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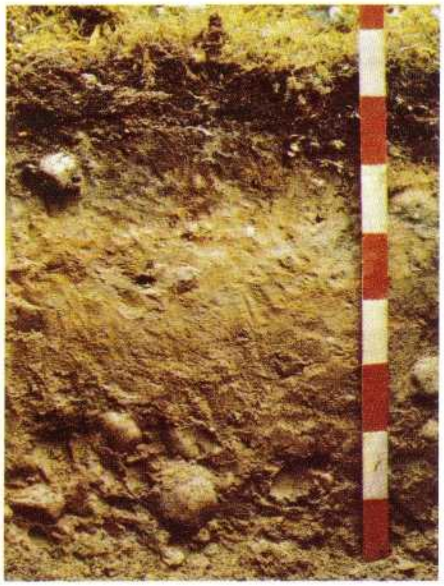
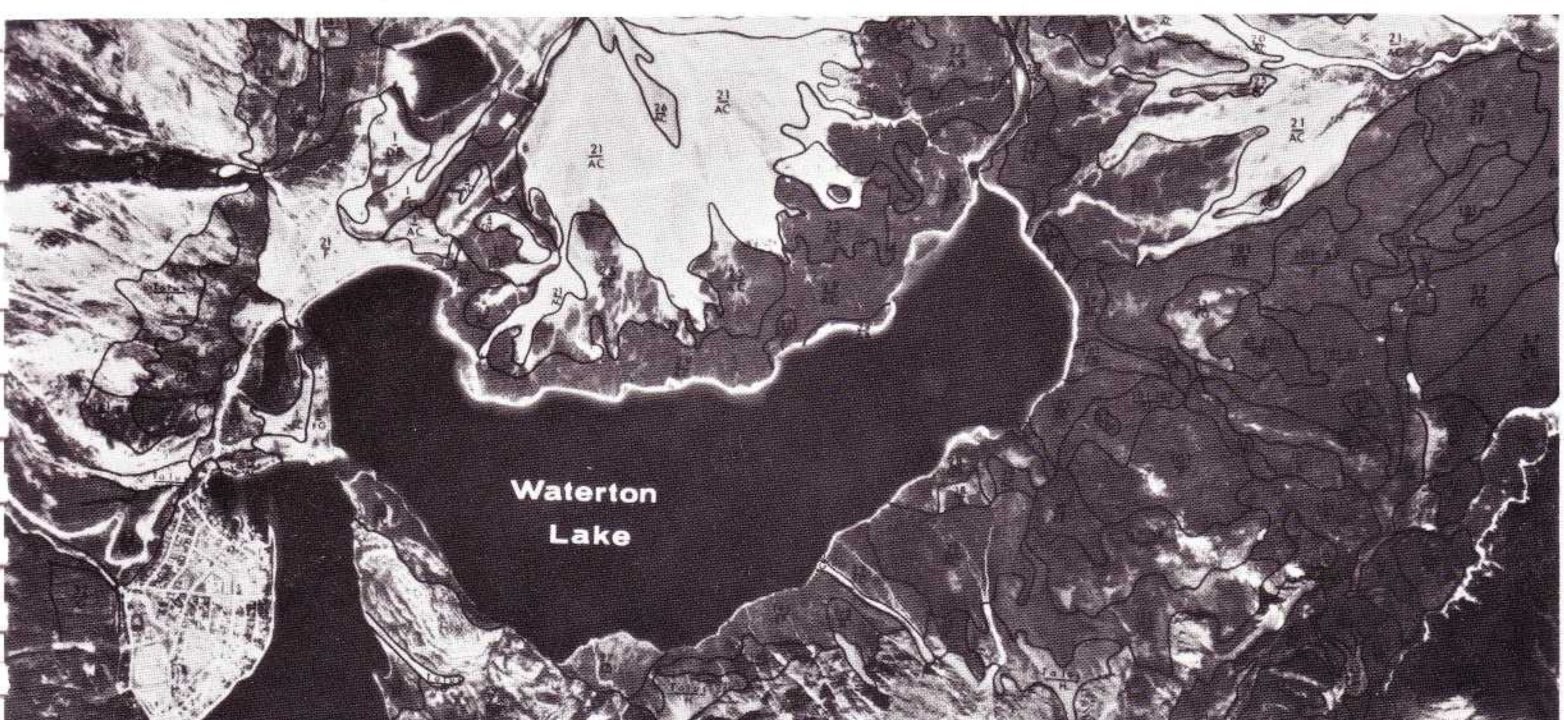


