 a.m. and at 45° 10 a.m.

The solar illumination angle depends on the time of day and season of the year. Since the time of day at the subsatellite point is dependent only on latitude, the illumination angle will be a function of latitude and season only and will vary slowly and systematically with both.

Although the ground swath will cover every point at least once every 18 days, usable pictures will generally be a good deal less frequent due to cloud cover. On the average, the probability of a point being visible from space is about 50%. The probability of an area 185 Km square being cloud free is considerably less. If one is looking at a particular feature, a lake or a city, the probability of the feature being cloud free depends on the area, the larger the area the smaller the probability. Some users will require entirely cloud free images while others will be able to use small clear areas on partially obscured images. Haze and thin cloud cover may distort spectra while allowing pattern recognition, and will generally have a greater effect on the shorter wavelength spectral bands.

In order to obtain quantitative information on cloud cover, 10 years of data from 100 weather stations across Canada has been analyzed to determine the probability of clear conditions as a function of location and season. The criterion was that of aerial photography, cloud cover $\leq$ 1/10. A criterion of 2/10 or 3/10 would very roughly double or triple respectively the probability of clear conditions. A study of arctic cloud cover was used to extend the data into the far north. Fig. 5* shows the probability of clear conditions for the various regions of Canada on a monthly basis. In Figs. 6 to 10*, Canada has been divided up into areas of 340,000 sq. km. (100,000 n.mi^2) so that each area corresponds to 10 ERTS pictures except the northernmost which is half the area of the others. Fig. 6* shows the total number of pictures that will be taken on the descending portion of the orbit over each area during a season, i.e. in 5 complete cycles of coverage. Figs. 7 to 10* show the number of clear pictures with the sun at least 10° above the horizon that can be expected in each season. Less than 10 pictures would provide poor coverage of the area while more than 10 means complete or almost complete coverage on a seasonal basis.

Acknowledgments

The technical specifications for the ERTS system were taken from the NASA document Design Study Specifications for the Earth Resources Technology Satellite ERTS-A and B. Permission to publish this material was given by NASA and is gratefully acknowledged. Calculations and illustrations of orbits, solar illumination angle, and cloud cover were done by the author and therefore NASA cannot be held responsible for these interpretations.

*Figures not shown in this report

REPORT ON ORGANIZATION AND OBJECTIVES OF SOIL SURVEY

A special session was spent in discussion on organization and objectives of soil survey for Canada. Discussion leaders were J. S. Clark, Soil Research Institute, C.D.A.; P.J.B. Duffy, Canadian Forestry Service, F. F.; E. Penner, Division of Building Research, N.R.C.; R. J. McCormack, Canada Land Inventory, D.R.E.E.; and W. A. Ehrlich, Pedology, C.D.A.

The discussion revolved around the need for acceleration and expansion of soil survey coverage and interpretations of soils data to meet the requirements of the various disciplines concerned with the use of land. Attention was also given to the present roles of various groups concerned with soil surveys and the possibilities of working with others on a cooperative basis.

Some of the points discussed relevant to soil survey follow:

It was pointed out that the federal soil survey, being within the Department of Agriculture, is not encouraged to survey lands that have no farming potential. For this reason it was indicated that other departments, particularly Fisheries and Forestry, were compelled to establish groups of their own to provide soils information on areas within their responsibility. This development of new soils groups to do surveys is considered undesirable by the C.S.S.C. but is understood when the needed information is not obtainable in any other way.

It was considered that the functioning of soil survey groups operated by different departments is more costly and less efficient than one unit with comparable capabilities. It is thought to be more costly because of duplication in coverage of some areas, and to be less efficient because different groups tend to use different or modified systems that do not permit adequate correlation with each other. Also new groups, in general, have less soil survey experience with the result that they produce less reliable information than the experienced group.

With these thoughts in mind the members of the C.S.S.C. and some foresters in attendance felt that a central agency responsible for soil surveys is needed. It was proposed that departments who have need for this kind of information share some of the costs. Additional costs would be incurred because an increase of staff and facilities would be required if the needs of the various departments are to be satisfied within a reasonable length of time.

