THE LANDSCAPE APPROACH TO LAND CLASSIFICATION:

An Evaluation of the Technique as Applied in the Merritt Area, British Columbia

by

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Abstract

Land evaluation, the assessment of the suitability of land for man's use in agriculture, forestry, engineering, hydrology, regional planning, recreation, etc., requires land classification because the environment is too complex to evaluate as a whole. The landscape approach to land classification is utilized to test its applicability to land evaluation at a relatively large-scale (1:50,000), and in a settled area.

In Part One, three approaches to land classification are recognised, and the history of each approach is discussed. The landscape approach, whereby natural areas are defined in terms of their physical and biological attributes, is treated in detail.

In order to test the applicability of large-scale, landscape land classification in a settled area, a land classification of the Merritt area, British Columbia, is presented in Part Two. This classification was based on an analysis of aerial photographs, previous documentation, and field research. Six "land systems," areas of relatively homogeneous topography, geology, vegetation, and soils, are defined, and the characteristics of each are described.

Because land-use patterns are firmly established, land tenure is independent of the land systems, and the land-use decision-making process is complex, a land evaluation based on this classification would not be realistic.

The reasons for the failure of the landscape approach in this area are discussed in Part Three, and alternatives are suggested. A land classification system that would combine remote-sensing and computer technologies to produce single- and multiple-attribute classifications would probably better serve present land classification needs in this area. A possible framework of such a system is suggested. This system would utilise a small arbitrary area as a spatial framework, rather than natural or institutional areas. These small areas can be combined to approximate natural or institutional areas, and thus satisfy the needs of a variety of land users.

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Introduction and Definitions

The objectives of this study are to explore the history and philosophy of land classification and land evaluation, and to apply and critically analyse the "landscape approach" to land classification for land evaluation. The study will concentrate on multidisciplinary land classification and evaluation. Monodisciplinary classifications, such as soil, vegetation, or hydrologic surveys are specifically excluded. However, physiographic subdivision of large areas is discussed because many of these studies have considered more than physiography, and they have also influenced the concepts used in landscape land classification and evaluation.

The first part of the study provides a historical background to land classification and evaluation. Three approaches to land classification and evaluation are identified and considered separately; these are referred to as the genetic, the landscape , and the parametric, approaches. This subdivision is primarily for convenience because there is considerable overlap in both terminology and techniques.

The second part presents an example of the landscape approach to land classification from the Merritt area, British Columbia. This area was chosen because it has recent aerial photograph coverage, is easily accessible from Vancouver, and basic studies of its geology, land forms, and soils are available. Furthermore, because it has large areas of open grassland and few areas of dense forest, photo-interpretation and field work were both simplified. These qualities allowed a rapid, reconnaisance-type classification of the area using the landscape approach. The utility of the land classification of the Merritt area will be discussed in light of the present approach to the land-use decision-making process, and specific problems concerning land-use policy-making and implementation will be identified where warranted.

In the third part of the study, I will discuss the classification process, recent advances in remote-sensing techniques, and the modifications of land classification techniques suggested by these advances. The three methods of land classification discussed below are arranged in a chronosequence of development; each in turn relies more heavily on remote-sensing techniques than the previous one. It appears certain that future land classification will continue this trend.

Land (terrain) evaluation has been defined as "the assessment of the suitability of land for man's use in agriculture, forestry, engineering, hydrology, regional planning, recreation, etc." (Stewart, 1968a, p. vii), and will be used in that way in this study. The term land, or terrain, is used in an integrating sense, combining the effects of the major natural attributes such as climate, geology, land form, soil, vegetation, fauna, and hydrology. Each of these attributes can be, and has been, classified separately in numerous ways for a variety of purposes, but this study will consider only the integrated approach in detail. An evaluation is a judgement of suitability or desirability for use by man (modified from Stewart, 1968b, p. 1), and thereby goes beyond classification.

Land evaluation involves three major steps: first, an analysis of the environment, secondly, classification and characterisation of the land, and thirdly, evaluation of the land for practical ends (Mitchell, 1973, p. 5). In practice, analysis and classification overlap each other, and both of these steps influence the evaluation.

Although land evaluation is often limited to the physical environment, man's use of the land is largely dependent on human factors -- technology, finance, and labour -- which are subject to unpredictable changes. Land evaluation then, cannot be considered absolute, but must be subject to revision in light of changing circumstances (Stewart, 1968b, p. 1).

Because the natural environment is too complex to manage (in the land management sense) as a whole, man classifies the environment in various ways in order to obtain units that can be usefully studied and managed. Land classification is defined as the delimitation of discrete land units that differ one from another in one or more ways. These units can be used to organise our knowledge of the land, index that knowledge, and to transmit it to others.

The way in which land is classified depends upon purpose, knowledge, and resources. A classification of land for agricultural productivity would not be entirely suitable as a basis for urban or recreational land-use planning, and a general purpose land classification will not serve all potential users equally well. If the purpose is to provide basic data required by many users, the classification will reflect this purpose. The classification will, of course, depend on knowledge of land attributes, but to be useful it should also depend on knowledge of user requirements. Knowledge of alternative classification methodologies and the advantages and disadvantages of each also will influence the nature of the classification. Finally, the resources available to the classifier -- time, money, equipment, facilities, and expertise -- will also affect the suitability and sophistication of a classification.

It is often a simple task to establish boundaries to separate distinctly different portions of a particular physical or biological phenomenon. For example, mountains are often separated from adjacent valleys by a sharp break in slope, and a grassland may end abruptly at the forest edge. More often, however, land attributes vary continuously, and the boundary between two distinctly different areas is gradational. Therefore, an arbitrary division line must be established, either in the form of a subjective central line or a defined value of the attribute in question. Whether subjectively chosen or defined for a particular purpose, the value, to a land user, of many boundaries will vary from one land user to another because different users have different needs.

Most land classifications attempt to integrate the various physical and biological attributes into a concept of "land" (see below for an elaboration of this concept). Areas are defined and delimited on the basis of several arbitrarily bounded land attributes; or a "homogeneous" land area is arbitrarily defined, then described in terms of its attributes. In many cases, boundaries of separate attributes coincide or nearly coincide (e.g. soil and landform), but often a complete delineation of boundaries based on consistent criteria would result in a maze of intersecting lines, nearly useless in the case of more than a very few defined attributes. For this reason, nearly coincident boundaries are often generalised to simplify the map, but this introduces an element of uncertainty to already arbitrary boundaries. The descriptions of the units thus delineated must recognise the generalised nature of the boundaries, thereby reducing the precision of the information supplied to the user. This is one of the major problems in land classification and will be discussed in more detail in the final part of this study.

Part One: Past Approaches to Land Classification

Introduction

Mabbutt (1968) recognised three basic approaches to land classification which he called the genetic, the landscape, and the parametric approaches. The genetic approach involves subdivision of continental areas into areas having a unity of structure upon which certain processes have operated through time to produce a characteristic physiography. In other words, this approach defines land units on supposed genesis. These units can be subdivided to form a hierarchy of units of varying homogeneity.

Practitioners of the landscape approach identify relatively homogeneous areas of land -- originally this was done through field work, but later studies have depended heavily on aerial photographs -- then they attempt to determine the factors that result in the perceived homogeneity, primarily through field work and photo-interpretation, but supplemented by other documentation where possible. Unlike the genetic approach, no a_priori assumptions are made concerning the basis of homogeneity, and the factors responsible may, in fact, differ from one unit to another. The units identified through the landscape approach can be combined to form a hierarchy of units of varying homogeneity.

The parametric approach defines land units on the basis of measured attributes. This approach attempts to overcome a major drawback inherent in both the genetic and landscape approaches -- their subjective bases. The parametric approach can also be used to establish hierarchical units.

The Genetic Approach

In 1905, Herbertson made one of the earliest attempts at a systematic subdivision of the Earth into "natural regions" having "a certain unity of configuration, climate and vegetation" (Herbertson, 1905, p. 309). Rather than systematizing individual "elements" on the Earth's surface, Herbertson considered "definite areas of the surface of the Earth. . .as a whole, not the configuration alone, but the complex of land, water, air, plant, animal, and man" (p. 301).

Herbertson was much influenced by the evolutionary ideas of the nineteenth century and their application to biological and human affairs. To him, the biological species and genera suggested the existence of different orders of geographical divisions. This is reflected in his recognition of five natural regions and their subdivision into "types" of regions (Table 1.1). He presumably left further subdivision to a later time or to other workers.

There were at least three applications of this subdivision seen by Herbertson. First, as an educational tool, the recognition of the chief types of natural regions would simplify learning the varieties. Second, a study of the "history of the exploitation of the variety of any type of region where human development is most advanced should be of

Polar	Lowlands (Tundra type)
	Highlands (Ice-cap type)
Cool Temperate	Western margin (West European type)
	Eastern margin (Quebec type)
	Interior lowlands (Siberian type)
	Interior mountain area (Altai)
Warm Temperate	Western margin (Mediterranean type)
	Eastern margin (China type)
	Interior lowlands (Turan type)
	Plateau (Iran type)
Tropical	West tropical deserts (Sahara type)
	East tropical lands (Monsoon type)
	Inter-tropical tablelands (Sudan type)
Lofty Tropical or Sub-tropical mountains	(Tibetan type)
Equatorial Lowlands	(Amazon type)

Table 1.1 Herbertson's (1905) Natural Regions

great profit to those interested in the exploitation or administration of the relatively undeveloped varieties of the same type." Thirdly, the regions would give the historian a geographic basis for his study of the development of human societies and the "invariable effect of a type of environment on its inhabitants." The environmental determinism upon which these last two applications were perceived has been disavowed since Herbertson's time, but can be understood when Herbertson's work is placed in its historical perspective. Herbertson also suggested that his natural regions would "permit some estimation of the non-environmental factors in human development" (p. 309), presumably by controlling for the effects of the environment.

Bowman (1911) described natural regions or provinces with the object of acquainting foresters with the geographic basis of their work (p. 108). In accordance with the Davisian model of landscape evolution, each of these regions was described as having a mainly uniform topographic expression resulting from geologic structure, physiographic process, and stage of development. Bowman dealt at length with the physical properties of soils and the processes operating to produce these properties. He also discussed physiographic, climatic, and forest regions, but most of his book is devoted to detailed descriptions of the natural regions he defined. He avoided the problems associated with boundaries by not attempting to draw them; however, he did discuss these problems (p. 108-110). Bowman's work is descriptive, and single-purpose oriented. It appears to meet his objective.

Fenneman's work (1914; 1916) is the best known of the various descriptions of natural regions, which he called physiographic "provinces." These were based on "unity or similarity of physiographic history," again in accordance with the Davisian interpretation of land forms as the products of structure, process, and stage. Fenneman derived his provinces from eight "major divisions" of North America. Since many of the areas he outlined had borne the designation "province" for some time, he continued the use of that term. He subdivided the provinces into "sections" and reserved the term "district" for "divisions of low, generally undetermined order whose boundaries were as yet undefined." Although form was the "primary basis of subdivision, it (was) understood to be form as a result of certain processes" (Fenneman, 1916, p. 24).

As Linton (1951, p. 200) has noted, although many of Fenneman's subdivisions (provinces and sections) were borrowed from earlier workers, when Fenneman began his work there was disagreement concerning the "existence of some regions, the status of others and the boundaries of all."

Fenneman (1914, p. 85) saw two purposes in physiographic subdivision. The first was to provide a basis for "discussion and explanation of the features of the country," and the second, "as a basis for the plotting and discussion of social, industrial, historical and other data of distinctly human concern." He saw topography and soils as the end product of physiographic history and the beginning of geographic development, thereby uniting the two stated purposes. He states that these "are the most fundamental criteria in determining physiographic provinces."

Natural regions have also been outlined in Canada. Daly (1912) made one of the first systematic classifications of the physiography of the Canadian Cordillera, concentrating especially on the area along the 49th parallel. Bostock

(1948), dealing primarily with the Cordillera north of the 55th parallel, provided a framework for physiographic subdivision which was used by Holland (1964), with some modification, to produce a physiographic outline of British Columbia.

Holland subdivided the Canadian Cordillera, which would include a part of both the Rocky Mountain system and the Intermontane Plateaus divisions in Fenneman's (1928) scheme, into "Western, Interior, and Eastern systems." Each of these would rank as a province in Fenneman's scheme. The Interior system (wherein lies the area discussed in the second part of this thesis) was subdivided by Holland into three "plateau and mountain areas" and the "Rocky Mountain Trench" (equivalent in rank to Fenneman's "sections"), and these in turn were subdivided into still smaller units equivalent to Fenneman's "district," or lower, ranks. Fulton (1975, Table II on p. 5) presented "primary, secondary, and tertiary subdivisions" of the Southern plateau and mountain area.

As noted by Mabbutt (1968, p. 13), Herbertson's and Fenneman's units are large (1 thousand to 1 million square miles; 2.6 thousand to 2.6 million square kilometers), internally complex, and vaguely delimited. Mabbutt also noted that it is not possible to further subdivide the units on the basis of similarity of physiographic history to yield management areas, because the factors controlling the qualities of land vary in importance from one area to another. Subdivision per se is possible, but the basis of subdivision changes, the hierarchical structure is lost, and genetic relationships become the rationalisation for subdivision rather than the criteria (Mabbutt, 1968, p. 13). Linton (1951) had earlier expressed the same idea, pointing out that the physiographic section cannot be subdivided on the basis of structure, process, and stage, because lithology assumes more control on physiography than genetic history at this point.

Holland (1964) claimed that his subdivision of the Cordillera was based on natural regions that were the result of "(1) similar processes of erosion and deposition, (2) similarities in bedrock response to erosion, and (3) similarities of orogenic history." However, Holland described the subdivisions in terms of topography -- not process, resistance to erosion, and orogenic history. Although these factors were discussed, the subdivisions were not, and could not be, defined on these bases.

Another problem with the genetic approach is that its users purport to classify land by the land's genesis. However, landform genesis is not as well understood as many of those engaged in land classification believed that it was when this approach was in vogue. Actually, most of the classifications that Mabbutt (1968) considered under the genetic approach are physiographic land classifications based on form and structure, but not process or stage.

This is not to say that physiographic subdivision is meaningless, but it does not lead to land units that are homogeneous enough to constitute planning or management units. The units are simply too complex to be treated as uniform areas. "Genetically" derived units can provide a framework in which to place land units derived by way of some other approach to land classification, and many educators regard them as useful learning devices.

The Landscape Approach

While the genetic approach attempts to divide the world into natural regions, the "landscape approach" (Mabbutt, 1968, p. 15) attempts to synthesise natural regions from combinations of more basic land units. Bourne (1931) was perhaps the first to express the concept inherent in this approach. This concept is that units of landscape often recur in a regular pattern throughout an area, and that like units can be assumed similar in terms of their physical attributes.

Bourne (1931, p. 16) defined "sites" as areas of practically homogeneous climate, physiography, geology, soil, and edaphic factors in general. These were often seen to occur "again and again within some readily identifiable area," although unique sites are occasionally found. As an example of this concept, Bourne pointed out that all hilltops within an area may be similar to each other; and while slope character is more variable, depending on position, aspect, and steepness, a particular slope facing in a particular direction may be uniform (forming a site) and similar to other slopes in similar topographic positions. Further, the valleys within an area may be divisible into sites, and these sites may often recur.

Bourne (1931, p. 17) noted that, in traversing an area, points are reached at which a particular site, or very commonly the assemblage of sites, ceases to occur. Other sites beyond this boundary can be identified, but they are often distinctly different in character. Bourne saw these points as regional boundaries and suggested that a region is really an association of sites.

It is this idea of a hierarchical arrangement of recurring land units that separates the genetic approach from the landscape approach to land classification. The genetic approach is hierarchical, but each area is considered as unique rather than recurring. Bourne was influenced by the overall impression of an area given by aerial photographs, and he made much use of these in his classification. The landscape approach to land classification has remained dependent on the aerial photographic image since Bourne's initial exposition of the concept of recurring land units.

Unstead (1933) presented a clear exposition of this approach, illustrating the technique in northwestern Europe. He saw the landscape approach not as an alternative to the genetic approach, but as a complementary technique.

Unstead outlined areas in England having similar "relief, structure, water system, plant covering, and form of human utilisation," and having similar inter-relationships. These were regarded as first, or lowest, order units to which he applied the term "stow," an old English word for "place" which had no previous geographical connotation. Each stow could be divided into "features" whose natural arrangement and relative size gave the stow its characteristic appearance. The features differ from stows in that they are very closely inter-related both in position and in causal relationships, and hence best studied together, while stows can be studied as separate units.

Unstead combined the individual stows, each with its own set of features, into a larger unit called a "tract." Tracts were in turn combined to form "sub-regions," sub-regions combined to form "minor regions," and finally, minor regions combined to form "major regions." Table 1.2 lists Unstead's land units, and gives the major criteria by which he suggested they could be differentiated.

Unstead presented his approach as a general method, not as a rigid hierarchy of five orders. He suggested that other areas might need fewer or more levels of classification and that the size of a region is irrelevant to the question of its order. The advantages of this approach according to Unstead include the assurance of increased accuracy through the combination of small regions, and the general view of a region provided by the combined effects of the geographical factors

Land Unit	Criteria
Feature	Close inter-relationship in both position and cause.
Stow	Relief, geologic structure, and soil (singly or in combination) This is the smallest area that can profitably be studied as a unit (p. 185).
Tract	Relief; may include soil, geology, drainage conditions (including man's influence), plant association, and human influence.
Sub-region	Marked relief, geologic structure; may include soil and climate.
Minor Region	Wide extent, marked differences of contained stows and tracts; may include characteristic relief and structure, climate, soil, and plant formation.
Major Region	Climate with characteristic natural vegetation; may include greatly elevated areas where climate and vegetation vary with altitude and exposure.

Table 1.2 Recognition Criteria of Unstead's (1933) Land Units

rather than the limited, single or two feature approach. Additionally, observation of the general character of stows in the field could lead to an investigation of their genesis.