Soils of Waterton Lakes National Park, Alberta



Soils of Waterton Lakes National Park, Alberta

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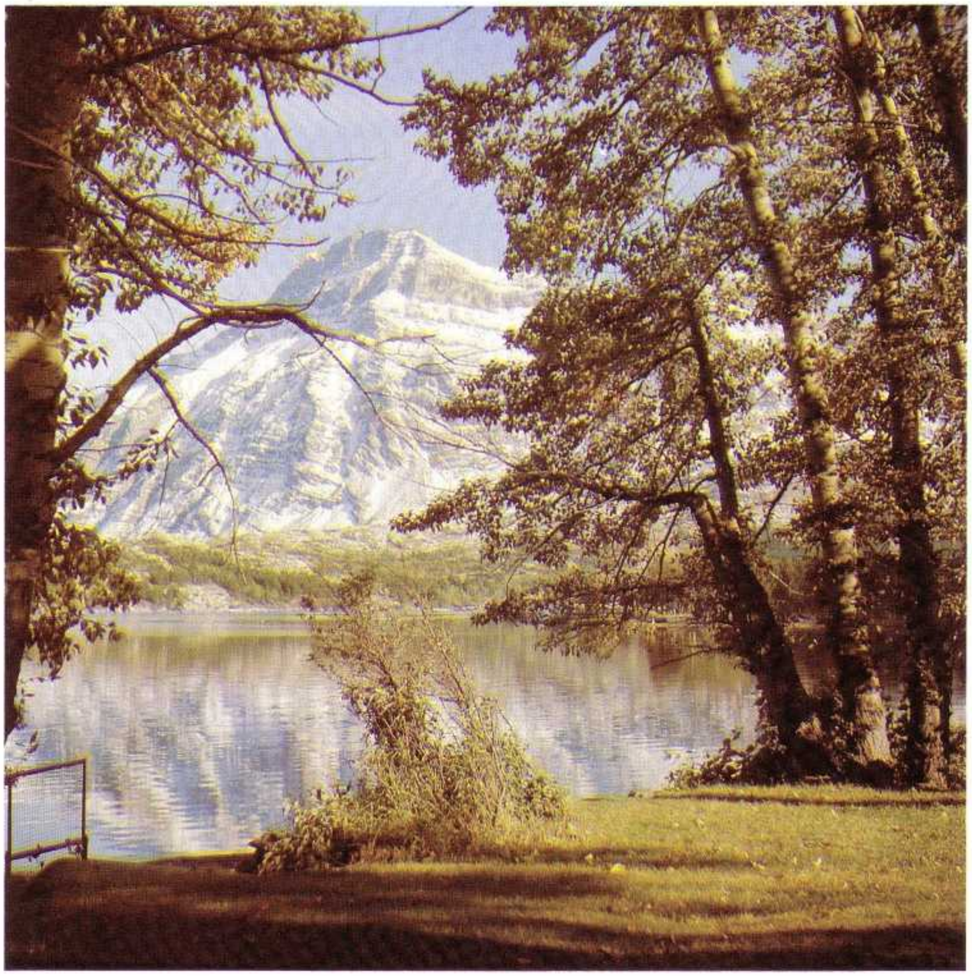

Mount Vimy: a scenic view in Waterton Lakes National Park.

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ABSTRACT

The soil survey of Waterton Lakes National Park establishes the complexity of the soils in the Park and provides the basis for identification of some of their attributes and limitations for specific recreational uses. The rapid change from prairie vegetation associated with the northern portion of the main Waterton valley to coniferous forests in the steep U-shaped mountainous valleys results in the development of soil profiles which were classified as belonging to 7 of the 8 Orders as defined in *The System of Soil Classification for Canada.*