Reference was made to administrative control. It was felt that all federal survey units and correlation staff be under the Soil Research Institute to allow more flexibility and more cooperation in operation between provinces. A suggested alternative to the proposal made was secondment of the federal soil survey staff to a department such as Energy, Mines and Resources or some other department whose main concern is the natural resources of Canada.

Two other points received attention and they are soil correlation and interpretations of soil information.

The subject of correlation was reported earlier at this meeting and to recapitulate it was agreed in a canvass of all survey units, provincial and federal, that correlation within and between provinces and regions was inadequate. They blamed this inadequacy on a shortage of correlators. It was considered that a minimum of four is required for interprovincial field correlation; that is, one for British Columbia and Alberta, one for Saskatchewan and Manitoba, one for Ontario and Quebec, and one for the Maritime Provinces. It was also indicated that an organization for correlation was needed within the provinces, particularly in those with separate provincial and federal survey units. The latter problem, however, is not considered to be serious. It is felt that this can be satisfactorily worked out within the respective provinces.

Another problem pointed out was that the correlator has no authority over the federal units in provinces administered by research stations and thus his effectiveness in obtaining uniformity can be impaired. The matter of authority for the correlator, however, would be circumvented if a single administration was in effect for all federal units.

The need for more interpretations of soils information for various purposes, particularly in agriculture, forestry and soil mechanics, was expressed by various members and approval was received from the committee for greater efforts along these lines.

It was felt that the survey units, notwithstanding their knowledge of agriculture, did not provide nearly enough interpretive information in the soil reports for users in the agricultural field. Interpretations for agriculture that were specified were crop yield assessments, soil ratings, soil, crop and grazing capabilities, soil management, and irrigation potential.

For interpretations for forestry, it was considered that those survey units without expertise in forestry would need assistance. It was pointed out that an attempt would be made for cooperation in interpretations between the two departments concerned. At present three provinces are providing productivity and capability classifications.

The discussion on soil interpretations for engineering uses received considerable attention. Two persons in the engineering field who attended the meeting felt that cooperative arrangements could be made between engineers and soils men similar to the one between the universities of Guelph and Waterloo. Three survey units have some cooperative arrangements with engineering departments.

Other interpretations that received some attention from the group were land capabilities for wildlife and recreation. To the present time the survey groups, with the exception of the provincial soils group in British Columbia, have not actively taken part in interpretations in these fields. In this matter the C.S.S.C. was not prepared at this time to make recommendations.

With reference to the recommendation by the C.S.S.C. members for an

Interpretation and National Correlation Service recorded in the report on Soil Correlation, it is felt that this matter should receive full support from all concerned if we are to embark successfully on widescale interpretations. It is evident to all of us that interprovincial correlation in soils and in interpretations is essential if the data available are to be meaningful from one province to another. For the service referred to, it is considered necessary to have expertise in agronomy, forestry, soil mechanics (including hydrology), remote sensing, storage and retrieval of data,and soil correlators. It is expected that priorities in surveys and in interpretations will change from time to time and adjustments will have to be made to suit the needs.

REPORT ON MONOGRAPH ON SOILS OF CANADA

W. A. Ehrlich

At the 1968 N.S.S.C. (now C.S.S.C.) meeting in Edmonton a resolution was passed that the national committee be responsible for the preparation of a monograph on the Soils of Canada. The resolution also recommended that an editorial board be selected to plan the preparation of this monograph. To get the project under way, the national committee chairman, with guidance, selected an editorial board consisting of the following: H. J. Atkinson, R. W. Baril, W. E. Bowser, D. B. Cann, J. S. Clark, J. S. Clayton, J. H. Day, A. Leahey and P. C. Stobbe.

Four meetings were held to decide on the format for the monograph and the procedure to be followed. The format proposed is as follows:

(1) Introduction.

(2) General description -
(a) Location and extent; (b) Relief and drainage; (c) Geology; (d) Climate; (e) Vegetation.

(A section chairman will be responsible for the preparation and editing the subsections under general description.)

(3) Soil formation - concerned with soil-forming factors.