Veatch (1933; 1937; cited by Lacate, 1961, p. 272) described "land types" in Michigan based on topography and soil, although he stated that ideal units would combine climate, physiography, topography, vegetation, animal life, and soil. In 1953, Veatch approached this ideal in his descriptions of land types in terms of soil, physiography, topography, and to a limited extent, vegetation criteria. He also outlined general land-use suitability for specific uses, relative productivity, and adaptability to various land-use intensities for each major landtype (Lacate, 1961, p. 273). In a limited sense, this was land evaluation.

Borrowing Bourne's (1931) concept of site, Linton (1951) proposed unifying subdivision and synthesis in order to place all of the earth into a hierarchical structure. Seeking to standardise the hierarchy and its nomenclature, he further proposed using Unstead's (1933) stow for the basic unit. This would be equivalent to Bourne's (1931) site. Combinations of stows would form tracts, (again Unstead's term) this having previous connotations very similar to its proposed use as a "first subdivision of the physiographic section." The higher units would continue as in previous (American) usage -- section, province and continental subdivision. Linton intentionally avoided the use of the term region because of its indiscriminate previous application. Linton fails to provide the method by which he overcomes the philosophical objections to a changed basis of division. He appears to suggest that subdivision and synthesis mesh at the section-tract boundary.

Weeks and others (1943, cited by Lacate, 1961, p. 273) recorded data on climate, soils, topography, natural vegetation, and timber-site quality in the northern Sierra Nevada of California on a series of maps. The combination of these single component maps was then used to delimit "land-character types." This is the "factorial approach" (Lacate, 1961, p. 273) to land classification, a modification of landscape synthesis.

A further refinement of the landscape approach to land classification, whereby the landscape is divided into relatively homogeneous units whose component physical resource attributes are described, but not mapped, was developed in Australia as a practical means to rapidly survey large areas of land. Christian (1957, p. 75) listed the objectives of these surveys. These were to "describe, classify and map, and (to) assess the land use, developmental possibilities and technical problems of large areas of country about which there was relatively little recorded scientific information and in which there was not any long term traditional form of land use other than hunting and gathering of native foods." The Australian experience in land evaluation requires detailed discussion because it serves as a model for the land classification that is presented in part two of this study.

Christian (1952; 1957), Christian and others (1960), Mabbutt and Stewart (1963), and Lacate (1961) have discussed the development of land research in Australia. The following draws heavily from their reports.

The Northern Australia Regional Survey, later the Division of Land Research and Regional Survey, was established in 1946 by the Commonwealth and the States of Queensland and Western Australia to conduct reconnaisance resource surveys covering up to 50,000 sq. miles (1,300,000 sq. km) in a single season. The landscape approach to land evaluation was developed for these surveys because it was not possible to map individual characteristics in detail at this scale, precise information and detailed maps were nonexistent, and it was unknown what characteristics were important to map in the absence of traditional land uses.

The concepts used in the surveys have been defined by Christian (1952; 1957) and Christian and others (1960). "Land" is regarded as the integration of all the individual land attributes which affect land-use potential and set limits on productivity. These include topography, soils, vegetation, fauna, climate, hydrology, and the range of microenvironments.

The mapping unit, the "land system," was originally defined as "an area, or group of areas, throughout which there is a recurring pattern of topography, soils and vegetation. A change in the pattern determines the boundary of a land system" (Christian and Stewart, 1952). This definition was later changed to include the geomorphological and ecological implications of the land system concept -- "a pattern of landscape, the extent of which is determined by some common factor or factors in the genesis of the landscape such as common geological parent material, geomorphological process, or the stage which the process has reached" (Christian and others, 1960). The land systems are described in terms of their component "land units" and the interrelationships between these. The use of genesis as a criterion of definition in the landscape approach is subject to the same criticisms as its use in the "genetic" approach, but the landscape approach does rely less heavily on this criterion than the latter definition of the land system implies.

The "land unit" resembles Bourne's (1931) site, but it relies more heavily on the genesis of the land form that constitutes the unit than did Bourne's site (Christian and others, 1960, p. 218). (Both the land unit and the site utilise observable characteristics of the unit, also). The value of landscape genesis was believed to lie in its predictive capabilities: "The common genesis of the various occurrences of one land unit. . .implies that they may be similar in many respects additional to those most easily observed," and conversely, separate genesis implies that different units will differ in unobserved characteristics in addition to those observed even though they are superficially similar (Christian, 1957, p. 76).

Christian (1957, p. 76) suggested that the land system is not just a convenient mapping unit, but a natural aggregation of natural units because it results from the recurring and recognisable patterns produced by land units. These in turn have been produced by particular geomorphological processes acting on particular parent materials over a particular length of time. Therefore, Christian believed, land systems will have unrecorded differences of significance to land use because of different origins, irrespective of their appearance.

Mabbutt and Stewart (1963) outlined the methods employed in the Australian surveys. A survey team, consisting of a geomorphologist, pedologist, and plant ecologist, and possibly additional specialists such as a geologist, plant taxonomist, agriculturalist, forester, etc., plans a sampling program based on an aerial photograph layout. A preliminary appraisal of the geomorphology and geology is made from the aerial photography, and aids the planning of field sampling. To ensure rapidity, sample areas are chosen along roads whenever possible. Stress is laid upon coordinated sampling of typical photographic patterns, but allowance is also made for individual scientific interests.

Traverses are planned to sample the sites selected, normally between 300 and 400 sites along about 3000 miles of traverses can be sampled in a three or four month field season in Australia. As the field sampling progresses, an attempt is made to understand the genesis of the patterns observed; further sampling is then directed toward testing the validity of these interpretations. In addition to recording bedrock geology, surficial deposits, soils, vegetation, micro-relief, etc., evidence of landscape dynamics is also sought. This includes erosion or deposition, mass movement, and soil stability.

At the completion of the field survey, the various land attributes are delimited on aerial photographs, using geomorphic, genetic, chronologic, and dynamic principles to be discussed below. After each team member has mapped the boundaries that he requires, some simplification is generally possible by grouping some mapping types as land systems. Each land system is then given a geographic name from a typical occurrence.

Although land system mapping is based on the complex of land features including land forms, surficial deposits, and vegetation, land form is perhaps the easiest to interpret from aerial photographs. Further, pedologically and vegetatively complex environments often may be simply interpreted in geomorphic terms. Land system mapping, therefore, is often based on geomorphic elements such as drainage and relief.

These elements are dominant factors influencing soils and vegetation, and are of additional relevance in land evaluation due to their influences on access and land use. In many land forms, genetic as well as morphologic criteria are combined.

Consideration of land genesis in terrain classification and mapping allows inherent features not visible on aerial photographs to be discerned. Soil type is an example because, under given climatic conditions and with sufficient time available, soil is the product of parent material, relief, and vegetation. Erosional and depositional surfaces are usually separated at some level of classification, and alluvial surfaces can be further subdivided on a genetic basis.

Establishment of a landscape chronology aids in the recognition of genetically-related land forms. Features noted in Australia to establish a chronology include relict weathering profiles, surficial deposits, paleosols, continuity and altitude of land surfaces, and degree of dissection.

Most "landscape processes are too complex to serve alone as a mapping base," but distinction can be made between active and stable land forms in some cases; for example, young depositional landforms such as floodplains (Mabbutt and Stewart, p. 102). The possibility that some landscape features may be inherited from previous conditions must also be considered. It is important to try to understand the dynamic relationships, because interference may upset the natural equilibrium of landscape processes.

Christian (1952; 1957) and Christian and others (1960) discuss the assessment of land-use potential in the Australian surveys. In the absence of established land uses in the areas surveyed, or of areas nearby or far away with which to make reliable comparisons, information on land-use potential has only been available through experimentation.

They contend that an assessment of land-use potential within a particular land unit can confidently be extended to all occurrences of that land unit within its associated land system, but not to apparently similar land units in other land systems without confirmation. Further, if land-use potential is assessed for each land unit within a land system, a general idea of the land system's potential is gained through knowledge of the relative size of its individual land units. Land systems of similar potential can be combined to form "Land-Use Groups" if desirable.

The Australian surveys do not attempt to provide detailed land-use recommendations or even land-use potential assessments. Rather, they "establish the basic facts on which subsequent investigations can be planned. . . .Broad forms of land use can be predicted, but it is not possible to predict levels of production or their degree of economic success" (Christian and others, 1960). Since the "best" form of land use depends on present knowledge of land-use problems and markets, land classification and land assessment are treated as separate phases of the investigation (Christian, 1957, p. 78).

Land research, using concepts very similar to those developed in Australia, has been carried out at the Soil Science Laboratory, Oxford, for the Military Engineering Experimental Establishment. However, during the course of this research, it became clear that the applications would be mainly civil, and it is in this context that Webster and Beckett (1970) described the classification system and its use. The following is a summary of their review.

The purpose of the research was to develop the potential "for predicting soil and terrain or land conditions over large areas of undeveloped countries where information is sparse." In order to appraise land resources within a reasonable time frame, aerial photographs were chosen as the basic data source to be supplemented by limited ground observations.

The system of land classification developed to meet this objective is remarkably similar to that developed in

Australia; and through the efforts of Brink and others (1966) even the terminology has converged. It also influenced the land classification presented in part two of this study.

The mapping unit, land system (originally called "recurrent landscape pattern"), in essence is equivalent to the Australian land system. Each land system is composed of smaller areas "usually with simple form, on a particular rock or superficial deposit, and with soil and water regime that are either uniform over the whole. . .(or) vary in a simple and consistent way" (Webster and Beckett, 1970, p. 54). These smaller areas are analogous to the Australian "land unit" but are called "land facets" after Wooldridge's (1932) "facet."

This classification was intended for moderately extensive land use, but for some purposes it was felt that the land facet might not be sufficiently homogeneous. Therefore, "land elements" and "variants" were defined. Land elements are "the smallest unit of terrain likely to be of interest." Examples would be a flat crest element, and convex margin element of a plateau facet. Land elements must be recognisable on aerial photographs. Variants, on the other hand, are usually not recognisable from surface appearance. They are parts of a land facet that are important, but not obvious, such as substrate differences important for engineering purposes.

Land facets are restricted to single land systems in a particular locality because of the difficulty and uncertainty of recognising a particular facet in a different landscape with different associates, and because widely separated homologous facets are extremely unlikely to have identical properties. It was originally thought that similar rocks, weathering under similar climatic, tectonic, and erosional conditions would produce similar landscapes, but long range prediction proved very risky. Knowledge of the "environmental controls (on landscape) was rarely complete enough to allow matching of widely separated landscapes" (Webster and Beckett, 1970, p. 56). When land facets belonging to different land systems are shown to be sufficiently similar, prediction may be made from one to the other by cross-referencing, or by defining "abstract" land facets.

Webster and Beckett (1970) described their classifying and mapping procedure in three stages. First, provisional land system boundaries were delineated on aerial photograph mosaics where many distinct visual patterns are evident. Additional boundaries were inserted where field knowledge or supplementary sources such as geologic, ecologic, soil, or topographic maps indicated their existence. It was considered important at this stage to include as many boundaries as could be detected; redundant boundaries could be omitted later, and all could be adjusted because they were only provisional.

Once the patterns had been delineated, the next stage was their definition and identification. Stereoscopic examination of the aerial photographs, in conjunction with field records, was used to define the land facets and describe their land form, rock, soil, water regime, and land cover. Tentative land facets were defined in the absence of prior field work, and these were revised when field work was completed. The land facets in part of each area were then mapped to ensure that all land was included.

The land systems were defined in terms of their contained land facets and of the relationships between them. Webster and Beckett stated that most occurrences of a land system should contain all the land facets found in that land system, but that one or two may be missing as long as the remainder retain the same relationships. Block diagrams and annotated stereo-pairs or triplets are provided in the reports to aid user recognition of the land facets.

The last stage is the actual map production. Land system boundaries are located on the aerial photographs, and the provisional map is modified by drawing in the now accurate land system boundaries.

Webster and Beckett (1970, p. 73) had intended to "collect information on the use and potential of the land resources of a territory and to index them in a data store according to the classes of land to which they referred. But the work was drawn to a close before this could be demonstrated." Therefore, their work is land classification, not land evaluation.

The landscape approach to land classification has been widely applied in Canada, where it has come to be known as "Ecological Land Classification" (Wiken and Ironside, 1977). Much of the early impetus toward an integrated landscape approach to land classification (and evaluation) in Canada was provided by a forester, G.A. Hills, in Ontario. Hills described the principles of "ecological classification of land," for various uses, as applied by the Ontario Department of Lands and Forests (Hills, 1961). He referred to the classification as a "total site" classification "based on the perceivable features of both vegetation and physiography (i.e. landform and climate) which are significant in the establishment and growth of crops." Total site type was equated to an ecosystem (Hills, 1961, p. 17).

Hills defined a "landtype" as "an area of land within a specific climatic region which is classified according to the texture and petrography of the geologic materials," but stated that, because these are areas of land, they possess "characteristics of 'relief' as well as those of 'materials.'"

Landtypes may then be "described as a combination of landform and climate" (Hills, 1961, p. 18).

Hills presented a scheme for landtype subdivision into "physiographic site units" at several levels. Physiographic site "classes" are subdivisions of the landtype based on soil moisture, depth of material, and local climate. Since site classes based on one criterion are not necessarily coincident with site classes based on other criteria, a physiographic site "type" was defined as the unit resulting from subdivision of a landtype based on all gradients used in establishing site classes. The ultimate physiographic site unit, simply called the "physiographic site," was a subdivision of the site type based on "any physiographic feature of significance in land use." Hills cited variations in soil profile, stoniness, slope, aspect, texture, and petrography of soil materials as examples of criteria for subdivision of site types into sites (Hills, 1961, p. 21-22).

The basic taxonomic unit, the site type, was seen as inconveniently small for management purposes; therefore, Hills defined "landtype components" composed of one or more physiographic site types. These management areas were not separately mapped, but could be located by reference to their defining site types (Hills, 1961, p. 23). Hill was fully aware that classification is purpose oriented. He developed his scheme for use in agriculture and forestry, but suggested that it could be applied to other problems with some modification.

Other than Hills' scheme, few approaches toward land classification in Canada considered more than a very few land attributes prior to the early 1960's, being primarily soil surveys, timber surveys, or other monodisciplinary classifications. However, the need for a land capability inventory, expressed at the "Resources for Tomorrow" Conference in 1961, lead to the establishment of the Canada Land Inventory (CLI) and the development of an integrated approach to land classification for land capability assessment (Canada, 1965, p. 1).

The Canada Land Inventory, as noted by Wiken and Ironside (1977, p. 273), was interpretive, "providing land capability ratings for agriculture, forestry, recreation, wildlife (ungulates and waterfowl) and sport fish." The baseline data necessary for these interpretations, however, was not available for much of the area to be covered by the inventory. In 1964, the National Committee on Forest Lands established a subcommittee to explore alternative approaches to a rapid and inexpensive survey to gather the essential data. The Subcommittee on Bio-physical Land Classification published guidelines to this end in 1969 (Lacate, 1969) after a series of preliminary guidelines and pilot studies.

The guidelines were designed to "differentiate and classify ecologically-significant segments of the land surface, rapidly and at a small scale. . .to satisfy the need for an initial overview and inventory of forest land and associated wildland resources (Lacate, 1969, p. 2). Patterns of soil, landform, vegetation, and water, rather than single attributes, were to be mapped, and the subcommittee strongly recommended that photo-interpretation be undertaken prior to field work.

The subcommittee outlined a hierarchy of land units for four levels of generalisation which would be practical for mapping at scales of 1:3,000,000 to 1:10,000. "Land regions" were defined on the basis of regional climate as expressed by vegetation. "Land districts" were subdivisions of land regions characterised by a distinctive pattern of relief, geology, geomorphology and associated regional vegetation." "Land systems" were defined as "area(s) of land throughout which there is a recurring pattern of landforms, soils, and vegetation" (A definition admittedly borrowed with slight modification from Christian and Stewart, 1952). This unit was suggested as the most appropriate level at which to concentrate mapping efforts in light of the objectives set forth above. The "land type," however, was the basic unit for which specific use capability ratings were to be made. It was defined as "an area of land, on a particular parent material, having a fairly homogeneous combination of soil. . .and chronosequence of vegetation."

The subcommittee noted that not all pilot studies used land regions or land districts, and that meaningful boundaries for these might not be developed until after the smaller land units are documented and understood. The land type was not intended as a map unit, but its characteristics, and its distribution within the land system, were to be clearly indicated by cross sections or block diagrams and accompanying tables.

An example of the application of the guidelines contained in the Canadian Bio-physical Land Classification (Lacate, 1969) is found in Hawes' (1974) thesis in Soil Science at the University of British Columbia. Hawes mapped land systems in the southern Okanagan Valley on aerial photographs, then field checked the land systems and their boundaries at approximately 130 sites. Sixty of these sites were studied in detail to provide habitat descriptions. Fourteen soils were sampled and analysed for engineering interpretations.

Thirty-nine land systems were described. The description of each land system includes its name, a vertical air photo stereo pair of a typical occurrence, and one paragraph descriptions of landforms and materials, vegetation, soils, and landscape features (elevations, slopes, etc.). A comment on suitability for engineering, recreation, and wildlife, and a ground level color photograph completes the individual land system descriptions. Hawes also presented tables of "limitation ratings" (ranging from none or slight to severe) for engineering, recreation, and wildlife, and discussed the criteria by which these were developed. He did not map or discuss land regions, districts, or types.

Considering the importance of the land type in the overall scheme, the omission of this level of classification seriously affects the utility of Hawes' report. The land system, as noted by Lacate (1969, p. 7), is a complex unit, within which there is a heterogenous pattern of vegetation and soils. The land system, as defined by Lacate and used by Hawes, is not a suitable vehicle for land evaluation in other than very broad terms.

The National Committee on Forest Land (NCFL) was dissolved in 1972. Thereafter, the guidelines for bio-physical land classification, originally intended as "first approximations," were left without a forum for discussion and improvement. The NCFL was dissolved because its original purpose as an advisory body to the Canada Land

Inventory no longer existed when the CLI was terminated. However, many people in government, education, and industry felt that a nationally coordinated approach to land classification was still desirable. In 1976, a meeting was called at Petawawa, Ontario, to discuss the state of bio-physical land classification in Canada, and to determine if a national forum was necessary and feasible. From this meeting, the Canada Committee on Ecological (Biophysical) Land Classification (CCELC) emerged.