The most evident soils to the casual visitor belong to the Chernozemic Order and are generally associated with the grassland area in the main Waterton valley. To the east of this valley, soils of the Luvisolic Order develop in the forested areas wherever erosion does not obliterate the horizons. Immediately adjacent to the main Waterton valley and up some of the side valleys, soils of the Brunisolic Order can be identified. These soils appear as transition soils in one instance between the Chernozemic soils and the Luvisolic soils to the east and in the other instance between the Chernozemic soils and the Podzolic soils to the west. In the extreme western portion of the Park, where the higher rainfall and associated more vigorous forests occur, soils of the Podzolic Order predominate on stable slopes. Soils of the Regosolic Order are found throughout the Park wherever erosion or deposition continually disrupts the profiles preventing horizon development or where the natural environment is not conducive to horizon development. Soils adjacent to streams and lakes, and in poorly drained positions belong to the Gleysolic Order and are found throughout the Park. Occasional areas of deep accumulations of organic matter were noted. These soils belong to the Organic Order. Soils of the Solonetzic Order were not encountered in the Park. Some of the well-defined reddish horizons in the western portion of the Park appear to be related to weathering of pyroclastic material from at least one eruption which deposited ash on the soil surface. Pockets of well-preserved Mazama ash have been encountered.

Textural, stoniness, and slope phases of Subgroups were used to name delineated soil areas. Such areas correlated well with landform boundaries providing an external feature as an aid in extrapolating soil boundaries. The composite characteristics of the Subgroup phases as embodied in the mapping legend, through the map unit descriptions, allow each mapping unit to be assessed as to its limitations for specific park uses.

Detailed guidelines were established to assess the soil limitations of each map unit for various park land uses. The findings of this study are summarized in a table listing the nature and degree of soil limitations associated with each map unit within the Park. The location of map units is shown on soil maps. Landform maps, maps of soil drainage classes, and maps indicating soil suitability for certain Park uses can easily be derived from the above information.

ACKNOWLEDGMENTS

The soil survey of Waterton Lakes National Parks was conducted jointly by Environment Canada, Canadian Forestry Service, Northern Forest Research Centre, Edmonton and Agriculture Canada, Soil Research Institute, Soil Survey, Edmonton with funding for field expenses by the Department of Indian Affairs and Northern Development, Parks Branch.

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The drafting of the detailed soil map was done by the Cartography Section of the Soil Research Institute, Ottawa. Photographs and photographic assistance were provided by P.S. Debnam, Canadian Forestry Service, Edmonton.

INTRODUCTION

A resource inventory of Waterton Lakes National Park has been initiated by the National Parks Service. A part of the resources inventory is a soil survey, initiated in May 1971, to obtain data about the kind, distribution, and characteristics of the soils in the Park. The results and conclusions of the soil survey are presented in this report.

Contained in this report are generalized descriptions of soil map units and interpretations for park use. More detailed information on the characteristics of the horizons of all the soil mapping units and a redrafted planimetric soil map, which will remove many of the air photo distortions inherent in the soil map accompanying this report, are available from the authors.

The report is written in four main sections. Part I is a general description of the area. Some of this information, vegetation for example, is only briefly described as it is obtainable from the literature. Part II describes the survey and analytical methods, landforms, and parent materials. Part III provides a key to the soil mapping units plus descriptions of morphology and site characteristics. The fourth part is an interpretation of soil characteristics. The intent of Part IV is to identify the limitations of various land areas for selected uses.

The complete report is comprised of the written text and the soil maps. The best results will be obtained when the soil maps and report are used as an integral unit.

No attempt has been made to provide soil interpretations for all possible land uses. Additional interpretations can be made as required.