(4) Soil classification - concerned with classification and descriptions of the soils designated on the map.

(A section chairman will be responsible for obtaining some degree of uniformity in style and descriptions prepared under section 4.)

(5) Appendix - to include tabular descriptions and analytical data of the 33 profiles, also the statistics on land use and a glossary on soil terms.

Two aspects pertaining to the project are under way - the collection and analyses of representative soil profiles and the preparation of the Soil Map of Canada*. Some progress on the soil profiles (33 in all) has been made but not as much as had been hoped. The Soil Map of Canada is nearly complete. This map will have an expanded type of legend providing most of the important information so that a text will not be essential. The legend includes: (1) map symbols of the Canadian and equivalent World unit; (2) subgroup both dominant and subdominant; (3) major physical characteristics; (4) physiography; (5) climate; (6) land use; (7) extent (square miles); (8) location (map grid); and (9) reference to source and

*This map will be a replica of the one to be used by FAO/UNESCO for the Soil Map of the World.

reliability of information.

The editorial board also discussed the possibilities of including sections on fertility, soil capability and forestry. After some debate it was concluded that this type of information would be too general to be significant. It was proposed, however, that reference to fertility, limitations and problems in land use be included in the descriptions of the great groups.

Authors have been selected by the board for the various parts to be written. Dr. H. J. Atkinson has volunteered to undertake the editing of style and grammar of the monograph. He has had a great deal of experience in this field and we are indeed fortunate to have him.

Before the new year it is hoped to have the authors assigned for the different sections of this report.

RESOLUTIONS

C.S.S.C. Meeting

1970

1. Be it resolved that the Canada Soil Survey Committee express the sincere appreciation of its members to Messrs. Ehrlich, Clayton, Clark, Day and McKeague, and to their wives, for their hospitality on the occasion of the social evening at Dr. Ehrlich's home.

Moved: C. A. Rowles
Seconded: D. Rennie
Carried

2. Be it resolved that the C.S.S.C. express its sympathy to Dr. A. Klingebiel, who was unfortunately called home on learning of the death of his brother.

Moved: D. Rennie
Seconded: C. A. Rowles
Carried

3. Be it resolved that the C.S.S.C. express to:

a) W. E. Bowser
b) L. J. Chapman
c) W. Odynsky
d) R. E. Wicklund

its appreciation for their many years of service on the Committee and our regrets at not seeing them and renewing acquaintances at this, our eighth meeting.

Moved: D. Rennie
Seconded: C. A. Rowles
Carried

4. Whereas, in the opinion of some of our members, simultaneous translation of our reports and deliberations is of prime importance if we are to make the best use of the abilities of our French-speaking colleagues,

Therefore, be it resolved that simultaneous translation services be provided at all the eastern regional and national meetings of the C.S.S.C.

Attendu, de l'avis de plusieurs membres du comité canadien de la classification des sols, que la traduction simultanée est de première importance pour nos délibérations si l'on veut profiter pleinement de la collaboration compétente de nos collègues de langue française.

Nous proposons qu'un service de traduction simultanée soit assuré à toutes les réunions régionales de l'est du Canada ainsi qu'à toute les réunions du comité canadien de classification des sols.

Moved: D. W. Hoffman
Seconded: J. Hilchey
Carried

5. Whereas the Plenary Session of the C.S.S.C., meeting on October 21, expressed approval for the establishment of a National Soil Correlation and Soil Resource Interpretation Service,

   Therefore, be it resolved that the C.S.S.C. forward to C.A.S.C.C. a request that the development of this service be supported.

Moved: J. S. Clayton
Seconded: T. W. Peters
Carried

6. Be it resolved that the C.S.S.C. establish a committee to assess the advantages and disadvantages of adopting the U. S. system of soil classification.