The CCELC was described by Wiken and Ironside (1977, p. 274) as "an interdisciplinary group consisting of representatives from federal and provincial governments, universities and private sectors." The main objective of the CCELC is "to encourage the continued development and to promote the application of a uniform ecological (bio-physical) approach to land classification for resource planning, management and environmental impact assessment purposes" (CCELC, 1976). The technical work of the CCELC is to be provided by working groups -- Methodology/Philosophy, Applications, Data Handling, Wetlands Classification, Land/Water Integration, and possibly others not yet established.

It can be seen then, that many individuals in Canada are interested in a landscape-type approach to land classification. The third approach to land classification recognised by Mabbutt (1968) -- the parametric approach -- has been integrated to various degrees with the landscape approach by some of these individuals, and is not necessarily an alternative approach. Mabbutt recognised this and suggested that these approaches can be combined with the genetic approach to reinforce each other (Mabbutt, 1968, p. 26). However, Mabbutt discussed each approach separately in order to maintain clarity, and this report follows his example.

The Parametric Approach

Mabbutt (1968, p. 21) has defined the parametric approach to land classification as "the division and classification of land on the basis of selected attribute values." Mitchell (1973, p. 34) outlined the three paramount considerations inherent to this approach: the choice of attributes to be mapped, their subdivision into classes, and the recognition of these classes.

Selection of the attributes to be mapped depends on the purpose of the classification, but whatever the attributes, they must be recognisable and measureable. The landscape approach often defines land units on the basis of criteria that are either present or absent. This greatly facilitates recognition, but limits precision. The parametric approach, however, often subdivides a land attribute into classes based on measured limits. The selection of the limiting values used to define classes may be arbitrary, especially if the classification must be general to meet a range of needs; the limits may be chosen as the value of the attribute in question at significant natural breaks in the landscape, either directly significant or significant to a particular land use; or they may be based entirely on the attribute values that limit a particular use even in the absence of a natural break.

Both Mabbutt (1968) and Mitchell (1973) discuss particular applications of the parametric approach to land classification and evaluation. The majority of these applications have been for military, engineering, or detailed governmental planning purposes, but the parametric approach has also been used in geology, geomorphology, hydrology, biology, meteorology, climatology, pedology, and other fields.

This approach offers several advantages over the genetic and landscape approaches to land classification. As noted by Mitchell (1973, p. 36), it reduces the subjectivity of the classification because the land units are objectively delimited once the attributes and their class limits are chosen; the sampling procedure can be rationalised to achieve a particular level of confidence, and the variance and probability limits of attributes can be statistically determined. It is more suited to computer data handling and storage, and can be modified in light of new information about the land attributes or user needs.

Mitchell also noted several disadvantages (1973, p. 36) including the difficulty of selecting the parameters and class limits used to define the land units, the inability to extrapolate results beyond the location where they were determined, and therefore, the necessity of collecting data on a detailed level. It may by possible, however, to select parameters and class limits through the application of numerical taxonomy (Sneath and Sokal, 1973), and data collection problems are largely overcome if the defining parameters can be remotely scanned. Remote-sensing techniques are presently capable of sensing a wide range of attributes, and rapid advances are being made in this field. Some of these techniques and their potential will be discussed in the final part of this study.

Part Two: A Land Classification of the Merritt Area

Introduction

This part of the study presents the results of a landscape land classification of the Merritt area, British Columbia (See inset map on Plate 1 for location). Although land-use practices are firmly established in the area, it was hoped that an integrated approach to land classification would produce a basis for an evaluation of present use and suggestions for improvements in land use.

The landscape approach to land classification has been widely employed in Australia, Britain, Canada, and elsewhere, but primarily at a reconnaisance level in sparsely settled areas, and rarely with a meaningful evaluation. Land classification, using a landscape approach, has been conducted at large scales; but an evaluation, in the sense of judging the suitability or desireability of land for man's use (see Stewart, 1968, p. 1), based on a large-scale landscape land classification has not been presented.

Several advantages of a landscape approach to land evaluation have been suggested: the method (1) can make use of remote-sensing techniques, (2) minimises field research time and expense because it allows transfer of information from one area to other similar areas, (3) can be applied at any scale, (4) facilitates understanding of land attributes and their interactions, (5) provides a basis for further studies, (6) can make use of computers for data entry, manipulation, storage, and retrieval, and (7) the evaluation can be modified in light of new information about the land, or changing technolcgy, finances, and attitudes. These advantages will be critically evaluated in the final part of this study, based on the testing of the technique within the study area.

The study area was selected for the following reasons. It was originally perceived as a relatively discrete, functional unit, but it soon became apparent that this perception was naive, if not entirely false. Nevertheless, the area is bounded almost entirely by impressive topographic barriers, penetrated at only four points by important corridors linking it to the outside. Three of these links are through narrow river valleys, while the fourth must ascend to the plateau surface. Therefore, although the area is not discrete, it is somewhat isolated from surrounding areas, and it was felt that the mthod could be applied and tested here.

Secondly, much of the area is open grassland, and both grassland and forest are criss-crossed by "dirt" roads. This allowed relatively easy access for field investigations.

Additional considerations included accessibility from the Vancouver area, availability of large-scale aerial photography, and personal aesthetic appreciation of the area.

A search for previously documented information applicable within the study area produced a physiographic framework (Bostock, 1948; Holland, 1964; Fulton, 1975), climatic data (British Columbia, 1975; Weir, 1964), treatises on bedrock geology (Dawson, 1879; 1895; Cockfield, 1948) and surficial geology (Fulton, 1975), vegetation studies of nearby areas (Spilsbury and Tisdale, 1944; Tisdale, 1947; van Ryswyk and others, 1966; Brayshaw, 1970; McLean, 1970; McLean and Marchand, 1968), limited hydrologic information (Canada, 1972; Fulton, 1975), a preliminary map of soil associations (British Columbia, 1976b), historical information (Weir, 1964), a cultural and economic summary (British Columbia, 1972), a topographic map (Canada, 1968), and aerial photograph coverage (British Columbia, 1976a). These documents provided important information used to classify land in the study area. They could also provide information that would be useful in any evaluation of potential land use.

The study area is located in the southern Interior Plateau region of British Columbia between 50° 0' and 50° 13' N latitude and 120° 35' and 120° 52' W longitude. The only town within the area is Merritt. Kamloops is 95 km north, Princeton is 90 km east, and Vancouver is 370 km southwest by way of Spences Bridge and the Thompson and Fraser River Canyons. Construction of the Coquihalla Pass Road, slated for the mid 1980's, will shorten the distance to Vancouver by about 100 km.

The boundaries of the study area were selected to include an area around Merritt which appeared to be large enough to include a variety of land types, yet small enough to allow a reasonably thorough reconnaisance-level landscape land evaluation in a single field season. The boundaries cross Nicola Lake, the Nicola and Coldwater Rivers, and Shuta and Clapperton Creeks at arbitrarily selected points, but elsewhere are drawn along major or minor drainage divides.

The positions of the study area boundaries have no special significance, being chosen primarily for convenience. Many of the land systems later identified would extend across the study area boundaries if the same land classification technique was applied to adjacent areas, and even drainage "divides" are occupied by closed depressions that perhaps drain in both directions. A universally acceptable, natural boundary does not exist.

Physiography

The Interior Plateau is part of Bostock's (1948) and Holland's (1964) Southern Plateau and Mountain Area of the Interior system. The study area lies within the Thompson Plateau, a subdivision of the Interior system, described by Holland (1964, p. 71) as "a gently rolling upland of low relief. . .dissected by the Thompson River and its tributaries and by the Similkameen and Okanagan Rivers tributary to the Columbia." Fulton (1975, Table II on p. 5, and figure 4) has subdivided the Thompson Plateau into valleys, midlands, and uplands. The study area includes parts of Fulton's Nicola and Coldwater valleys, and the Nicola, Iron, and Coutlee Uplands.

The Nicola Valley, as defined by Fulton, extends from beyond the northeast boundary of the study area, where it is occupied by Nicola Lake, through Merritt, to and beyond Lower Nicola located just northwest of the study area. The floor of the valley descends from 627 metres at the outlet of Nicola Lake to less than 580 metres northwest of Merritt. Elsewhere, the Nicola Valley is a narrow trench, but within the study area it is generally a broad, open valley.

The Nicola Upland lies to the north of the Nicola Valley. Little of the upland exceeds 1200 metres in the study area, but a large proportion lies between 1200 and 1750 metres further north.

More than half of the study area is contained within the Iron Upland, an area similar to the Nicola upland but extending southeast from the Nicola and Coldwater Valleys. Iron Mountain, in the southern part of the area is the highest point in this upland at 1693 metres. Most of the Iron Upland lies between 1100 and 1400 metres.

The Coutlee Upland occupies a small area in the west of the study area, rises to 1160 metres within the area, and is separated from the Iron Upland by the Coldwater Valley, a deep trench occupied by the Coldwater River.

Relative relief (the elevation difference between peaks or ridges, and their adjacent valleys) within the uplands of the study area is generally about 150 metres, but these areas stand generally 450 to 750 metres above the main valleys and reach more than 1000 metres above the Nicola Valley at Iron Mountain.

Climate

The study area is located in the interior dry belt of British Columbia, but the climate is much more varied than this label implies. Located in the rain shadow of the Coast Mountains to the west, and bounded on the east by the Columbia Mountains, it is a relatively dry belt, but elevation and other topographic influences create a climatic mosaic within the area. Unfortunately, virtually all reasonably long term climatic records pertain to stations located in the valleys. It can reasonably be concluded that the plateau proper is cooler and moister than the intervening valleys, but to what precise degree is a matter of conjecture.

Mean monthly temperature and precipitation data for Merritt (585 m), and for Craigmont Mine (731 m) nine kilometres northwest of the study area, illustrate the effect that even a small elevation difference can have on these climatic variables (Table 2.1). Precipitation is higher at Craigmont Mine for every month of the year, and annual precipitation is 140 percent of that at Merritt. Winter snowfall is almost double. Temperature differences are not as pronounced, but Craigmont Mine's mean monthly temperature is less than Merritt's during four months, and more only during February.

Merritt (585 m)
Mean Monthly Temperatures (°C.) and Precipitation (cm)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
T.	-7	-3	2	7	12	15	18	17	13	7	1	-4
P.	2.4	2.1	1.6	1.4	1.6	2.1	1.4	1.9	1.8	1.9	2.4	3.4

Mean Annual Temperature: 7° C.
Mean Annual Precipitation: 23.9 cm
Mean Annual Snowfall: 73.7 cm

Craigmont Mine (731 m)
Mean Monthly Temperatures (°C.) and Precipitation (cm)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
T.	-7	-1	2	5	10	15	17	17	13	7	1	-7
P.	5.3	2.5	2.3	1.9	1.7	2.6	2.0	2.0	1.9	2.9	2.9	5.5

Mean Annual Temperature: 6° C.
Mean Annual Precipitation: 33.6 cm
Mean Annual Snowfall: 139.2 cm

Table 2.1 Climatic Data for Merritt and Craigmont Mine. (from British Columbia, 1975).

Merritt is within Koppen's middle latitude steppe climate (BSk), but very close to the boundary between the steppe and humid microthermal (Dsb) climates. Craigmont Mine, because of its higher precipitation, is across this boundary, which can be approximated very generally in the study area by the 2200 foot (670 m) contour. Due to the absence of climatic data on the plateau surface, the upper limit of the dry summer phase of the humid microthermal climate (Ds) cannot be estimated with even this semblance of accuracy, but most of the study area above about 3500 to 4000 feet (1050 to 1200 m) receives enough summer rainfall to be classified as humid microthermal with no pronounced dry season (Dfb) (Fulton, 1975, p. 2). Iron Mountain, only seven kilometres from downtown Merritt, extends up into the subarctic climate zone (Dfc).

Spatial climatic variation in the study area is accompanied by marked temporal variation of climatic parameters. The July mean temperature at Merritt (18° C.) is the result of a July mean daily maximum temperature of 25° C. and mean daily minimum of 10° C. During thirty-seven years of record, the July temperature reached an extreme of 39° C. The January range of mean daily temperatures is smaller (-2 to -12° C.), but the temperature dropped as low as -43° C. during the same thirty-nine year period.

Precipitation, too, is very variable, as is common in arid and semi-arid climatic zones. In October, 1965, only 0.33 cm of rain fell at Craigmont Mine, while the same month recorded 14.78 cm two years later. Annual rainfall totalled 26.31 cm in 1963, and 40.54 cm in 1971 at the same station. Snowfall in 1963 at Craigmont mine was low also, only 27 cm, but 1972's snowfall totalled 266 cm. This variability is evident from only eleven years of record at Craigmont Mine; it undoubtably only hints at the actual long-term variation.

The variability in temperature and rainfall is primarily the result of the types of air masses that penetrate to the southern Interior. These are of three types: (1) maritime polar air modified by passage over the Coast Mountains, (2) polar continental air originating in the high pressure cell over the Yukon, and (3) modified dry interior air found in the valleys and and basins (Weir, 1964, p. 32). Generally, the air flow is from the Pacific bringing the possibliity of rain or snow. Much of its moisture, though, is usually lost in passing over the Coast Mountains and it warms and dries as it descends in the Interior, accounting for much lower precipitation totals here than in the mountains both west and east.

The normal flow of Pacific air is sometimes blocked by invasions of polar continental air from the Yukon. There are no major topographic barriers to prevent this from happening, and when it does the temperature plummets under clear blue skies. In the absence of a pronounced flow of Pacific air, or an outbreak of polar continental air, stable dry air collects in the major valleys from where it can only be displaced by renewed Pacific air flow or an outbreak of polar air.

In summer months, warm dry air from the Pacific high pressure cell is further warmed by its descent over the Coast Mountains, resulting in the high temperatures and low humidities characteristic of the plateau at this time of year.

Frost severely limits the agricultural potential of much of the southern Interior. An outbreak of cold polar air may bring frost to areas above 3000 feet (910 m) even in July and August (Weir, 1964, p. 34). In addition, the frequently clear skies allow rapid radiation of heat from the ground surface, especially at higher altitudes where the air is clearer. This cools the air in contact with the surface, increasing its density. This cold, dense air then flows downslope, displaces the air in the valley, and collects as a pool of cold air. Only those terraces and slopes above this cold air will escape the resulting frost. This phenomenon probably accounts for the higher February mean temperature, noted above, at Craigmont Mine than at Merritt (See figure 2.1).

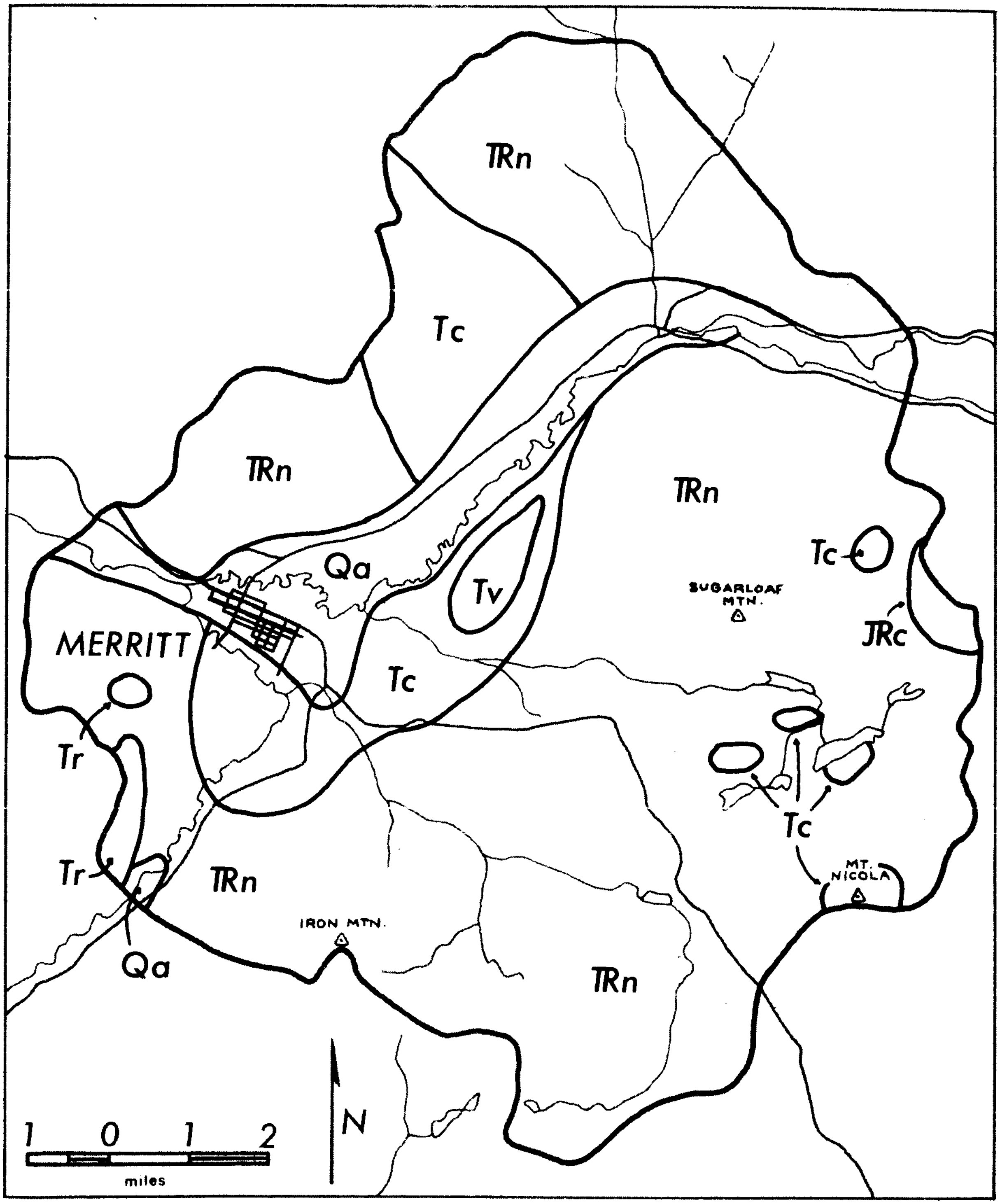
This second frost producing phenomenon is an example of the effect of some of the micro-climatic factors found in the southern Interior. These factors include aspect, exposure, topographic position, orientation, albedo, vegetation, and even soil bulk density. It is outside the scope of this study to discuss in detail the effects of these factors, but several are mentioned in the land classification presented below. Detailed consideration of any of these factors was prohibited by time considerations, but their effects would need to be considered in meaningful land planning and management.