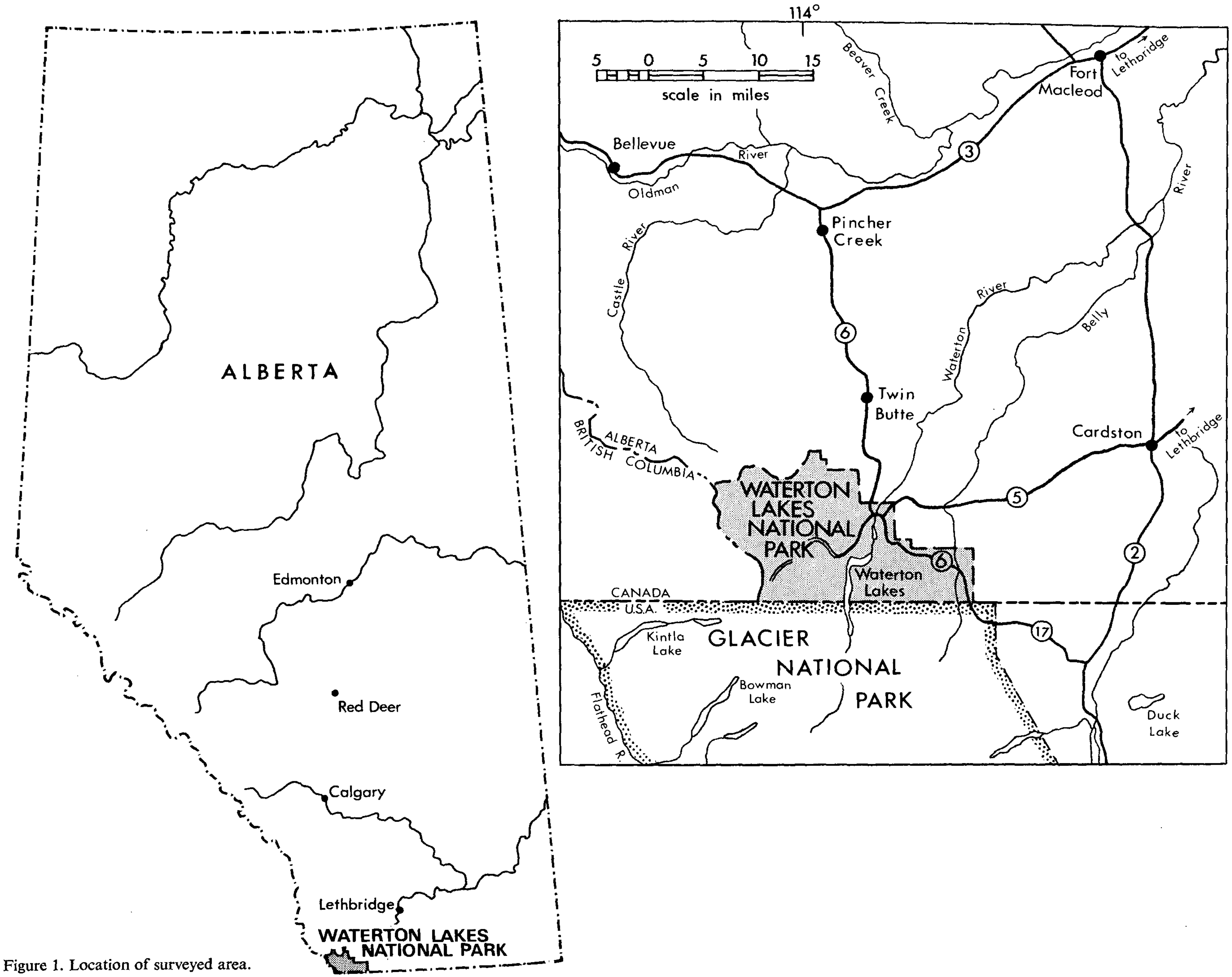

Figure 1. Location of surveyed area.

PART I

GENERAL DESCRIPTION OF THE AREA

LOCATION AND EXTENT

Waterton Lakes National Park is located in the extreme southwest corner of Alberta (Figure 1). The western extremity of the Park is approximately 114°10′ W longitude; the boundary of the Park is the Continental Divide coincident with the Alberta – British Columbia border. The northernmost extent of the Park is approximately to 49°12′ north and the southern boundary is the 49th parallel of latitude coincident with the International Border between Alberta and the state of Montana, USA. The eastern boundary is about 113°39′ W longitude.

The Waterton Lakes Park area is about 203 square miles; 14 miles at its widest north–south dimension and 19 miles wide at the 49th parallel. The Park bounds the Blood Indian Reserve Timber Limit A on the west side of the Belly River.

HISTORY, DEVELOPMENT, AND PRESENT CULTURAL FEATURES

The earliest visitors to the area were probably the Kootenay Indians, who as far as we know were nomadic in their habits. In 1858 the area was visited by the Lt. Blakiston party, associated with the Palliser expedition (Spry 1963).

Early accounts of the area came from "Kootenai" Brown (Rodney 1969). These accounts are fairly well known locally and his general comments augment certain observations on wind velocities, the variability of the snowfall, and wildlife features, all of which are still being documented. Evidence of Brown's reported efforts at cultivation has largely disappeared.

There is evidence that commercial logging was conducted just north of Sofa Mountain and on some of the higher land just north of the International Border on the west side of Waterton Lake. Much of this logging was probably done before the establishment of the Park and does not really detract from the area, as regrowth has hidden most of the cutting evidence.