Moved: L. Farstad
Seconded: J. A. McKeague
Carried

MEMBERS OF SUBCOMMITTEES

Land Forms	D. F. Acton (Chairman), L. J. Chapman, J. E. Gillespie, L. M. Lavkulich, R. Marcoux, J.F.G. Millette, T. W. Peters, G. G. Runka, K.W.G. Valentine, M. A. Zwarich
Soil Moisture Regime	J. A. McKeague (Chairman), T. A. Black, E. de Jong, D. W. Hoffman, J. I. MacDougall, A. A. Mailloux, T. W. Peters, M. A. Zwarich
Soil Climate	A. R. Mack (Chairman), W. Baier, T. A. Black, D. M. Brown, J. S. Clayton, P. G. Lajoie, J. I. MacDougall, G. F. Mills, W. Odynsky, B. Rochefort, J. A. Shields, P. N. Sprout
Engineering Applications	S. Pawluk (Chairman), E. de Jong, P. Heringa, J. Hilchey, K. K. Langmaid, L. M. Lavkulich, W. Michalyna, E. Penner, E. W. Presant, L. Tardif
Crop Yield Assessments	R. A. Hedlin (Chairman), L. Henry, J. Hilchey, D. W. Hoffman, K. K. Langmaid, J.F.G. Millette, C. A. Rowles, M. Tabi, J. A. Toogood
Soil Correlation	J. S. Clayton (Chairman), D. F. Acton, D. B. Cann, J. S. Clark, J. H. Day, J. G. Ellis, L. Farstad, P. Heringa, D. W. Hoffman, P. G. Lajoie, K. K. Langmaid, J. I. MacDougall, T. W. Peters, R. Raymond, R. E. Smith, P. N. Sprout
Handling Soil Survey Data	R. Protz (Chairman), A. K. Ballantyne, R. Baril, A. Dubé, P. Duffy, J. Dumanski, M. K. John, K. K. Langmaid, L. M. Lavkulich, W. Michalyna, J.F.G. Millette, P. N. Sprout
Kind of Soil Survey Reports	D. B. Cann (Chairman), H.W.R. Chancey, J. G. Ellis, R. A. Hedlin, J. Hilchey, D. W. Hoffman, K. K. Langmaid, G. F. Mills, W. Odynsky, R. Raymond, C. A. Rowles
Soil Families	R. Baril (Chairman), H.W.R. Chancey, J. H. Day, L. Farstad, D. W. Hoffman, K. K. Langmaid, J. I. MacDougall, W. Odynsky, B. Rochefort, R. E. Smith, B. H. Stonehouse

Organic Soils	J. H. Day (Chairman), C. J. Acton, B. Bernier, D. Carrier, L. Farstad, P. Heringa, J. D. Lindsay, R. Marcoux, J. Nowland, G. Padbury, R. E. Smith
Chernozemic Soils	J. S. Clayton (Chairman)
Solonetzic Soils	T. W. Peters (Chairman)'
Luvisolic Soils	D. B. Cann (Chairman)
Podzolic Soils	D. B. Cann (Chairman)
Brunisolic Soils	P. G. Lajoie (Chairman)
Regosolic Soils	L. Farstad (Chairman)
Gleysolic Soils	A. McKeague (Chairman)

Non-Committee Presentations

Biophysical Land Classification	S. C. Zoltai
Biophysical Land Analysis	G. G. Runka
Capability Classification of Organic Soils	D. W. Hoffman
Panel on Remote Sensing	L. Philpotts (Chairman), J. N. de Villiers, A. F. Gregory, E. A. Godby, R. O. Chipman

ATTENDANCE AT PLENARY SESSIONS

British Columbia

L. Farstad	Research Branch, C.D.A.	Vancouver
M. John	Research Branch, C.D.A.	Agassiz
B. Kloosterman	Dept. of Soil Science, U.B.C.	Vancouver
L. M. Lavkulich	Dept. of Soil Science, U.B.C.	Vancouver
C. A. Rowles	Dept. of Soil Science, U.B.C.	Vancouver
G. G. Runka	B. C. Dept. of Agriculture	Kelowna
J. I. Sneddon	Research Branch, C.D.A.	Vancouver
P. N. Sprout	B. C. Dept. of Agriculture	Kelowna