Geology

Dawson (1879, 1895) was the earliest to describe the geology of this part of the southern Interior in detail, but the most comprehensive report on the bedrock geology is by Cockfield (1948). Except as otherwise indicated, this discussion of bedrock geology is based on Cockfield's report and map (See figure 2.1).

The consolidated rocks in the study area range from upper Triassic to Miocene or later. The type section of the oldest rocks of the area, the upper Triassic Nicola group, is near Nicola Lake and was first described by Dawson (1895, p. B131). Cockfield (1948, p. 11) describes the Nicola group as principally altered andesitic and basaltic volcanic rocks with minor limestone, argillite, and conglomerate. The Nicola rocks are more abundant than any other in the study area and form most of the upland surfaces. They extend northward from here in a broad band to north of Kamloops Lake. Some copper ore has been recovered from quartz lenses in these rocks south of the Nicola River just west of Merritt, but these mines are not presently being worked. Small amounts of silver, gold lead, iron, tungsten, and gypsum have also been recovered from the Nicola group.

Northwest of Lundbom Lake in the study area, and at



Quaternary	Qa - Recent alluvium
Tertiary	Tv - Valley basalts Tr - Rhyolites Tc - Coldwater sediments
Jurassic	JRc - Coast intrusions
Triassic	TRn - Nicola group

Figure 2.1 Bedrock Geology (after Cockfield, 1948)

numerous places outside the study area, the Nicola group is intruded by Jurassic, and possibly later, granitic rocks referred to as the Coast intrusions. These vary generally from granodiorite to quartz diorite, but locally include gabbro and ultrabasic rocks. Important copper deposits are being mined from these rocks outside the study area.

Miocene or earlier sediments of the Kamloops group occupy much of the Nicola and Coldwater River Valleys in the study area, and extend from west of the outlet of Nicola Lake, up on to the plateau. Small areas of similar rock are found around Lundbom Lake and at Mount Nicola on the Iron upland, but these may include some younger rocks. The preserved remnants of the Kamloops group in the study area include the Coldwater beds, the similar deposits on the upland surface, and volcanic rocks. This group also includes the Tranquille beds, but these are not found in the study area.

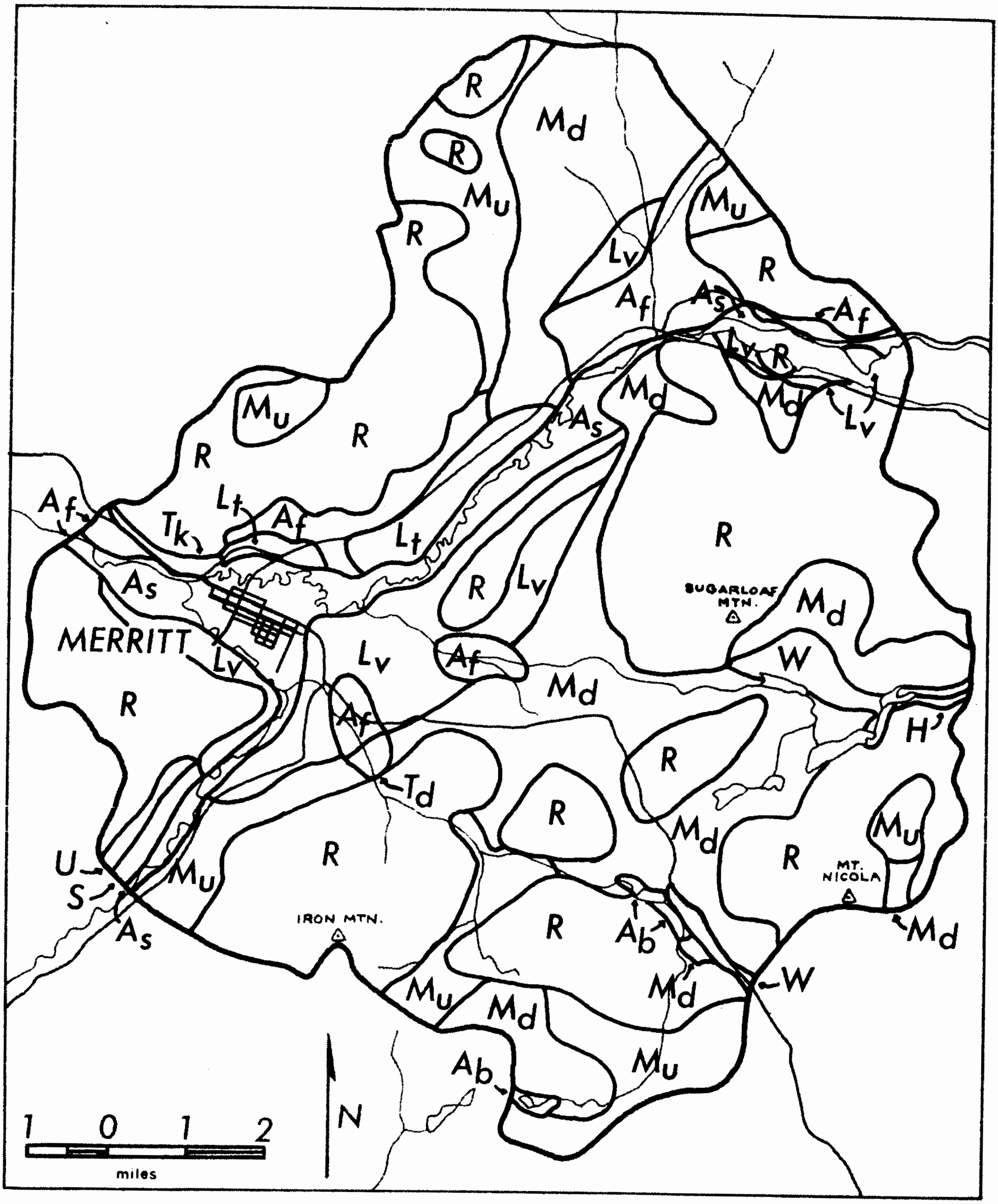
The Coldwater beds are conglomerates, sandstones, shales and coal. The coal seams are up to 4.5 metres thick, but are difficult to trace and cannot be correlated over any distance because the beds are folded and faulted, and they change character throughout the basin. High Volatile Bituminous B Coal was produced from these sediments between 1906 and 1963, but the mines are presently idle. The Kamloops group volcanic rocks include rhyolites, andesites and basalts, and associated tuffs, breccias and agglomerates. These are found above the Coldwater River southwest of Merritt, and also occur outside the study area.

The youngest rocks on the southern Interior Plateau are a series of flat-lying, dark basaltic lava flows which occur as benches along the southeast side of the Nicola River northeast of Merritt, and along the west side of Quilchena Creek just east of the study area. These are referred to as the valley basalts. The bench northeast of Merritt consists of little-altered, usually vesictlar flows that form a prominant scarp about 100 metres high.

No contact between the valley basalts and the Coldwater sediments has been discovered, but the Coldwater rocks dip 25 to 30 degrees where found nearby, and dips cf 70 degrees to near vertical are found "less than a mile from. . .outcrops of these horizontal basalts" (Cockfield, 1948, p. 41). Cockfield assigned a Miocene or younger age to the lavas, and suggested that they may be of Pliocene age. Fulton (1975, p. 4), however, states that their occurrence in valley bottoms, lack of surface modification, and superposition on unconsolidated, possibly interglacial sediments suggests a possible Quaternary age. This is supported by a potassium-argon analysis that failed to detect any argon in a whole rock sample containing one percent potassium. This would indicate an age of less than one million years or that argon had escaped from the sample. Fulton further noted that the basalts predate the last (Fraser) glaciation because deposits of this age contain striated valley basalt erratics.

With the possible exception of the valley basalts discussed above, all Pleistocene and Recent deposits in the Merritt area consist of unconsolidated materials -- glacial, lacustrine, alluvial, and colluvial deposits. Dawson (1895) was the first to discuss glaciation and surface deposits in the southern Interior in detail. Fulton (1975) summarised other reports dealing with unconsolidated deposits in the Nicola-Vernon area, which includes the study area, and discussed in detail the surficial geology, Quaternary historical geology, and economic geology of the surficial deposits. Except where indicated, the section on surficial geology which follows is based on Fulton's report as it pertains to the Merritt area (See figure 2.2).

Evidence of at least two glaciations can be found in the southern Interior, separated by, and overlain by, non-glacial deposits. The older of the two recognised glacial deposits is referred to as Okanagan Centre drift (Fulton, 1975, p. 11). A laminated silt that is probably correlative with the upper part of Okanagan Centre drift is found south of Merritt near the Coldwater River in the study area. A pre-Olympia



A - Modern Alluvium: A_s, Stream; A_f, Alluvial Fan; A_b, Bog
S - Landslide Deposits
L - Lacustrine Deposits: L_t, Thick; L_v, Veneer
T - Terrace Deposits: T_d, Delta; T_k, Kettle
W - Rill Complex
H - Hummocky Gravels
M - Morainal Deposits: M_d, Drumlinoidal; M_u, Undifferentiated
U - Older Unconsolidated Deposits
R - Rock Outcrops and Near-surface Rock

Figure 2.2 Surficial Geology (after Fulton, 1975)

Interglacial age is assigned to these deposits, indicating that some may be older than the glacial period immediately preceding Olympia Interglacial time.

Overlying Okanagan Centre drift are sand, silt, and gravel deposits of Olympia Interglacial age -- the Bessette sediments (Fulton, 1975, p. 15). These are probably represented in the study area by 39 metres of oxidised sand, silt, and gravel south of Merritt.

The Besette sediments are overlain by glacial deposits consisting of a lower stratified unit, a middle nonstratified unit, and an upper stratified unit. These three units are thought to represent the Fraser glaciation (Armstrong and others, 1965) in the southern Interior, and are referred to as Kamloops drift (Fulton, 1975, p. 17).

The probable lower unit of Kamloops drift is represented south of Merritt by nine metres of sand and silt, and up to twelve metres of gravel. The lower unit is thought to represent proglacial deposits laid down between 18 and 20 thousand years before present.

The most widespread glacial deposits in the study area are those of the nonstratified unit of Kamloops drift, which primarily take the form of drumlinoidal moraines here.

Drumlinoidal moraines are "morainal deposits characterized by streamlined ridges and grooves" (Fulton, 1975, p. 20). Ground moraine without streamlined or linear elements is also found in the study area.

The upper stratified unit of Kamloops drift is well represented in the study area and can be subdivided into deposits laid down by running water and those formed in standing water. The fluviatile deposits include rill complexes, terrace deposits, and hummocky gravels in the study area.

Rill complexes are found at two places in the study area, both occupying former outwash channels. One is in the valley followed by the road to Princeton, extending to and beyond the southeast boundary of the study area, while the other is in a similar valley north of Hamilton Lake and extending northeast from Lundbom Lake to the edge of the study area and over the divide to the upper end of Teenamilsts Creek, a tributary of Quilchena Creek.

Two types of terrace deposits are represented in the study area, a delta terrace southeast of Merritt that has been bisected by Godey Creek, and a small kame terrace north of the Nicola River at its junction with the Coldwater River. Hummocky gravels, deposited by running water in contact with ice, are poorly represented in the study area where they occur as chaotic hummocks and ridges northeast of Lundbom Lake.

The lacustrine deposits included in the upper unit of Kamloops drift include thick lacustrine deposits and lacustrine veneer deposits in the study area, and undifferentiated, complex, and collapsed lacustrine deposits elsewhere. Only the units occurring in the study area are considered here. Thick lacustrine deposits are confined to the north and northeast side of the Nicola River from Merritt to a point about seven or eight kilometres northeast. The river is entrenched more than twenty metres below their surface forming an abrupt, scalloped scarp, and they are overlain on their north and northeast flank by post-glacial alluvial deposits. Lacustrine veneer deposits occur in the main valleys throughout the study area except where overlain by Recent deposits or where slopes were too steep to retain these deposits.

Post-Fraser glaciation deposits in the southern Interior include modern stream and lake alluvium, alluvial fans, bog deposits, landslide deposits, colluvium, aeolian deposits, and volcanic ash. Many of these deposits overlie and were derived from the unconsolidated deposits of glacial age.

Fulton (1975, p. 28) described alluvial deposits as "complexes of sand, gravel, silt, muck, and peat, deposited. . .in stream floodplains, deltas, and along shorelines." These deposits occupy the lowest portions of the Coldwater River valleys, isolated reaches along minor drainage courses, and lake basins in the study area.

Alluvial fan deposits, consisting of poorly sorted gravel, sand, silt, and clay, are formed where tributary streams leave laterally confined channels and deposit their load in a generally fan shaped wedge. Ryder (1971), and Church and Ryder (1972), have discussed the development of "paraglacial" alluvial fans in part of the southern Interior. They define paraglacial fans as alluvial fans formed shortly after glaciation, by processes that are directly conditioned by glaciation. These fans were constructed by streams that derived their load from the abundant sediment supply produced by glacial erosion and deposition prior to about 6000 years ago. They have since been subject to degradation. The incised portion of Clapperton Creek's alluvial fan, near the outlet of Nicola Lake, is probably attributable to paraglacial sedimentation.

Other alluvial fans, probably actively receiving sediments, are found where Hamilton and Godey creeks leave confined reaches, and at similar positions on numerous small creeks elsewhere in the study area. A fairly continuous alluvial apron is found at the base of valley walls in several areas.

Bogs are common on upland surfaces in the study area and are also found on modern floodplains in the major valleys. They are dominately organic deposits occupying shallow closed depression, lake or stream margins, or poorly drained, gentle slopes. Sand, silt, and clay may be interbedded with organic deposits in some bogs, and all bogs contain one or two beds of volcanic ash.

Landslide deposits of notable extent are found only along the northwest side of the Coldwater River south of Merritt. The river here appears to have cut down about 100 metres in post-glacial time and this may have initiated the instability that resulted in these landslides. Colluvial deposits, poorly sorted and poorly washed materials produced by mass movement processes, are found at the base of, and sometimes on, slopes in many parts of the study area.

No extensive aeolian deposits were noted in the study area, but as Fulton (1975, p. 31) suggested, the most active aeolian activity would have occurred before vegetation was established following glaciation. Most soils in the area have probably been enriched by aeolian silt, and extensive areas of loess would be difficult to distinguish from lacustrine veneer deposits.

At least two volcanic ash deposits are found in the study area. These are valuable stratigraphic markers that have been tentatively correlated with eruptions at Mount Mazama and Mount St. Helens about 6600 and 3200 years ago, respectively. The Mazama ash was used by Church and Ryder (1972, p. 3063) to estimate the end of paraglacial sedimentation.

The rocks of the Nicola group record a period of volcanic activity, interspersed with marine (and continental?) sedimentation, during the Triassic. These rocks were laid down on apparently eroded Cache Creek rocks (Cockfield, 1948, p. 8). Local conglomerates and minor unconformities within the Nicola rocks represent minor periods of erosion and attest to the presence of local basins of sedimentation, but apparently do not indicate any general time break (Cockfield, 1948, p. 13).

Sometime after deposition of the Nicola group rocks, the Coast intrusions were emplaced, probably mostly during the Jurassic (Cockfield, 1948, p. 18), and the Nicola group was folded, sometimes steeply, into northerly trending synclines and anticlines (Cockfield, 1948, p. 14).

The time interval between the Jurassic and(?) later intrusive period and deposition of Kamloops group rocks is not represented in the study area. However, alteration of the Nicola group volcanics and evidence from nearby areas indicate that the southern Interior continued to experience extensive volcanic activity, weathering and erosion, local sedimentation, and some intrusive activity during this time.

By the early Tertiary, an erosional surface had formed, which Jones (1956, p. 53) described as "an irregular land surface upon which were accumulated lake and stream sediments, weathered detritus, slide-rock or talus breccia, sand and gravel of alluvial fans, and debris of plants." Jones stated that these deposits are the basal member of the Kamloops group (i.e. Coldwater beds) onto which the volcanic flows of the group were erupted. These flows are separated in places by conglomerates containing other Kamloops group, and older, clasts, indicating periods of erosion and deposition during Kamloops time. The Kamloops group accumulated to an average thickness of about 150 metres, locally exceeded 900 metres, and formed a "great. . .horizontal sheet" (Jones, 1956, p. 52-53).

The present valleys within the study area were probably formed during the early Tertiary because Miocene or earlier rocks are found within them; but, by Jones' interpretation, they were filled by these rocks, and have since been re-excavated.

Local basaltic eruptions occurred within the Nicola valley in the study area, and in other valleys in the southern Interior probably later than, but possibly during, Miocene time, and perhaps as recently as the Pleistocene. These are the Valley basalts.

During the Pleistocene, at least two glacial advances occurred. The glacial periods were immediately preceded, and followed, by periods of intense fluvial erosion, and fluvial and lacustrine deposition. Ice flow during the last glacial stage was to the south-southeast within the study area.

During the last phase of Fraser glaciation (the latest), a series of huge lakes, contained by ice dams, occupied many of the major valleys in the southern Interior, including the Nicola Valley. The largest and deepest of these represented in the study area was Lake Hamilton (Mathews, 1944) whose shorelines are easily observed on the slopes east of Merritt and can be traced for possibly 50 percent of their original extent (Mathews, 1944, p. 44). Its depth at Merritt would have exceeded 350 metres. It was contained by ice in the vicinity of Lower Nicola and in the Thompson River valley to the north, and probably had an outlet to the headwaters of the Salmon River, northeast of Merritt (Fulton, 1975, fig. 33).

As the ice melted further north, Lake Hamilton was drained through the channel now occupied by Napier Lake to the South Thompson River. The lake at this newly stabilised level, controlled by the elevation of the present drainage divide between Campbell Creek and Napier Lake, has been called Lake Merritt (Mathews, 1944). It was contained by the ice still occupying the lower Nicola River valley. Its shorelines, like those of Lake Hamilton, can be seen east of Merritt, and indicate a depth of about 150 metres.