There is evidence of recent cutting scattered throughout the Park. Examples are the salvage of windthrow about a mile south of Red Rock Canyon; cutting for campsite fuel west of Red Rock; removal of dead and diseased trees west of the Information Office; and removal of trees in campgrounds where user damage has occurred.

The Park was established in 1895 with an area of approximately 54 square miles. Since then, the area has been changed on a number of occasions. At one time it was about as big as 540 square miles and subsequently reduced in size. Observations during this survey indicate that the present 203 square miles of Waterton Lakes National Park is a popular place to visit and that visitor use and pressure will probably continue to increase (599,380 visitors in 1971-72; Visitor Services Office, Calgary. Personal communication).

Access is provided by paved Highways 5 and 6, from Cardston, Pincher Creek, and Montana. Paved highways lead from the Park entrance to the townsite of Waterton Park and to Cameron Lake and Red Rock Canyon. Motorized transportation is limited to the main roads and Waterton Lakes. Winter access is somewhat limited. The closest cities are Lethbridge and Calgary, both of which provide rail and airport facilities. Bus services to Waterton Park are restricted to the tourist season.

A number of cultural features have been developed (Figure 2). The locations of campsites and picnic areas are water-oriented, and the trails connect such sites throughout various parts of the Park. A few viewpoint lookouts have been established along the access routes. The townsite of Waterton Park (Figure 3) provides the modern facilities of a tourist service center. Other cultural features include a golf course, riding stable, cemetery, fire tower, docks, telephone and power lines, institutional camps, and pits for quarry-rock, gravel, and soil stripping for topsoil.

The intensity of cultural features present in a park of this size makes it obvious that man has become a significant part of the environment. The concern is whether the biological systems of the park can support the present and/or anticipated levels of development and use without significant damage.

PHYSIOGRAPHY AND TOPOGRAPHY

The north-central part of the Park (near the Park gate) is an extension of the Alberta Plains section (Figure 4) of the Interior Plains (Bostock 1970). However, the major portion of the Park is in the Rocky Mountains region (Bostock 1970). The land surface is extremely variable, ranging from relatively level outwash plains and low-angle alluvial fans to high, rugged mountain peaks (Figure 5). Four main valleys cut across the mountains: the Belly River valley in the east; the main valley, which is largely occupied by the Waterton Lakes