Alberta

G. M. Coen	Research Branch, C.D.A.	Edmonton
J. Dumanski	Alberta Research Council	Edmonton
A. A. Kjearsgaard	Research Branch, C.D.A.	Edmonton
J. D. Lindsay	Alberta Research Council	Edmonton
S. Pawluk	Dept. of Soil Science, Univ. of Alta.	Edmonton
T. W. Peters	Research Branch, C.D.A.	Edmonton
W. Pettapiece	Research Branch, C.D.A.	Edmonton
J. A. Toogood	Dept. of Soil Science, Univ. of Alta.	Edmonton

Saskatchewan

D. F. Acton	Research Branch, C.D.A.	Saskatoon
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A. Ballantyne	Research Branch, C.D.A.	Saskatoon
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L. Henry	Dept. of Soil Science, Univ. of Sask.	Saskatoon
D. A. Rennie	Dept. of Soil Science, Univ. of Sask.	Saskatoon
R. J. St. Arnaud	Dept. of Soil Science, Univ. of Sask.	Saskatoon
J. A. Shields	Research Branch, C.D.A.	Saskatoon
H. B. Stonehouse	Research Branch, C.D.A.	Saskatoon

Manitoba

R. G. Eilers	Man. Dept. of Agriculture	Winnipeg
R. A. Hedlin	Dept. of Soil Science, Univ. of Man.	Winnipeg
G. F. Mills	Man. Dept. of Agriculture	Winnipeg
R. E. Smith	Research Branch, C.D.A.	Winnipeg
S. C. Zoltai	Canadian Forestry Service, F. F.	Winnipeg

Ontario

C. J. Acton	Research Branch, C.D.A.	Guelph
I. S. Alemdag	Canadian Forestry Service, F. F.	Ottawa
W. Baier	Research Branch, C.D.A.	Ottawa
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D. M. Brown	Dept. of Soil Science, Univ. of G.	Guelph
A. A. Buys	Canadian Forestry Service, F. F.	Ottawa
R. O. Chipman	Program Planning Office, E.M.R.	Ottawa
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J. S. Clark	Research Branch, C.D.A.	Ottawa
J. S. Clayton	Research Branch, C.D.A.	Ottawa
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W. S. Ferguson	Research Branch, C.D.A.	Ottawa
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A. F. Gregory	Program Planning Office, E.M.R.	Ottawa
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P. A. Murtha	Canadian Forestry Service, F. F.	Ottawa
J. P. Peaker	Canadian Forestry Service, F. F.	Ottawa
E. Penner	National Research Council of Canada	Ottawa
L. Philpotts	Economics Branch, C.D.A.	Ottawa
E. Presant	Research Branch, C.D.A.	Guelph
R. Protz	Dept. of Soil Science, Univ. of G.	Guelph
M. J. Romaine	Canada Land Inventory, D.R.E.E.	Ottawa
W. Sly	Research Branch, C.D.A.	Ottawa
P. C. Stobbe	Retired	Ottawa
W. L. Wallace	Canadian Forestry Service, F. F.	Ottawa
O. L. White	Dept. of Civil Engineering, Univ. of W.	Waterloo
C. R. Wood	Research Branch, C.D.A.	Ottawa

Quebec

R. Baril	Dept. des sols, Univ. Laval	Quebec City
J. L. Belair	Laboratoire de Recherches Forestieres	Quebec City
M. Jurdant	Service Forestier du Canada, F. F.	Quebec City
C. de Kimpe	Research Branch, C.D.A.	Quebec City
J.F.G. Millette	Dept. of Soil Science, Macdonald College	Montreal
A. A. Mailloux	Quebec Dept. of Agriculture	La Pocatiere
R. Marcoux	Quebec Dept. of Agriculture	La Pocatiere
R. Raymond	Quebec Dept. of Agriculture	La Pocatiere
B. Rochefort	Quebec Dept. of Agriculture	La Pocatiere
L. Tardif	Quebec Dept. of Agriculture	La Pocatiere

New Brunswick

D. B. Cann	Research Branch, C.D.A., Maritimes Soil Survey	Fredericton

Nova Scotia

J. Hilchey	N. S. Dept. of Agriculture	Truro
J. L. Nowland	Research Branch, C.D.A., Maritimes Soil Survey	Truro

Prince Edward Island

A. Raad	Dept. of Agriculture and Forestry	Charlottetown

Newfoundland

H.W.R. Chancey	Research Branch, C.D.A.	St. John's West
P. K. Heringa	Research Branch, C.D.A.	St. John's West

Washington, D. C.