Lacustrine and deltaic sediments, deposited in both of these lakes, attest to extensive late-glacial fluvial erosion of the surrounding uplands.

The disappearance of ice from the lower Nicola River valley and the consequent drainage of Lake Merritt marked the end of the "ice age" in the study area, but not the end of paraglacial (Church and Ryder, 1972) erosion and sedimentation. The period during which paraglacial activity was active, ended when the alluvial fans produced by this type of sedimentation began to be incised by their parent streams. The same processes have been active since that time, but rates of erosion and sedimentation are presently less than they were, and the landforms produced by these processes are changed.

Vegetation

The first detailed investigation of vegetation in the southern Interior of British Columbia is Spilsbury and Tisdale's (1944) study of soil-plant relationships and vertical zonation conducted on the Tranquille Range near Kamloops. They defined three grassland zones associated with three soil types, and three forest zones associated with three additional soil types. The grasslands were designated simply as the Lower, Middle, and Upper Grassland zones, associated with Brown Earth, Dark Brown Earth, and Black Earth soils, respectively. Similarly, the three forest zones, Montane, Subalpine and Upper Subalpine, were considered to be associated with Lower, Middle and Upper Podzols. Table 2.2 shows these relationships.

Table 2.2. Spilsbury and Tisdale's (1944) Soil and Plant Zones

Altitude		Soil zone	Plant Zone
335 - 700m	1100 - 2300'	Brown Earth	Lower Grassland
700 - 850m	2300 - 2800'	Dark Brown Earth	Middle Grassland
850 - 975m	2800 - 3200'	Black Earth	Upper Grassland
975 - 1225m	3200 - 4000'	Lower Podzol	Montane Forest
1225 - 1775m	4000 - 5800'	Middle Podzol	Subalpine Forest
1775 - 1850m	5800 - 6100'	Upper Podzol	Upper Subalpine Forest

Tisdale (1947), expanding the theme of this early work, presented detailed information on the presence, relative cover, yield, average dates of growth development, and mature heights of species within the three grassland zones. He also applied terminology similar to that used by Daubenmire (1942) in southeastern Washington and adjacent Idaho to the grassland zones of British Columbia. Thus, the Lower Grassland zone was referred to as the Agropyron - Artemesia zone, the Middle Grassland zone as the Agropyron - Poa zone, and the Upper Grassland zone as the Agropyron - Festuca zone.

Tisdale described the climax vegetation of each zone, and the principal communities which have replaced the climax communities due to disturbances such as overgrazing. He also showed that increases in cover, yield, and number of species occurred from the Agropyron - Artimesia (lower) zone through to the Agropyron - Festuca (upper) zone.

Van Ryswyk and others (1966) found a correlation between climate, vegetation, and soils in the vegetation zones described by Spilsbury and Tisdale (1944), and Tisdale (1947). Their results, however, are of little predictive value because they based their conclusions on data from only five stations (at various elevations) which were in operation from April to October for only three years.

The dry forests of southern British Columbia were studied by Brayshaw (1965; 1970). He first divided the vegetation into zones (Table 2.3) that corresponded to the forested zones described by Daubenmire (1952) in eastern Washington and northern Idaho. Local edaphic or topographic conditions were then used to subdivide the zones into associations. Subassociations were recognised as local variants of the associations dependent usually upon historical influences such as overgrazing, fire, local disturbance, or the failure of certain component species to reach some localities. He also

Table 2.3 Brayshaw's (1970) Dry Forest Communities

Zonal Communities
- Pinus Ponderosa zone
  - Pinus ponderosa-Purshia tridentata association
  - Pinus ponderosa-Agropyron spicatum association
- Pseudotsuga menziesii zone
  - Pseudotsuga menziesii-Pinus ponderosa-Arctostaphylos uva-ursi association
  - Pseudotsuga-Arctostaphylos-Calamagrostis rebescens association (transitional)
  - Pseudotsuga-Calamagrostic rubescens association
  - Pseudotsuga-Agropyron spicatum association

Azonal Communities
- Pinus ponderosa-Rhus spp. association
- Pseudotsuga-Symphoricarpos albus association

Alluvial Sere
- Salix spp. pioneer subassociation
- Populus balsamifera-Rosa nutkana gallery forest subassociation
- Populus balsmifera-Pinus ponderosa-Rosa subassociation
- Elymus condensatus var. cinereus savanna association
- Betula occidentalis-Salix spp. meadow margin association

utilised Daubenmire's concept of vegetation unions -- groups of species with ecological requirements so similar that they tend to be found in association with each other. The unions transgress the associations and can be used as ecological indicators within associations. Figure 2.3 shows the positions of Brayshaw's associations in relation to soil textural type and altitude.

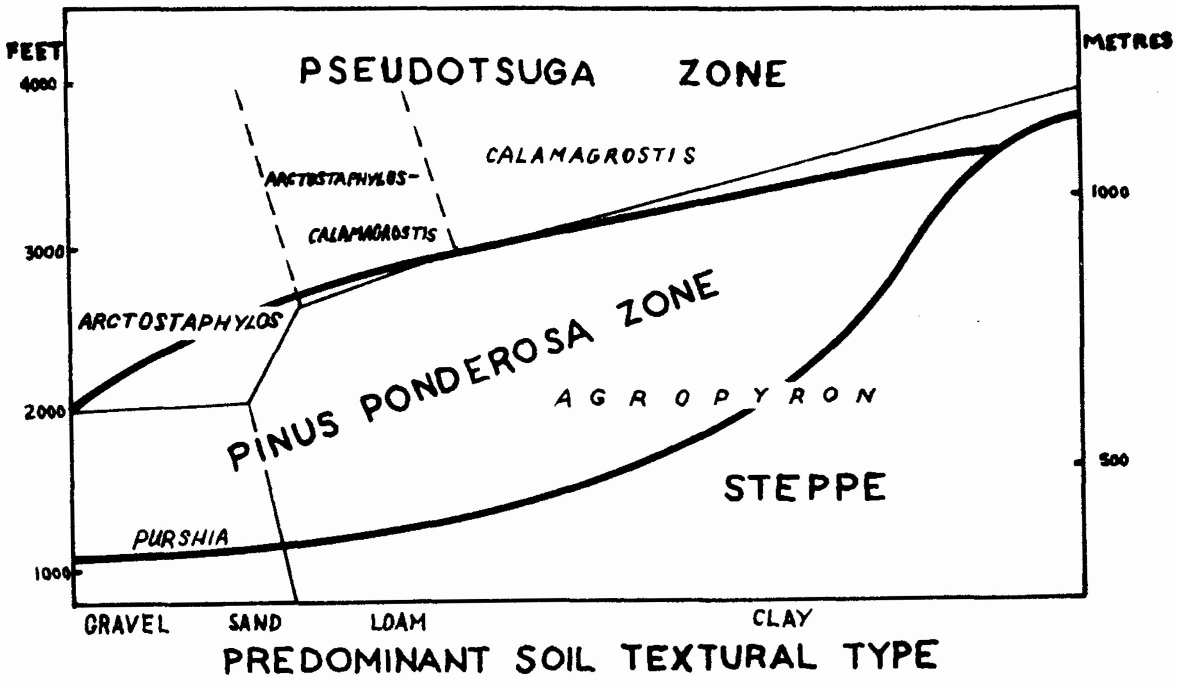


Figure 2.3 Relationship of Brayshaw's (1970) Zones and Zonal Associations to Alitude and Predominant Soil Texural Type

In a study of the vegetation of the Similkameen Valley to the south of the study area, McLean (1970) described five vegetation zones ranging from low to high elevation. These five zones -- Artemesia tridentata, Pinus ponderosa, Psuedotsuga menziesii, Abies lasiocarpa, and Alpine -- were defined as areas which are occupied, or potentially occupied, by a single climatic climax association. He also described habitat types (i.e. subassociations) within each association. This allowed him to include stands potentially capable of supporting a climax association but not necessarily in climax condition at the time of the study.

McLean found a good correlation between some habitat types and soils at the great group level, and suggested that the lack of a more perfect correlation could be due to other site factors, analogues of various soil characteristics, and biases within the Canadian soil classification system.

McLean and Marchand (1968) classified grassland ranges in the southern Interior into four "range sites" -- areas of rangeland with certain potentials for growing forage dependent on soil, climate, and slope. The range sites are (1) Big Sagebrush (Artemesia tridentata) - Bluebunch Wheatgrass (Agropyron spicatum), (2) Bluebunch Wheatgrass - Sandberg's Bluegrass (Poa secunda), (3) Bluebunch Wheatgrass - Rough

Fescue (Festuca scabrella), and (4) Ponderosa Pine (Pinus ponderosa).

For each range site they described the environmental conditions (elevation, precipitation, temperature, topography, and soils), season of grazing use, growing season, condition classes (based on percentage ground cover of certain species), forage yields (based on condition class), and the species composition at the site. Effects of overgrazing, local edaphic factors, soil texture, and regional variation in species composition were also discussed. The recognition of the zones, communities, associations, subassociations, habitat types, and range sites defined by McLean and Marchand demands recognition of the component species and detailed knowledge of abundance and cover.

Because the present study is not intended as a detailed vegetation study, no attempt has been made to map the distribution of vegetation zones, communities, associations, etc. However, the descriptions of the land systems include vegetation descriptions based on limited field observations and the cited literature.

Hydrology

The Nicola River rises in the Pennask and Tahaetkun Uplands (Fulton, 1975, figure 4) about 70 km east of Merritt and flows northwest, then west, into Nicola Lake. Leaving Nicola Lake in the study area, it is joined by Clapperton Creek from the north and the Coldwater River from the south. It turns northwest at Merritt to join the Thompson River at Spences Bridge. Other important streams in the study area are Hamilton Creek, which drains most of the northeastern part of the Iron Upland, and Godey Creek, which drains most of the remainder of this upland in the study area. Both of these creeks have built large alluvial fans, as has Clapperton Creek. Minor intermittent creeks drain the remainder of the area, mostly into the Nicola or Coldwater Rivers.

Although the Nicola River drains an area five times as large as the area drained by the Coldwater River at Merritt, its mean monthly discharge is never more than three times the Coldwater's, and except during August and September, is less than two times the mean monthly discharge of the Coldwater River. The mean annual discharge of the Nicola (14.8 cubic metres per second) is considerably less than two times that of the Coldwater River (8.9 cubic metres per second). These contrasts are accounted for by considering the source areas of the rivers. The Coldwater and its tributaries originate in the moisture-intercepting Cascade Range to the southwest of Merritt, while the drainage basin of the Nicola at Merritt lies entirely within the southern Interior Plateau, an area with a much drier climate.

The southern Interior contains numerous lakes caused by landslides, alluvial damming or glaciation, but all the lakes within the study area are of glacial origin. Fulton (1975, p. 9) divided glacial lakes in the southern Interior into upland types and valley types. Lundbom, Marquart, Hamilton, Garcia, Mathew, and numerous smaller lakes in the southeastern portion of the study area are small, shallow, and variably shaped lakes lying in glacially formed basins in bedrock, till, or both. These represent the upland type lakes. The valley type is represented in the study area by Nicola Lake in its long, deep, and narrow basin in a pre-glacial valley. The very poorly integrated drainage of the southern Interior, especially on the broader uplands, is also a legacy of glaciation.

Surface water resources are presently being used to, or nearly to, their practical limit in the Merritt Area. For this reason, ground-water sources which are already being tapped must supply most future needs. Fulton (1975, p. 41-42) discussed ground-water in part of the southern Interior.

Because no detailed investigation of ground-water resources was undertaken in the present study, this account summarises Fulton's discussion.

In general, the uplands of the southern Interior serve as recharge areas, while the major valleys act as discharge areas for ground-water. Rainfall and snowmelt flow through unconsolidated deposits in tributary stream valleys, cracks in bedrock, or sheets of unconsolidated materials that extend into the valleys. The water may return to the surface as springs, flow directly into stream channels, or it may enter unconsolidated deposits in the valley where it can be tapped by a well. Similar systems are found at a smaller scale in upland areas.

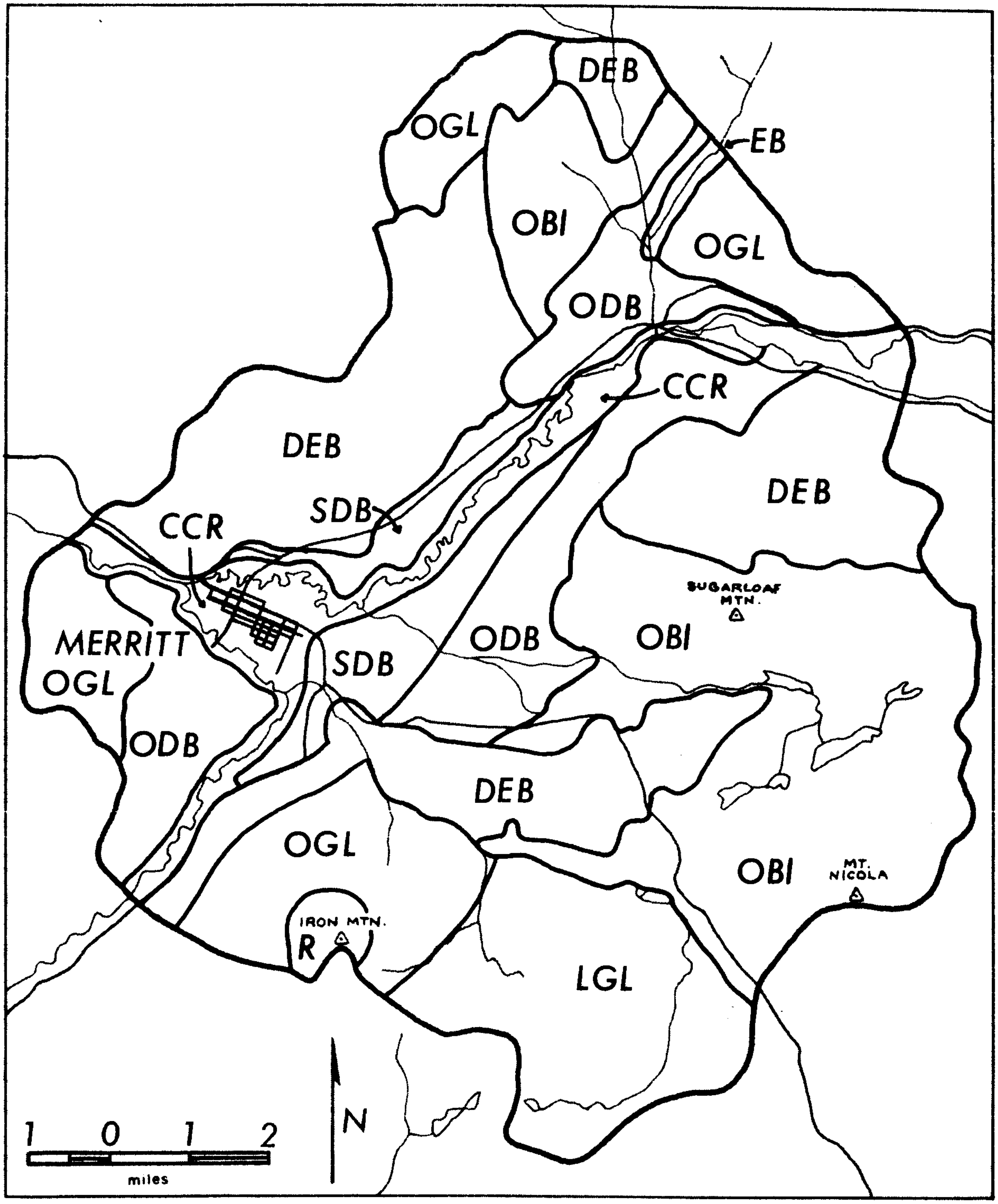
The apex areas of alluvial fans are especially favourable sites for ground-water because they are composed of permeable deposits and receive water from large areas. Silts and clays occupying many of the large valleys are not suitable aquifers because they have low permeabilities, but aquifers may be encountered beneath these deposits. Artesian pressures could be found in such an aquifer because recharge is from areas that may be hundreds of metres higher.

Soils

Spilsbury and Tisdale (1944) discussed soil-plant relationships and vertical zonation of soils and vegetation in the southern Interior. Some of the results of their study are briefly summarised in the discussion of vegetation above, and Table 2.2 (p. 69) shows the soil-vegetation zones that they recognised. Other reports, dealing primarily with vegetation in the southern Interior, but also commenting on soils, include those by Tisdale (1947), van Ryswyk and others (1965), Brayshaw (1965; 1970), and McLean (1970). None of these reports, however, deal specifically with the detailed distribution of soils in the Merritt area.

The soils within the study area have recently been mapped under the direction of Young and Bedwany (British Columbia, 1976b), but as of this writing the map is provisional and has not been published. A copy was kindly provided by the British Columbia Lands Directorate (See figure 2.4).

The soil subgroups, within the land systems identified below, are listed in the land system descriptions, but the association names shown on the provisional soil map legend are no longer being used in the area (the associations have been correlated with other soils -- Luttmerding, 1977, personal communication), and are not used in this report.



CCR - Calcareous Cumulic Regosol
DEB - Degraded Eutric Brunisol
EB - Eluviated Brown
LGL - Lithic Gray Luvisol

OBl - Orthic Black
ODB - Orthic Dark Brown
OGL - Orthic Gray Luvisol
SDB - Solonetzic Dark Brown
R - Rock

Figure 2.4 Soil Associations (after British Columbia, 1976b)

Very generally, the soils within the study area show the type of vertical zonation suggested by Spilsbury and Tisdale's work (1944) on the Tranquille Range near Kamloops. The area is above their Brown Earth zone, but Dark Brown soils are common at lower elevations within the study area, while Black soils are more common at higher elevations. Neither great soil group is restricted to low or high elevations in the study area, there is no contour that would even approximate a generally applicable boundary, and numerous other soil groups are found within the study area, especially within the Brunisolic and Luvisolic orders; but the generalisation is useful as a starting point in interpreting soil distribution here.

The majority of the soils in the study area are developed on the glacial deposits that mantle much of the terrain. These soils strongly reflect the character of the parent material -- till, lacustrine silt, outwash or deltaic gravels -- especially in terms of soil texture and morphology. A few soils in the study area are developed in Recent deposits -- alluvial floodplains and fans, bogs, and meadows. These also are dominated by features inherited from their parent material. Areas scoured during glaciation have generally not had time to develop soil as defined by The System of Soil Classification for Canada (Canada, 1972, p. 19).