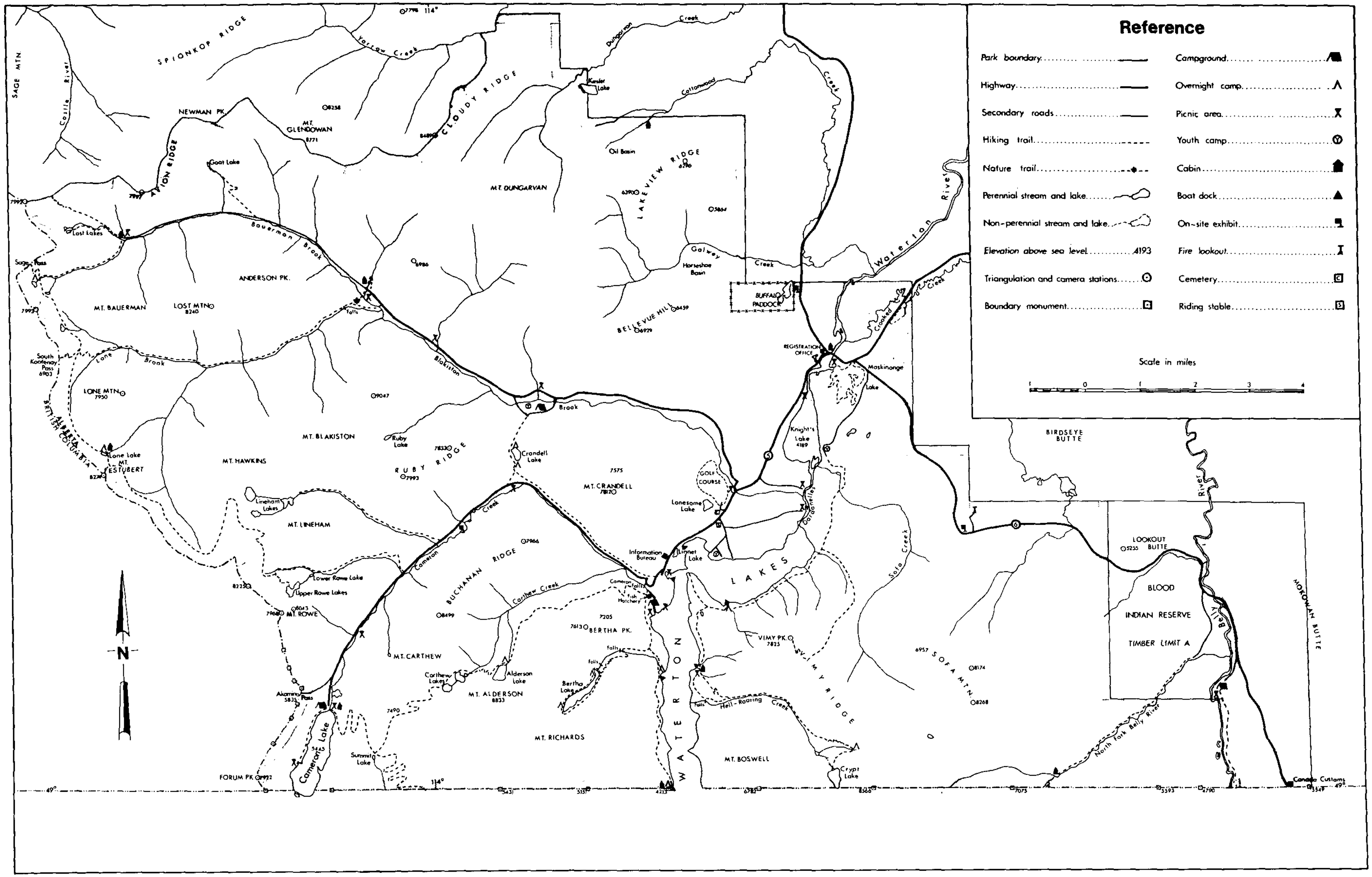

Figure 2. Cultural features of Waterton Lakes National Park.

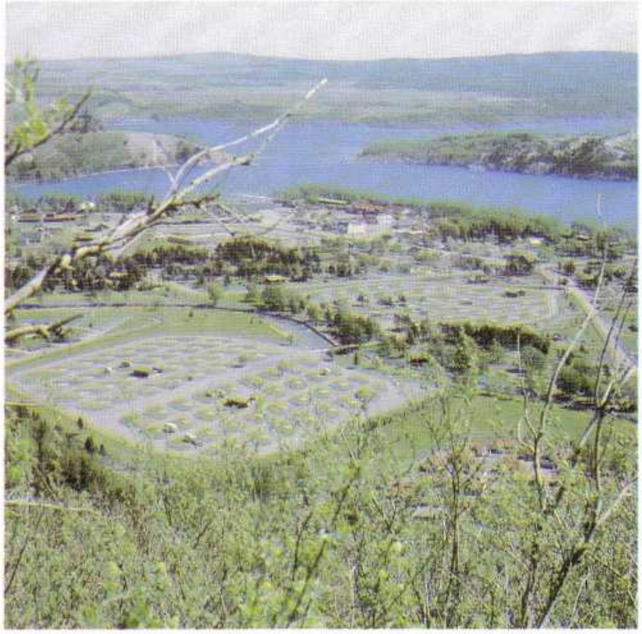

Figure 3. The townsite of Waterton Park provides the modern facilities of a tourist service centre.

Figure 4. Where prairie plains meet the Rocky Mountains.

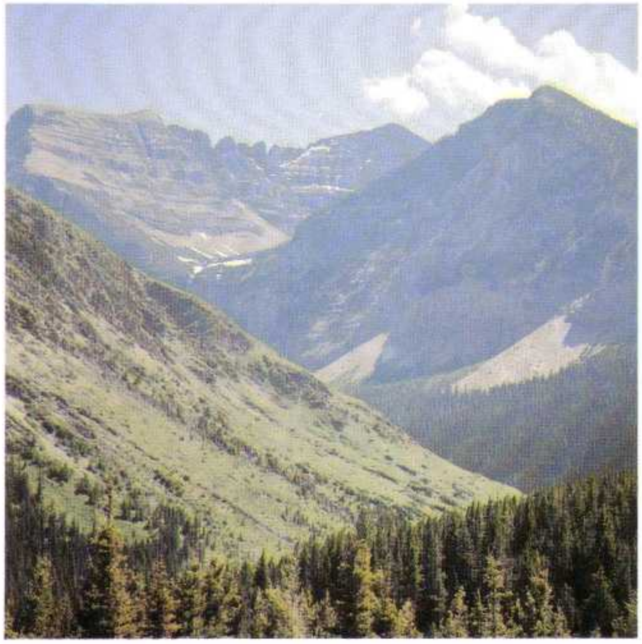

Figure 5. Rugged topography typical of the Rocky Mountains region.