J. Douglass	Soil Conservation Service, U.S.D.A.	Washington
A. Klingebiel	Soil Conservation Service, U.S.D.A.	Washington

New York

R. Arnold	Dept. of Agronomy, Cornell Univ.	Ithaca

CANADA SOIL SURVEY COMMITTEE

On July 9, 1969, the name of this committee was changed from National to Canada Soil Survey Committee. The National Soil Survey Committee was established by the National Advisory Committee on Agricultural Services in May, 1940. Since that date national meetings were held in 1945, 1948, 1955, 1960, 1963, 1965, 1968 and 1970.

TERMS OF REFERENCE

To act as a coordinating body among the soil survey organizations in Canada supported by the Canada Department of Agriculture, provincial departments of agriculture, research councils, and departments of soil science at universities. Its functions include:

1. Improvement of the taxonomic classification system for Canadian soils and revision of this system because of new information.

2. Improvement of the identification of the physical features and soil characteristics used in the description and mapping of soils.

3. Review of methods, techniques and nomenclature used in soil surveys and recommending changes necessary for a greater measure of uniformity or for their improvement.

4. Recommending investigations of problems affecting soil classification, soil formation, and the interpretation of soil survey information.

5. Recommending and supporting investigations on interpretations of soil survey information for soil ratings, crop yield assessments, soil mechanics and other purposes.

6. Cooperating with specialists in soil fertility, agronomy, agrometeorology, and other disciplines in assessing interrelated problems.

MEMBERS OF THE CANADA SOIL SURVEY COMMITTEE

Chairman: W. A. Ehrlich, Research Coordinator (Pedology), Ottawa

Federal Representatives:

British Columbia		
L. Farstad	Research Station	Vancouver
Alberta		
T. W. Peters	Soil Research Institute	Edmonton
Saskatchewan		
D. F. Acton	Research Station	Saskatoon
Manitoba		
R. E. Smith	Research Station	Winnipeg
Ontario		
C. J. Acton	Soil Research Institute	Guelph
J. S. Clark	Soil Research Institute	Ottawa
J. S. Clayton	Soil Research Institute	Ottawa
J. H. Day	Soil Research Institute	Ottawa
P.J.B. Duffy	Canadian Forestry Service	Ottawa
R. J. McCormack	Canada Land Inventory	Ottawa
Maritime Provinces		
D. B. Cann	Research Station	Fredericton
Newfoundland		
H.W.R. Chancey	Research Station	St. John's West

Provincial Representatives:

British Columbia		
P. N. Sprout	B. C. Dept. of Agriculture	Kelowna
Alberta		
J. D. Lindsay	Alberta Research Council	Edmonton
Saskatchewan		
J. G. Ellis	Sask. Dept. of Agriculture	Saskatoon
Manitoba		
G. F. Mills	Man. Dept. of Agriculture	Winnipeg
Quebec		
A. A. Mailloux	Quebec Dept. of Agriculture	La Pocatiere
Nova Scotia		
J. Hilchey	Nova Scotia Dept. of Agriculture	Truro

University Representatives:

C. A. Rowles	Dept. of Soil Science, Univ. of B. C.	Vancouver
J. A. Toogood	Dept. of Soil Science, Univ. of Alta.	Edmonton
R. St. Arnaud	Dept. of Soil Science, Univ. of Sask.	Saskatoon
R. A. Hedlin	Dept. of Soil Science, Univ. of Man.	Winnipeg
D. W. Hoffman	Dept. of Soil Science, Univ. of G.	Guelph
R. Protz	Dept. of Soil Science, Univ. of G.	Guelph
J.F.G. Millette	Dept. of Soil Science, Macdonald Coll.	Montreal
R. Baril	Dept. of Soil Science, Laval Univ.	Quebec City