During the field work phase of this investigation, several soil pits were dug in order to provide typical profile descriptions of some of the more commonly occurring soils (Tables 2.4 through 2.7). The close correspondence between the nature of the parent material and some of the profile characteristics is obvious.

Some features of the soils found in the study area are of especial importance in any general appraisal for land use. These include texture, structure, and consistence, of course; but also, many soils in the area have a saline or calcareous horizon, or horizons. These features will be noted, where appropriate, in the land facet descriptions.

Table 2.4 Calcareous Brown Soil Profile

Location: 50° 8.9' N 120° 42.3' W
UTM Grid Reference: 639574

Elevation: 634 metres (2080 ft.)

Aspect: East Slope: 18%

Vegetation: Scattered, unidentified bunchgrass, few scattered Chrysothamnus nauseosus, and isolated Pinus ponderosa. Bromus tectorum and Salsola kali occur in disturbed sites.

Horizon	Depth (cm)	Description
Ah	0 - 15	Brown (10YR 5/3d); very dark brown (10YR 2/2m); silt loam; massive; slightly hard; plentiful very fine roots; clear smooth boundary; pH 7.6.
Bmk?	15 - 28	Brown (10YR 5/3d); very dark brown (10YR 2/2m); silt loam; massive; slightly hard; plentiful very fine roots; moderately effervescent; diffuse smooth boundary; pH 8.4.
Cca	28+	Light brownish gray (2.5Y 6/2d); dark grayish brown (2.5Y 4/2m); silt loam; massive; slightly hard; plentiful very fine roots to 50 cm, very few very fine roots below 50 cm; moderately effervescent; pH 8.4.

Table 2.5 Calcareous Dark Brown Soil Profile

Location: 50° 8.8' N 120° 43.2' W
UTM Grid Reference: 628572

Elevation: 655 metres (2150 ft.)

Aspect: Southeast Slope: 27%

Vegetation: Open Pinus ponderosa forest with Chrysothamnus nauseosus, Astragalus spp., Opuntia fragilis, and unidentified bunchgrasses.

Horizon	Depth (cm)	Description
L	3 - 0	Dry grass litter; abrupt smooth boundary.
Ah	0 - 18	Dark grayish brown (10YR 4/2 d); very dark brown (10YR 2.5/2m); coarse sandy loam; weak coarse granular; slightly hard; plentiful very fine to medium roots; gradual smooth boundary; pH 6.7.
Bmk	18 - 34	Pale brown (10YR 6/3d); dark brown (10YR 3/3m); sandy clay loam; moderate coarse granular to medium subangular blocky; slightly hard; plentiful very fine to medium roots; moderately effervescent; clear smooth boundary; pH 7.4.
C	34+	White (10YR 8/2d); pale brown (10YR 6/3m); silty clay loam; moderate medium subangular blocky; very hard; plentiful very fine roots; strongly effervescent; pH 8.4.

Table 2.6 Orthic Black Soil Profile

Location: 50° 5.8' N 120° 40.3' W
UTM Grid Reference: 663517

Elevation: 1000 metres (3280 ft.)

Aspect: Northwest Slope: 23%

Vegetation: Populus tremuloides grove with few Psuedotsuga menziesii, Rosa spp., thick turf of unidentifed bunchgrasses and various, unidentified forbs.

Horizon	Depth (cm)	Description
L - H	3 - 0	Dry grass litter over less than 1 cm humus, abrupt smooth boundary.
Ah	0 - 13	Very dark brown (10YR 2/2d); black (7.5YR 2/0m); silt loam with sand; weak coarse blocky; slightly hard; plentiful fine and very fine, abundant medium, plentiful coarse roots; clear smooth boundary; pH 6.4.
Bh	13 - 29	Grayish brown (10YR 5/2d); very dark grayish brown (10YR 3/2m); loam; moderate medium granular; soft; few fine and very fine, plentiful medium, few coarse roots; hydrophobic, smooth clear boundary; pH 6.8.
Bm	29 - 87	Pale brown (10YR 6/3d); dark grayish brown (10YR 4/2m); silt loam with sand; moderate coarse granular; slightly hard to hard; few fine and very fine, plentiful medium, few coarse roots; abrupt wavy boundary; pH 6.8.
Cca	87+	Light gray (2.5Y 7/2d); dark grayish brown (2.5Y 4/2m); silt loam with sand; massive; very hard; few fine and very fine, plentiful medium, few coarse roots; strongly effervescent; pH 8.2.

Table 2.7 Orthic Eutric Brunisol Soil Profile

Location: 50° 10.9' N 120° 40.0' W
UTM Grid Reference: 664613

Elevation: 700 metres (2300 ft.)

Aspect: South Slope: 3%

Vegetation: Pinus ponderosa with some Pseudotsuga menziesii. Scattered, unidentified bunchgrasses, Vaccinium spp., Achillea millefolium, abundant Antennaria rosea (?), Arctostaphylos uva-ursi, and Chrysothamnus nauseosus.

Horizon	Depth (cm)	Description
L	1 - 0	Dry, mostly pine needles with some herbaceous litter.
Ah	0 - 4	Dark grayish brown (10YR 4/2d); very dark brown (10YR 2/1.5m); sandy loam; weak fine granular; soft; abundant very fine roots; gravelly; abrupt smooth boundary; pH 6.5.
Bm	4 - 24	Brown (10YR 5.5/3d); dark brown (10YR 3/3m); coarse loamy sand; weak fine granular; soft; plentiful very fine roots; plentiful medium to coarse roots below 15 cm; gravelly; few cobbles; gradual smooth boundary; pH 6.6.
C	24+	Grayish brown (2.5Y 5/2d); very dark grayish brown (10YR 3/2m); coarse loamy sand; weak fine granular; plentiful very fine roots to 60 cm, plentiful medium to coarse roots to 45 cm; gravelly, few cobbles; pH 6.8.

Historical Background

Weir (1964) discussed the history of settlement in the southern Interior in five periods: the pre-colonial period (1821-1858), the colonial period (1858-1871), the period of consolidation (1872-1885), the railway era (1885-1917), and the post-World War I period. Weir's report is concerned primarily with the history of settlement and tenure as it relates to the ranch industry. The following account is based primarily on Weir's report and on a report by the British Columbia Department of Industrial Development, Trade, and Commerce (British Columbia, 1972).

Prior to 1808, when Simon Fraser passed through the southern Interior on his journey down the river that now bears his name (British Columbia, 1972, p. 16), the region was inhabited only by Shuswap Indians (Weir, 1964, p. 79). The first permanent settlement, Fort Kamloops, was established in 1821 at the junction of the North and South Thompson Rivers. This date marks the beginning of Weir's pre-colonial period, although a trading post was built by the Pacific Fur Company in 1812 at this same site.

There was no settlement in or very near the study area during this period, although the Nicola and Coldwater River Valleys were followed by trails through the area. The pre-colonial period ended with the dissolution of the Hudson Bay Company's exclusive licence to trade with the Indians and establishment of the Crown Colony of British Columbia, a year after the discovery of gold along the Fraser River in 1857.

Settlement during the colonial period (1858-1871) was influenced primarily by four factors: the gold rush, travel routes, the Land Acts, and cattle (Weir, 1964, p. 81). The gold frenzy, begun on the Lower Fraser gravel bars, moved rapidly up the river as far as Prince George and the Nechako River, then retreated to the Quesnel River. "By 1860, some 4,000 miners were at work. . .(in) the interior," primarily along the Fraser River and its tributaries north of Lillooet (Weir, 1964, p. 83). New discoveries in 1861 brought more miners, but by 1865 the individual miner no longer enjoyed the prospect of easy money. He thus faced the choice of leaving the country, becoming a laborer for capital intensive mining, or settling on a bit of land. Many chose the latter.

Travel routes to the goldfields, and the supply points along these, were significant in establishing many of the routes used today in the southern Interior, and the settlements along these routes.

The Land Acts of 1859 to 1865 opened the lands of the colony, except Indian reserves and the Hudson Bay Company's land, to pre-emption, thus encouraging settlement during the colonial period. The Land Acts of most of the Colonial period allowed pre-emption of only 160 acres (65 hectares), although more land could be aquired through purchase. Partnerships were common because the area readily available to individuals was too small to support a viable ranch unit. Pre-emptions of 320 acres (130 hectares) were first allowed by the Land Act of 1870.

These three factors -- gold, travel, and land -- did not result in settlement of the present study area during the early part of the colonial period. Gold was found elsewhere, major travel routes followed the Fraser and Thompson Rivers, and the Okanagan Valley, and early pre-emptors settled along the major travel routes. The fourth factor -- cattle -- played a more important role, but its impact wasn't felt here until late in the colonial period. The first pre-emption of land in the vicinity of Nicola Lake was in 1868, by cattlemen from the south who recognised the advantages of the area for stock raising (Weir, 1964, p. 92).

The period of consolidation (1872-1885) was a time of economic recession precipitated by the decline of mining activity. Many settlers left the Interior during this time, but those who stayed consolidated their holdings. Although consolidation of small ranch units into larger did not cease with the coming of the railroads at the end of this period, this is when most of the major ranches that are still operating experienced their greatest growth. Steady growth in Nicola and vicinity during this period resulted in 80 ranches, with an estimated 80,000 acres (32,300 hectares) of alienated land, 30,000 head of cattle, and 2,000 sheep by 1887 (Weir, 1964, p. 94).

The railway era (1885-1917) began with the completion of the Canadian Pacific Railway through the South Thompson and Fraser River Canyons. In 1898, the Kettle Valley route of this railway, between Hope and Princeton, was constructed. In 1906, a spur line to Merritt, from Spences Bridge on the Thompson River, was built. This spur was linked to the Kettle Valley route in 1914 (Weir, 1964, p. 95-96; British Columbia, 1972, p. 17).

Nicola, near the outlet of Nicola Lake, was the supply centre for the study area prior to construction of the rail spur from Spences Bridge, but Merritt gradually assummed this function after 1907 (Weir, 1964, p. 96). This rail spur was constructed to exploit the coal resources at Merritt, but prior to this time, ranching had been the primary economic activity in the study area. The ranching activity had been centred about the Nicola Lake Stock Farm, now known as the Nicola Lake Ranch, at Nicola. Although mining did not replace ranching activity in the area -- both are still of major importance -- Nicola permanently lost it supply function during this time. Mining activity began at Merritt in 1906, and 2.7 million tons of coal were produced before the mines closed in 1963.

Since the end of the railway era, the settlement pattern of the southern Interior has changed very little. Between the two World Wars, ranching and mining activity fluctuated due to the Depression and with market demand, but these two industries accounted for the majority of economic activity during the post-World War I period.

Increased demand for lumber brought a major expansion of the forestry industries to the southern Interior, including the Merritt area, following World War II. The Craigmont Mine, opened in 1961, has been a leading factor in the rapid growth experienced by Merritt since that time, and certainly minimised the impact of the cessation of coal mining activity two years later. The construction of a veneer plant at Merritt in 1971, further diversified the economy, and a new plywood plant, built in 1976, continued this process.

Reconstruction of the main highway through town during the summer of 1977, along with a flurry of other construction activity, gave the impression that Merritt will likely continue to grow. Although tourism has never played as important a role in the Merritt area as it has in surrounding areas, it is gaining in importance. Construction of the Coquihalla Pass road would undoubtably give this industry a boost because Merritt presently lies off the main tourist routes through the province. It is impossible to predict the magnitude of the effects that will be wrought by this road link, but it is safe to say that they can only increase Merritt's importance in the southern Interior.

Land Classification

The methods employed in the land classification phase were modified from those used by Christian (1952), Christian and others (1960), Mabbutt and Stewart (1963), and Webster and Beckett (1970). These methods are described in the first part of this study. The primary modification, enforced by financial restraints and by the nature of the research, was that the present study was an individual effort rather than a team survey.

The term "land" has been used throughout this study in the same way that others involved in land evaluation have used the term, that is, as an integration of all the physical and biological attributes that interact to produce areal differentiation of the earth's surface. "Land units" are homogenous areas of land at whatever scale is being considered. This use differs from the earlier use of the term in Australia because it is being used here as a general term while the previous Australian usage denoted a specific level in a hierarchical classification. "Land systems" are land units that produce a recognisable aerial photograph pattern due to the character and arrangement of their component parts. The bases of these patterns vary from one land system to another, but are usually macro- and micro-relief, vegetation, drainage pattern, or topographic expression. The land systems are recognised by this aerial photograph pattern, but are defined by the "land facets" that they contain and by the relationships of these facets to each other. The land facets are land units that can be defined on the basis of their physical and biological attributes. In this study these attributes include topography, geology, soils, and vegetation. In addition to previous documentation and field investigation, the presumed genesis of each land facet was considered in an attempt to infer the probable physical and biological attributes of the land facets.

An aerial photograph mosaic was constructed before field work began, and tentative land systems were outlined. During the field work each land system was visited at least once and notes were taken on vegetation, soils, geologic materials, and present land uses. The land system boundaries were adjusted during and after field work as I became more familiar with the area. Some land systems, that had been separated originally because of the geographic location, were combined when it was realised that they were quite similar.

During the course of the field work, it became apparent that it would not be possible to characterise every land facet in as much detail as would be desirable. Attempts to describe, in detail, the geology, geomorphology, soils, vegetation, hydrology, and micro-climate of single facets were thwarted by the lack of intimate familarity with each of these attributes, especially vegetation, and secondly, soils. However, due to the availability of the secondary sources mentioned above, the descriptions that were obtained are generally comparable to the examples presented by Mabbutt and Stewart (1963), and Webster and Beckett (1970), although not all facets are equally well described.

After completion of the field work, the land systems were defined in terms of their land facets and the interrelationships among these. The completed map (Plate 1) shows only the land system boundaries; land facets are defined and described in Tables 2.8 through 2.13.

The discussion of land use presented at the conclusion of this part is based on an appraisal of the previously available information, and the information collected in the field. It does not ignore social and economic factors entirely, but these were not considered in any detail. For several reasons that are discussed below it was not possible to produce a land evaluation that would have meaning, but land-use problems and possible approaches to their solutions are discussed below.

The Land Systems

The land systems of the study area are defined by the land facets that they contain. These are defined in terms of topography, geology, soils, vegetation, and presumed genesis in Tables 2.8 through 2.13. This section describes the character and distribution of the land systems, but in general rather than definitive terms.

Coldwater Land System (Table 2.8) bears a name appropriate to both its location and its general geology. It occupies a triangular area, southwest of Merritt, bounded on two sides by the Coldwater River valley, and is generally co-extensive with the Coldwater sediments of the Kamloops group. Grasses are the principle vegetation, but various shrubs, forbs, and scattered Pinus ponderosa, are common.

Hamilton Land System (Table 2.9), named after Hamilton Creek, is characterised by drumlinoidal till. It occupies a large area east of Merritt extending up on to the plateau surface from about 750 metres, and a smaller area west of Shuta Creek above the same elevation. It also is primarily grassland, but supports larger shrubs and trees in protected or moist sites.

Iron Mountain Land System (Table 2.10) extends from the top of this mountain, at 1693 metres, down to less than 700 metres. As might be expected, certain features within this land system display a great deal of variation from place to place, but the entire land system is strikingly homogenous in terms of physiography and geology -- rough, broken terrain in Nicola group rocks. It also bears a relatively dense forest cover over its entirety, although the composition, structure, and density of this cover varies extensively. This land system is explicitly differentiated from Sugarloaf Land System (discussed below) by the factor that controls topographic expression in each land system. Linear elements within the Iron Mountain Land System appear to be the result of glacial erosion, and, to a lesser extent, glacial deposition, while bedrock attitude gives rise to the prominant linear elements within the Sugarloaf Land System.

Sugarloaf Land System (Table 2.11), named for Sugarloaf Mountain, is restricted to less altitudinal variation, and is less extensive than the Iron Mountain Land System. Like Iron Mountain Land System, it is characterised by rough topography, nearly complete homogeneity of geology, and presence of forest cover. The forest composition, structure, and density is variable in this land system, also, but to a lesser degree than in Iron Mountain Land System. Sugarloaf Land System fans out northward from Sugarloaf Mountain, and extends down to

Nicola Lake or to the upper limit of Merritt Land System (discussed below). It is also found north of Nicola Lake, extending from the upper limit of Merritt Land System up on to the plateau surface, and again west of Merritt, upward from the upper limit of Coldwater Land System.

Merritt Land System (Table 2.12), named after late-glacial Lake Merritt, is a diverse land system initially conceived of as a land system unified by the presence of sediments deposited in that lake, but later expanded to include adjacent post-glacial alluvial and colluvial deposits. It is found within the Nicola and Coldwater Valleys in areas that were protected from extensive post-glacial erosion, and in areas subject to deposition in post-glacial time. Most or all of Merritt Land System has been greatly modified by man's activities. This has multiplied the inherent diversity of the land system due to physiography, soils, and native vegetation. The land facets defined below begin the process of differentiation, but they are only a beginning. A division of this culturally vital land system into adequate planning or management units would require much more work.

Nicola Land System (Table 2.13), co-extensive with the Nicola and Coldwater Rivers' modern floodplains and low river terraces, is named for the Nicola River. Merritt, at the junction of the two rivers, is located within Nicola Land

System. The active floodplain is relatively pristine outside of Merritt, but in Merritt, and locally elsewhere in the study area, it has been modified greatly. This land system is the most dynamic of the land systems in the study area, and perhaps subject to the most abuse, but, again, it was not possible within the scope of this study to subdivide this land system in a meaningful manner.

Table 2.8 Coldwater Land System

Land Facet 1

Topography: Gently to moderately steeply sloping, smoothly rounded, but locally gullied knolls and valley side slopes.

Geology: Coldwater sediments with very minor lacustrine veneer, till patches, and alluvial and colluvial sediments.

Soils: Orthic Dark Brown, Lithic Dark Brown, Degraded Eutric Brunisol, and Lithic Eutric Brunisol.