Figure 8. Brownish-colored glacial till overlying Wapiabi shales; very prone to slumping.

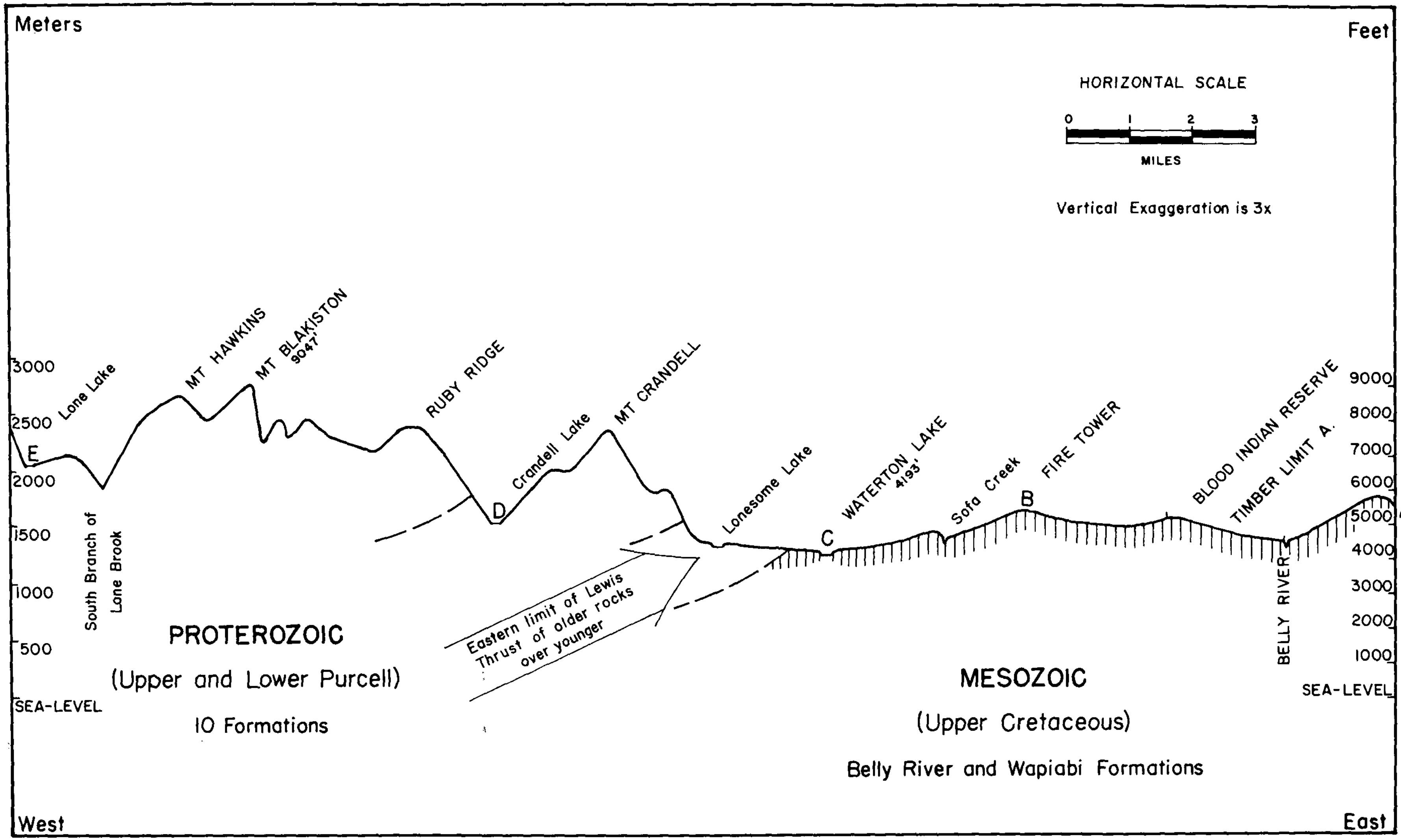

Figure 6. East-west topographic cross section of Waterton Lakes National Park from the northeast corner to Lone Lake.