Vegetation: Spilsbury and Tisdale's (1944) Middle grassland(?) and Brayshaw's (1970) Pinus-Stipa spp. sub-association(?) with Opuntia fragilis and Chrysothamnus nauseosus.

Presumed Genesis: Glacially eroded Coldwater sediments, gullied by post-glacial erosion.

Land Facet 2

Topography: Gently sloping, narrow benches separated by steep bluffs above Coldwater River creating "step-and-bench" topography.

Geology: Slumped Coldwater sediments with minor lacustrine, till, and alluvial and colluvial sediments.

Soils: Orthic Dark Brown.

Vegetation: Same as facet 1, but including slightly more Pinus ponderosa.

Presumed Genesis: Local slumping of Coldwater sediments due to post-glacial incision by Coldwater River.

Table 2.8 Coldwater Land System (cont.)

Land Facet 3

Topography: Gently to moderately steep slopes, gullied where steep.

Geology: Slumped lacustrine sediments, locally including alluvial and colluvial sediments derived from adjacent Iron Mountain land system.

Soils: Orthic Dark Brown.

Vegetation: Spilsbury and Tisdale's (1944) Middle grasslands(?) with Chrysothamnus nauseosus and Achillea millefolium (generally poor looking, discontinuous vegetation cover).

Presumed Genesis: Lacustrine sediments, deposited in late-glacial Lakes Hamilton and Merritt, since slumped, eroded, and mantled by locally derived alluvium and colluvium.

Table 2.9 Hamilton Land System

Land Facet 1

Topography: Strongly lineated drumlinoidal ridges and intervening valleys superimposed on major valley side slopes and on the rolling plateau surface.

Geology: Drumlinoidal moraines with very minor outcrops of Nicola group rocks.

Soils: Degraded Eutric Brunisol, Lithic Eutric Brunisol, Orthic Black, and Lithic Black.

Vegetation: Primarily Spilsbury and Tisdale's (1944) Middle and Upper grasslands, but locally supporting shrub and tree species in depressions between ridge and on north-facing slopes.

Presumed Genesis: Deposition of drumlinoidal ground moraine in linear ridges.

Land Facet 2

Topography: Slightly lineated drumlincidal hills and depressions superimposed on major valley side slopes and on the rolling plateau surface, locally gullied.

Geology: Same as facet 1, except minor rock outcrops, although primarily Nicola group, include Coast intrusions and Kamloops group rocks.

Soils: Orthic Black, Lithic Black, Degraded Eutric Brunisol, and Lithic Eutric Brunisol at higher elevations (above about 1000 metres), with Orthic Dark Brown at lower elevations.

Vegetation: Same as facet 1, but some exposed sites include numerous Verbascum thapsus.

Presumed Genesis: Deposition of weakly drumlinoidal ground moraine.

Table 2.9 Hamilton Land System (cont.)

Land Facet 3

Topography: Stream and large gully bottoms, lake margins, shallow closed depressions, very gently sloping flats, and protected northern exposures.

Geology: Recent alluvial sediments intermixed with varying amounts of organic matter.

Soils: Orthic Black, Calcareous and Saline Cumulic Black, and soils of the Organic order.

Vegetation: Extremely variable, includes most if not all of the species in Brayshaw's (1970) Alluvial sere in moister sites, but fewer species in drier sites which often contain Populus tremuloides groves with a ground cover of unidentified bunchgrasses, Rosa spp., Equisetum hymales, Agoseris spp., and associated herbaceous vegetation.

Presumed Genesis: Recent alluvial and organic deposition in modern stream channels, lakes, etc.

Land Facet 4

Topography: Irregularly ridged and grooved hillsides and valleys on the upland surface.

Geology: Outwash gravels, eroded till, and very minor eroded pre-Pleistocene rocks of the Nicola group.

Soils: Same as facet 2, but without Orthic Dark Brown.

Vegetation: Same as facet 1.

Presumed Genesis: Erosion and deposition by glacial melt-water streams, in places in contact with ice.

Table 2.9 Hamilton Land System (cont.)

Land Facet 5

Topography: Hummocky hillsides and valleys on upland surface, numerous small closed depressions.

Geology: Outwash gravels and sand.

Soils: Same as facet 2, but without Orthic Dark Brown.

Vegetation: Pseudotsuga menziesii(?) forest (Only one small area represents this facet in the study area. It was not visited during the field work phase of this investigation. Although it appears forested on the air photos, it occupies a steep valley bottom at the base of a north-facing slope, and similar facets identified outside the study area would likely be occupied by vegetation similar to facet 1).

Presumed Genesis: Outwash containing blocks of ice which upon melting caused local subsidence.

Table 2.10 Iron Mountain Land System

Land Facet 1

Topography: Steep to moderate slopes, rugged, broken terrain on uplands, extending down to less than 700 metres on steep slopes, and up to the top of Iron Mountain.

Geology: Nicola group rocks with minor till patches and colluvial deposits.

Soils: Bare rock outcrops, Orthic Gray Luvisol, with lesser Lithic Gray Luvisol, and Lithic Eutric Brunisol.

Vegetation: Ranges from sub-alpine forest to Brayshaw's (1970) Pseudotsuga-Pinus-Arctostaphylos association(?), and includes stands of Pinus contorta var. latifolia. Recently logged areas are in various stages of succession.

Presumed Genesis: Nicola group rocks overridden by glacial ice with extensive erosion, but very little deposition.

Land Facet 2

Topography: Moderately steep to gentle slopes, rugged, broken terrain confined to plateau portion of uplands.

Geology: Same as facet 1, but with larger, more numerous till patches and(?) lesser colluvium.

Soils: Bare rock outcrops, Lithic Gray Luvisol, Orthic Black, Lithic Black, Degraded Eutric Brunisol, and Lithic Eutric Brunisol.

Vegetation: Primarily Pseudotsuga menziesii forest, and Brayshaws (1970) Pseudotsuga-Arctostaphylos-Calamagrostis and Pseudotsuga-Calamagrostis associations(?); may include Pinus ponderosa, Populus tremuloides, Achillea lanulosa, Rosa spp., Aster spp., and Cirsium spp.

Presumed Genesis: Nicola group rocks overridden by glacial ice, with local deposition, and extensive erosion which now controls topographic expression.

Table 2.10 Iron Mountain Land System (cont.)

Land Facet 3

Topography: Stream bottoms, lake margins, shallow closed depressions.

Geology: Recent alluvial sediments intermixed with varying amounts of organic matter.

Soils: Orthic Black, Calcareous and Saline Cumulic Black, and soils of the Organic order.

Vegetation: Extremely variable, includes most if not all of the species in Brayshaw's (1970) Alluvial sere.

Presumed Genesis: Topographic positions allows deposition and maintains high moisture availability.

Table 2.11 Merritt Land System

Land Facet 1

Topography: Flat-lying or gently sloping benches northwest of Nicola River.

Geology: Lacustrine silts and fine sands, varved and locally eroded.

Soils: Solonetzic Dark Brown, Calcareous Black, and Orthic Dark Brown.

Vegetation: Presently cultivated, but probably supported Spilsbury and Tisdale's (1944) Middle grassland(?) with scattered Pinus ponderosa prior to settlement. Some sites contain Artemesia tridentata, A. frigida, and Chrysothamnus nauseosus.

Presumed Genesis: Late-glacial sediments of Lakes Hamilton and Merritt dissected by Nicola River, and locally eroded by intermittant drainage.

Land Facet 2

Topography: Gently sloping drumlinoidal ridges.

Geology: Drumlinoidal till mantled locally by lacustrine sediments and alluvium.

Soils: Orthic Dark Brown, Calcic Dark Brown, Calcic Rego Dark Brown.

Vegetation: Spilsbury and Tisdale's (1944) Middle grassland(?) with scattered Bromus tectorum and Pinus ponderosa, locally cultivated. Valleys between ridges support more hydrophytic vegetation including rhizomatic grasses, Typha latifolia, Equisetum spp., Agoseris spp., and Centaurea spp.

Presumed Genesis: Drumlinoidal till deposited by glacial ice, then drowned by Lakes Hamilton and Merritt and subjected to lacustrine deposition. Modified by local post-glacial erosion and deposition.

Table 2.11 Merritt Land System (cont.)

Land Facet 3

Topography: Gentle to steep slopes at, and extending up on to, the base of the major valley side slopes.

Geology: Alluvial and colluvial sediments, may include some till and/or lacustrine sediments.

Soils: Degraded Eutric Brunisol, Orthic Dark Gray, Solonetzic Dark Brown, Orthic Dark Brown, Rego Brown, bare rock.

Vegetation: Highly variable due to specific site characteristics and past use, but include's large areas of Spilsbury and Tisdale's (1944) Middle grassland(?), scattered Pinus ponderosa, and may include Chrysothamnus nauseosus, Achillea lanulosa, Bromus tectorum, Rosa spp., Opuntia fragilis, Astragalus spp., Cirsium spp., Lupinus spp., and Centauria spp. Various lichens occur on bare earth and rock surfaces. Artemesia tridentata and A. frigida noted southwest of the alluvial fan on Hamilton Creek.

Presumed Genesis: Local post-glacial mass movement and alluvial deposition at base of slopes, and alluvial fans where confined channels reach the open valley.

Land Facet 4

Topography: Flat-lying and gently sloping bench southeast of Nicola River.

Geology: Basalt flow veneered by lacustrine sediments.

Soils: Solonetzic Dark Brown, and Orthic Dark Brown.

Vegetation: Spilsbury and Tisdale's (1944) Middle grassland(?), locally supports Chrysothamnus nauseosus and very few Pinus ponderosa.

Presumed Genesis: Late-Tertiary or Pleistocene basalt eroded slightly by at least one glacial advance, subjected to lacustrine deposition in late-glacial Lakes Hamilton and Merritt. Locally eroded in post-glacial time, and locally poorly drained.

Table 2.11 Merritt Land System (cont.)

Land Facet 5

Topography: Moderately sloping terraces elevated well above main valley bottoms above the mouths of larger creeks, and deeply incised by these creeks.

Geology: Well sorted gravel to sand deposits, dipping toward the main valleys.

Soils: Orthic Dark Brown, Degraded Eutric Brunisol, Orthic Dark Gray.

Vegetation: Variable, includes Spilsbury and Tisdale's (1944) Middle grassland and Brayshaw's (1970) Psuedotsuga-Pinus-Arctostaphylos association.

Presumed Genesis: Deltaic deposition in late-glacial Lake Merritt and post-glacial incision by parent streams.

Table 2.12 Nicola Land System

Land Facet 1

Topography: gently sloping, usually narrow valley bottoms.

Geology: Modern alluvial stream deposits and associated organic sediments.

Soils: Calcareous Cumulic Regosol, Calcareous Black, and soils of the Organic order.

Vegetation: Variable, but probably fairly representative of Brayshaw's (1970) Alluvial sere.

Presumed Genesis: Modern Nicola and Coldwater River meander belts and floodplains.

Land Facet 2

Topography: gently sloping, low terraces only slightly above the Nicola and Coldwater Rivers. Often poorly drained.

Geology: Primarily late-Recent alluvial stream deposits and associated organic sediments, but may contain small areas of till.

Soils: Calcareous Cumulic Regosol and Calcareous Black.

Vegetation: Mostly cultivated. Original vegetation indeterminate.

Presumed Genesis: Abandoned river floodplain.

Table 2.13 Sugarloaf Land System

Land Facet 1

Topography: Moderate to extremely steep slopes, rugged, broken terrain on uplands extending down to less than 700 metres on steep slopes.

Geology: Nicola group rocks with minor till patches and colluvium and extremely minor Kamloops group volcanics.

Soils: Degraded Eutric Brunisol, Orthic Gray Luvisol, Orthic Black, bare rock outcrops, Lithic Black, Lithic Eutric Brunisol.

Vegetation: Primarily Pseudotsuga menziesii forest, and Brayshaw's (1970) Pseudotsuga-Arctostaphylos-Calamagrostis and Pseudotsuga-Calamagrostis associations(?), with scattered Pinus ponderosa, Abies lasiocarpa, and Populus tremuloides.

Presumed Genesis: Nicola group rocks overridden by glacial ice with local erosion and deposition. Topographic control is primarily by bedrock.

Land Facet 2

Topography: Stream bottoms, lake margins, shallow closed depressions.

Geology: Recent alluvial sediments intermixed with varying amounts of organic matter.

Soils: Orthic Black, Calcareous and Saline Cumulic Black, and soils of the Organic order.

Vegetation: Extremely variable, includes most if not all of the species in Brayshaw's (1970) Alluvial sere.

Presumed Genesis: Topographic positions allows deposition and maintains moisture availability.

Current Land Use

The primary land uses, and the land-use patterns, in the study area, have developed piecemeal since the area was first settled by cattlemen in the late 1860's. The ranch industry is the most important land user, a large portion of both public and private land being devoted primarily to ranching. Both the forestry and mining industries are extremely important to the economy of the study area, but in terms of land use within the area they are of only local and often incidental importance. The higher slopes of Iron mountain have been clear cut, but much timber production within the study area has been from privately owned lands where an important goal was increased forage production for cattle. Because the ranch industry is so important within the study area it is considered here in detail. Other land users are discussed where relevant.

Slightly more than half of the study area is crown owned land, much of which is "crown range" administered by the Range Division of the Forest Service. The study area is within the Kamloops Forest District and is part of the area administered from the Merritt Ranger District. The stock range administered by this ranger district is divided into several range units, administrative units bounded by either fences or natural barriers such as lakes or streams. Each range unit may be utilised by one or a few ranchers, and is represented by an industry spokesman, a rancher, elected by the Nicola Stock Breeders Association.

Grazing permits, issued by the Kamloops Forest District, control the utilisation of forage on crown range. An individual rancher desiring to use crown rangeland must apply for a grazing permit through the appropriate ranger district office. In the Merritt area, the district ranger consults with the representative of the Nicola Stock Breeders Association, then forwards the application to the Kamloops District office with his recommendation for approval or denial. The approved (or denied) application is then returned to the ranger district for implementation.

Grazing permits are issued for a specified number of "animal unit months" (AUM's, one AUM authorises grazing by one adult animal with calf for one month). They also specify the turn out and termination dates for each section of the range unit in which use is allowed. Unlike a crown lease, administered by Lands Service, a grazing permit only entitles the holder to utilise the forage resource. It does not convey the right to quiet enjoyment (i.e. the holder cannot exclude other legally authorised users). This means that other resources may be utilised contemporaneously, including and especially pertinent in the study area, forest resources and recreational resources.

Previous to 1978, grazing permits were issued on an annual basis. Although an established, stable rancher could expect almost "rubber stamp" renewal of his grazing permit if he adhered to its conditions, many ranchers expressed concern for the lack of absolute surety of grazing rights. Therefore, the Forest Service has initiated term grazing permits which were issued in the Merritt area for the first time in 1978. They are limited to ranchers who have been in business in excess of three years, have a stable operation, and do not have an unpaid account with the Forest Service. They are issued for a period of five years, but are to be reviewed in three years at which time they may be replaced by a new five-year permit by mutual agreement between the Forest Service and the rancher.

Most of the prime grazing lands, especially areas of winter range within the major valleys, were long ago pre-empted. Although slightly more than half of the study area is still held by the crown (137 sq. km out of 269 sq. km), a significant portion of this land is not well suited to grazing use due to steep slopes or dense forests. For these reasons, the areas of crown land that are suitable to forage production are much in demand. This demand is regulated through the system of grazing permits discussed above, and there is no reason to believe that this system will, or should, be replaced. However, the present basis for deciding allowable use intensity for each section of each range unit needs some consideration.

The number of AUM's authorised, and the period of use stipulated on each grazing permit, are presently based on an assessment of carrying capacity. This is estimated through past use experience, the grass species present, and the "quality" of the forage. The assessment in this area is presently made by the ranger at the Merritt Ranger District. The procedure is not standardised and, more importantly, is not based on a uniform classification that could be applied by another individual. At least two major drawbacks inherent in this subjective assessment are immediately apparent. First, it would be difficult to critically assess the long term effects of either over- or under-grazing. Species present and an estimate of relative abundance are recorded, but not in enough detail and with enough precision to determine what use intensity is optimum. Secondly, a transfer of responsibilities would initiate an extended period of uncertainty while the newly appointed person responsible for assessing carrying capacity familiarised himself with the task and/or the area.

A classification of range types specifically designed to indicate allowable carrying capacity would overcome, or at least minimise, both of these problems. There are, of course, several ways that such a classification could be produced. One would be to refine the landscape classification presented above, perhaps subdividing the land facets into "land elements" whose carrying capacity could be determined. It may be possible to descriminate these land elements with remote-sensing techniques, thereby obviating much of the field work that would otherwise be required. However, it would be necessary to "calibrate" such a system through field work, and the classification would have to be frequently revised.

Another method of classifying arid rangelands for evaluation of carrying capacity is described by Condon (1968). In this method, an area of land of known or confidently estimated carrying capacity is chosen as a standard by which the carrying capacity of other areas can be assessed. This should be an area that is intermediate in terms of rainfall, pertinent soil characteristics, topography, tree and shrub density, availability of drought forage, pasture type (species composition), and pasture condition (forage quality and density, degree of past degradation through erosion, etc.). Rating scales are then developed for each of these variables by assigning a value of 1.0 to a condition analogous to the condition of that variable in the base area, a value greater than 1.0 to a better condition, and less than 1.0 to a condition that would be more limiting than the condition of that variable in the base area. Carrying capacity is then estimated by multiplying the base value of carrying capacity by the ratings determined for each of the factors.

Condon applied this method to estimate carrying capacity within the land systems defined by Perry and others (1962) in the Alice Springs area of Northern Territory, Australia, but suggested that the land "unit" (i.e. facet) would be more appropriate. Although it takes some time to develop and adjust the rating scales, Condon found that they yielded "reasonable agreement with previous official assessments for lands in good condition." In areas of degenerate or poor pastures, results were "almost exactly coincident with the landholders experience" (Condon, 1968, p. 123).

The landscape land classification of the Merritt area presented above was originally conceived as a method of partitioning the study area into planning and management level units that would be meaningful to a variety of land users. It is now apparent that the classification does not mirror that conception. It does provide an introduction to the physical land base of the study area, but does not provide planning or management units. It might be possible to further subdivide the area to provide units useful for managing specific resources (e.g. forage), and it may even be possible to rate the land attributes of the land facets that have been described in order to calculate carrying capacity, but these are untested suggestions. Furthermore, the value of an evaluation based on this land classification would likely decrease with time due to the dynamic nature of the most important single land attribute in this area, the vegetation.

A land evaluation, an "assessment of man's possible use of land for agriculture, forestry, engineering, recreation, etc." (Mabbutt, 1968), based on the land classification presented herein is not justifiable. Some possibly desirable adjustments of land uses within the study area have been perceived throughout the study, but these possibilities were not based on the land classification, though they may have been inluenced by its concurrent formulation. They certainly were not derived from the completed classification.

Conclusions

In part three of this study, I argue that the landscape approach to land classification limits the potential of currently available remote-sensing and computer technology. I also outline a parametric approach to land classification that would make full use of this technology. This land classification system would not use natural areas as a spatial framework for several reasons. First, a natural area classification depends too heavily on the classifiers conception of what constitutes a "natural" area. Secondly, new data can be more easily accomodated by a computer compatible coordinate system, and they would not necessitate a revision of "natural" boundaries which these data may not honour. Finally, a parametric approach that uses a small arbitrary area defined by grid coordinates as the data vehicle, can be used to create a general classification, while it can also be used to create monodisciplinary and other special use classifications.

The British Columbia Forest Service introduced a system of integrated resource planning in 1973 that has come to be known as the Resource Folio Planning System. Pearse (1976, p. 259-260) outlined this system. Briefly, a portfolio of maps and other relevant documents is compiled, generally for a planning area that covers a watershed. This portfolio is then circulated to the various agencies concerned with land use for their comments and recommendations. Representatives of the various resource agencies, and sometimes potential land users, then meet in an attempt to coordinate objectives, and resolve conflicts. A five-year logging plan is then developed by the timber licencee of each area, and submitted for approval.

Pearse (1976, p. 267) recommended that the Resource Folio Planning System be further developed, although he also noted that basic data are often not available. A system of land classification along the lines of the one proposed could be used to supply and organise these data. It could also produce the maps included in the portfolio with a common format to facilitate their comparison.

Part Three: An Evaluation of Landscape Land Classification

Introduction

It was noted in part one of this study that the way in which land is classified depends upon purpose, knowledge, and resources. Each of these factors influenced the land classification of the Merritt area that was presented in part two.

The purpose of the classification was two-fold. First, it was to allow an evaluation of the most appropriate land uses within each classified area. Secondly, the classification was produced to assess the usefulness of landscape land classification for land evaluation in an area with established land uses, and at a large scale. It is apparent that the first purpose was not well served. This part of the study considers the factors that resulted in the inability to produce a reasonable land evaluation, based on the land classification presented. I conclude that a formal, mapped, landscape land classification is of little value for land evaluation, at least at this scale. Useful land evaluation must be based on detailed, site-specific knowledge of the land base and must also consider technology, economics, politics, land tenure, and more commonly in recent years, the desires of the public.

Knowledge, the second factor that inluences the classification process, can be subdivided into knowledge of the phenomenon being classified and knowledge of potential users' requirements. If detailed information is available about those phenomena being classified, it should be possible to produce a more useful classification than if information is less complete. This is not meant to imply that all available information must be incorporated into the classification. Knowledge that is used to guide the classification procedure is not necessarily required by potential users. Although different land users often require quite similar basic information, the information required at the land planning and management levels varies from one user to another. Therefore, knowledge of the requirements of prospective users of the classification should be used to guide efficient land classification.

Finally, the resources available to the classifier, including time, money, equipment, facilities and expertise, influence the classification procedure. The classification presented in part two was limited by all of these, but the classification methodology was also an important limiting factor.

It is appropriate at this point to consider the methodology of landscape land classification, and recent developments in classification theory, remote-sensing technology, and computer technology. There have been revolutionary developments in each of these fields since the first comprehensive application of landscape land classification techniques in the 1940's. I will return to the discussion of the Merritt land classification and suggest ways in which a different methodological approach might have produced a more useful land classification with the same resources. I will also suggest ways in which presently available remote-sensing techniques and computer technology might be applied to land-use planning and management problems in the southern Interior.

Classification

Sneath and Sokal (1973) have discussed the choices that must be made when designing a classification scheme. These choices include, but are not restricted to, agglomerative versus divisive methods, hierarchical versus nonhierarchical structures, overlapping versus nonoverlapping classes, monothetic versus polythetic classification criteria, and a qualitative versus a quantitative data base. Although these are discussed as alternatives, various combinations are also possible. If the phenomena being classified are spatially arranged, the classifier must also select a spatial framework. This may be organised as points, lines, or areas.

A distinction should be made at this point between classification and identification. Classification is the process of organising into groups or classes, or along a gradient or spectrum, by a definite procedure. A classification is the result of that process. Assignment of unidentified individuals to their proper place within a classification is the process of identification (Sneath and Sokal, 1973, p. 3).

Agglomerative methods of classification combine the individual examples of a phenomenon into groups of similar individuals. Divisive methods, on the other hand, partition the whole into groups of individuals. If either agglomeration or division is repeated during the classification process a hierarchical classification is produced. It will be a nonoverlapping hierarchy if all individuals in an agglomerative class at one level must be classed together at higher levels. If divisive classification is involved, a nonoverlapping classification results if division into a class at one level permanently isolates the members of that class from members of other classes. A nonoverlapping hierarchical classification is dendritic in diagrammatic form. Conversely, an overlapping hierarchical classification does not restrict any individual from a class at one level because of its classification at another level. Its diagrammatic form is braided -- it may bifurcate at one point, but branches are permitted to recombine. If a single attribute is used to define classes, the classification is monothetic. If the classification utilises more than one attribute to define classes, a polythetic classification results. A hierarchical classification may use monothetic or polythetic criteria, or may use both at different levels, or at different branches, of the hierarchy. Classes may be defined either qualitatively or quantitatively. A quantitatively defined classification has an advantage of objectivity, but it is often easier to define classes subjectively.

The spatial framework within which a classification is produced may be organised as points, lines, or areas (Reeves, 1975, p. 618-621). Points may be identified by a geographic name, but if no other information is given this does not allow a spatial classification. However, a spatial classification can be produced if points can be located by a coordinate system. Points can also be used to define lines or areas, and areas can be approximated by using a "centroid" point. Lines are commonly used as a spatial framework for classifying streams or roads, and for topological investigations of the patterns produced by these and similar features. Three categories of areas can be used as spatial frameworks: natural areas, institutional areas, and arbitrary areas. It usually easy to define natural areas if "single-feature" areas are desired (e.g. soil types), but "multi-feature" natural areas (e.g. vegetation communities) are more difficult to define on a consistent basis. Institutional areas include political, administrative, and legal units such as municipalities, planning districts, forest districts, and cadastral units. Arbitrary areas are normally defined by a rectangular, triangular, or hexagonal grid. They are useful in that they overcome some of the problems associated with the irregular size and shape of natural and institutional areas, and they facilitate systematic data collection. Further, if arbitrary areas are significantly smaller than natural or institutional areas of interest, they can be grouped in order to approximate the larger areas.

The land classification of the Merritt area, presented in part two, is an agglomerative, hierarchical classification with overlapping, polythetic, natural-area classes that are defined qualitatively. The agglomerative method overcomes the problems associated with continued subdivision of continental areas as in the genetic approach to land classification. These problems were discussed in part one. The hierarchical structure of the classification allows land facets to be identified without necessitating their mapping. It also organises the available information more efficiently than a nonhierarchical structure would do. Both levels of the hierarchy include overlapping classes. Several different land systems contain one or more essentially identical land facets (i.e. identical land facets are separated when land facets are grouped to form land systems). Additionally, although the combination of attribute values that defines each facet is distinct for every facet within a particular land system, a particular attribute may have the same value in more than one facet.

The land facets and land systems described in the Merritt area are natural-area classes. Because the land facets are defined by the combination of their topographic expression, geology, soils, and vegetation, they are also polythetic classes. Likewise, the land systems are polythetic because it is the combination of, and relationship between, the land facets that defines the land systems. Finally, the classification is qualitative because no attempt was made to define the basic land attributes, land facets, or land systems in terms of a quantitative data base, and classes are not assigned quantitative limits.

Remote Sensing and Computer Technology

The genetic approach to land classification and some of the early landscape approaches were based on field experience supplemented with whatever documentation was available. This usually consisted of maps, reports, and personal discussions with those familiar with the area. The utility of aerial photographs in land classification, however, was recognised by Bourne (1931) and has become a primary feature of landscape land classification. A cursory examination of aerial photographs of almost any area often reveal the existence of distinct patterns of "land." Landscape land classification attempts to delineate the boundaries between different patterns, usually on aerial photographs, then to describe (and often define) the areas so delineated in terms of more basic units.

A great deal of information can be extracted from conventional black-and-white aerial photographs by experienced photo-interpreters, especially if stereoscopic examination of aerial photograph pairs is possible. However, the amount and accuracy of the information is limited by resolution and tone contrast. Also, conventional photographic coverage is usually limited to a single date, or widely separated dates, and a single set of technical specifications including the film-filter combination and the flying height-focal length combination (Reeves, 1975, p. 5). Recent developments in remote-sensing techniques have greatly expanded the potential amount of information interpretable from remote-sensing imagery. These advances include new sensors and platforms, multiple image combining and enhancing techniques, and automatic data processing. In addition, conventional black-and-white photography is more frequently being supplemented by color, color infrared, and multispectral black-and-white photography.

Several nonphotographic sensors have been developed since the 1940's including infrared systems, electro-optical systems, laser and luminescence systems, and microwave ("radar") systems. Electro-optical sensors include thermal, photoemissive, and photoconductive detectors. Each of these produces an electrical analogue record of the image being scanned which can be used to reconstruct the image. Laser and luminescence sensing systems depend on the measurement of laser beam attenuation, or the luminescence stimulated by laser radiation. These systems show considerable promise in meteorological and pollution monitoring applications. Microwave systems are an outgrowth of radar systems and have proven useful in topographic, geologic, vegetation, meteorological, and oceanographic applications (Reeves, 1975).

Aerial photography during the 1940's was conducted almost exclusively from aircraft "platforms." Although propeller-driven and jet airplanes are the most commonly used aircraft platforms, also included are helicopters, balloons, blimps, and sailplanes. Rockets have been used as remote-sensing platforms since around the turn of the century, but the value of rocket photography was not demonstrated until 1963, two years after the first orbital photography had been obtained from an unmanned Mercury spacecraft (Reeves, 1975, p. 44-45).

The most widely-acclaimed, new, remote-sensing platforms are the manned and unmanned satellites of the 60's and 70's. The Mercury spacecraft photographs, alluded to above, were taken primarily to monitor the spacecraft altitude, but proved valuable for geologic interpretation, also (Reeves, 1975, p. 45). Except in conjunction with the manned space flight program, remotely sensed imagery from space has relied on electro-optical sensors and electronic data transmission. Although resolution is more limited with these systems than with photographic systems, excellent imagery is being obtained and has proven useful in many applications.

Since it is often possible to extract more information from a set of multiband photographs of a scene than from a single photograph of the same scene, techniques have been developed to combine two or more images into one. The images may be combined by either optical or electronic means. Optically combined images are usually sharper than electronically combined images, but it is possible with electronic techniques to remove unwanted portions of the grey scale, then to expand the remainder of the image to the full range allowing the interpreter to discriminate two different tones more readily. These are multiple image combining and enhancing techniques.

Recent advances in computer technology, when combined with the advances in remote-sensing technology, have vastly increased the potential data available to planners and resource managers. It is now possible to identify a unique multispectral signature for many natural and cultural phenomena, then to produce a "map" from either an analogue or digital record of a remotely sensed image. If the scale of the study is such that electro-optical imagery from orbital satellites is capable of supplying the necessary data, it is also possible to resurvey a given area frequently in order to monitor landscape dynamics.

Landscape land classification was developed before the presently available remote-sensing and computer technology could have been foreseen. However, the practice of manually interpreting a stereoscopic image to define natural-area land units remains the primary method of conducting a landscape land classification. The results depend very heavily on the experience of the photo-interpreter, and would, therefore, be impossible to duplicate. Further, even an experienced photo-interpreter is likely to overlook subtle tonal differences that would be detected by automated techniques. A more fundamental problem with landscape land classification lies in the use of natural-area land units. Their use in a polythetic classification necessitates more generalisation than is generally desirable if the classification is intended to go beyond a very broad introduction to an area.

A better approach to large-scale land classification would utilise available remote-sensing and computer technology to produce individual classifications of natural and/or cultural phenomena. Data collected through ground based surveys would supplement remotely sensed data, and both would be spatially coded. Individual maps could then be computer combined to produce polythetic land classifications tailored to the needs of different users.

The Advantages of Landscape Land Classification Reconsidered

Several advantages that have been claimed for landscape land classification were listed in part two of this study. These will now be discussed in light of the advances that have taken place since the early Australian landscape surveys.

The first advantage claimed is that the landscape approach to land classification can make use of remote-sensing techniques. This was an advantage over the earlier genetic approaches to land classification because the genetic approach recognised land units at a scale that was not compatible with the imagery available at that time. However, since the advent of high altitude and space photography, this is no longer true. Presently available imagery is more suited, however, to parametric land classification than to either genetic or landscape land classification, and the data available can be extracted from this imagery most efficiently through computer analysis.

Another advantage claimed for the approach is that it minimises field research time and expense because it allows transfer of information from one area to other similar areas. This extrapolation is done at the cost of some precision of definition. If the same level of precision is used, a grid-based, computer generated map, combining remotely sensed and field collected data, would require no more, and probably less, field research.

The third advantage claimed is that it is possible to apply the method at any scale. This is true, but as part two of this study demonstrates, it does not follow that the method is useful at all scales. At large scales, land planning and management are based on administrative units, not natural units, but a useable classification must be capable of providing the information necessary for making decisions that are to be implemented on administrative areas. This is better served through a classification that uses a small arbitrary unit as a spatial framework rather than a larger natural area. The size of the classification unit ultimately depends on the resolution of the sensing technique, but should be as small as practical. In any case, the size of the unit must suit the most rapidly changing land attribute. The most convenient arbitrary unit is based on a grid system, and can be referred to as a "unit cell." Once described, it is possible to combine different unit cells into natural areas, administrative areas, or larger arbitrary areas, depending on the needs of the user. Computer technology simplifies this process.

It is also claimed that the landscape method facilitates understanding of land attributes and their interactions. This is tantamount to circular reasoning because landscape land classification utilises landscape genesis as one of the criteria used to define the land units. If the aim of the classification is to investigate landscape genesis and attribute interactions a less subjective approach is dictated.

The method, it has been suggested, provides a basis for further studies. This must be considered in the light of the purpose of the land classification. If the purpose is to present a general introduction to the area in order to identify areas to be considered in detail, the landscape approach may serve adequately. However, a classification designed to aid planning and/or management must go beyond this. Furthermore, it is probably not necessary to produce a formal land classification in order to identify areas to be studied in more detail, except possibly in areas where very little basic information is available. In a settled area, even though sparsely settled, basic information to guide further investigation almost always exists already.

The fifth advantage claimed is that the landscape approach can make use of computers for data entry, manipulation, storage, and retrieval. It should be obvious by now that although the method can use computers it limits the computer's potential. The generalisation inherent in identifying landscape land units permanently removes some data from consideration and limits the detail of information that can be extracted from the remaining data. A computer program can be designed to produce a generalised classification if this is desired while retaining the data necessary for a more detailed classification.

A final claimed advantage of landscape land classification is that an evaluation based on such a classification can be modified in light of new information about the land, or changing technology, finances, and attitudes. If the land classification is to incorporate new information about the land, landscape land classification does not provide the best approach. Since the method defines land as the integration of various attributes, it is not possible to include new attributes, or new information about particular attributes, within a structure determined by other information, unless the new information correlates with some previously used information. In other words, new information requires a new classification. This is also true if a parametric, computer produced classification is used, but the new classification can be produced much more rapidly. Technological advances, and changing finances or attitudes can be accommodated easily with either approach.

Conclusion

It is now clear that a more flexible and useful classification of the Merritt area could be developed by combining currently available remote-sensing and computer technology with previously documented information. It would not be reasonable, of course, to apply these techniques only to an area as small as the study area, because the costs would probably outweigh benefits. However, it should be practical to develop integrated remote-sensing programs for larger areas that would make full use of computer technology. Such a program could produce a series of land classifications tailored to the needs of politicians, foresters, graziers, sportsmen, academics, or other special interest groups. It might also be used to produce a general classification that would provide the same type of information as a landscape land classification, but with known levels of precision for each attribute in each land unit.

It was claimed above that a more useful land classification of the Merritt area might have been produced with the given resources if a different methodological approach had been applied. Although this is an untested claim, I believe that by using a unit cell as the spatial framework -- perhaps the cells defined by the Transverse Mercator grid would have been suitable -- a more useful classification would have been obtained. Even without the aid of a computer it would then be possible to identify cells with administrative or natural areas of several types. The system suggested in the previous paragraph is merely an extension of this approach that would incorporate resources that were not utilised in this study.

This study has considered three approaches to land classification and has treated each approach separately. Mabbutt (1968), who defined these three approaches to land classification, concluded that although one method may be emphasised over another depending on the level of detail required and the resources available, it is often profitable to combine two, or even all three, of the approaches. An obvious drawback of a purely parametric land classification is the expense of data collection. In an area such as the study area, land-use intensity demands detailed information. However, limited funds may not justify a detailed parametric classification of the entire study area. A preliminary landscape land classification could be used to identify those parts (i.e. land systems) that would justify parametric classification. It could also facilitate determination of desirable sampling density. Whether it is necessary to formalise and map this preliminary land classification is, however, open to debate.

I believe that a useful parametric classification of the Merritt area could have been produced without a preliminary landscape classification, but it may be that other areas such as the Canadian North, would benefit from a formal, mapped, landscape-type classification. So little basic information may be available that it would not be possible to design a feasible parametric data collection scheme without a preliminary broad classification. However, land planning and management cannot be based on such a classification. These require hard data that can most profitably be obtained through a subsequent parametric data collection program in those areas that justify the additional expense that the parametric approach entails.

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