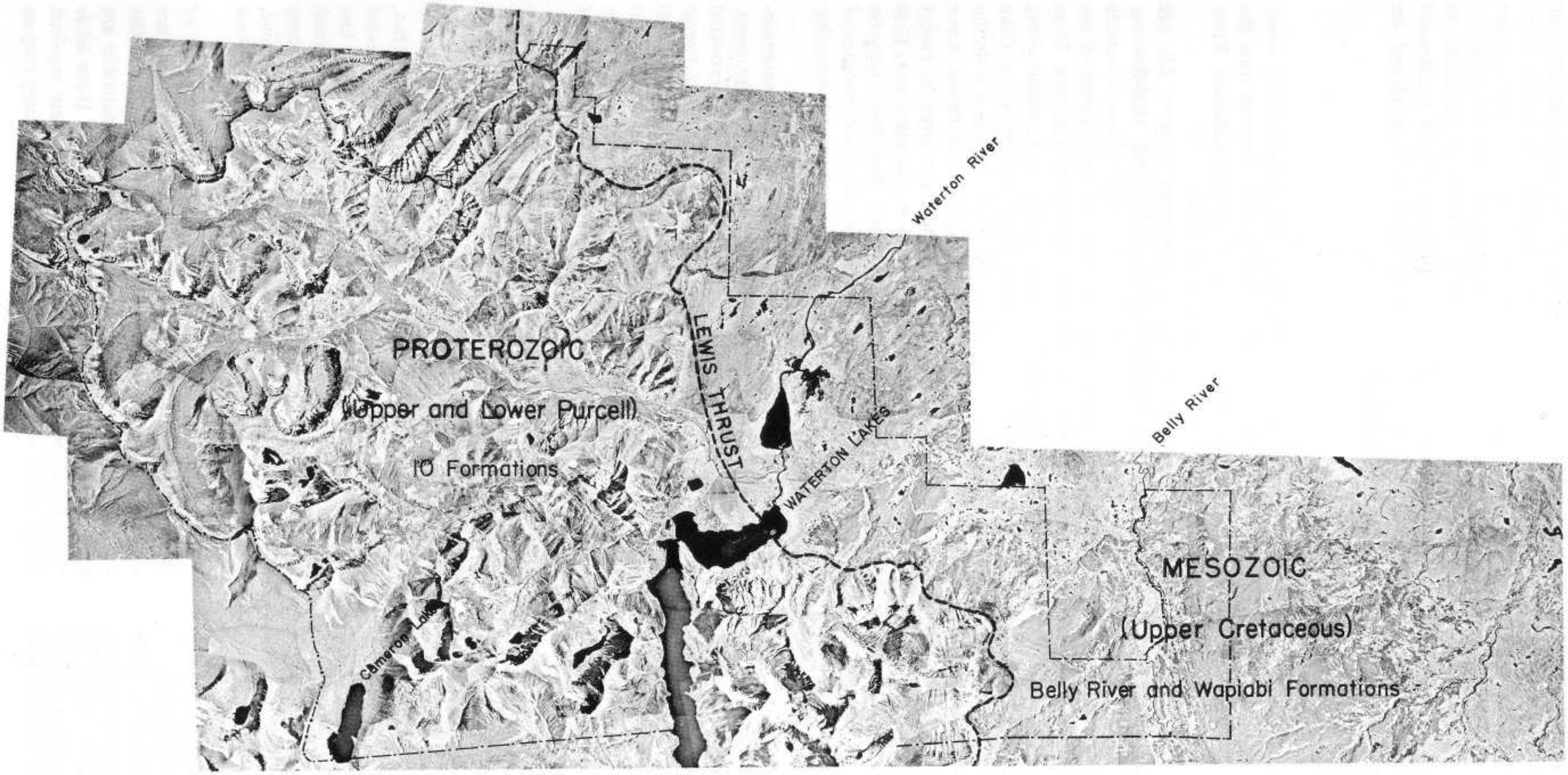

Figure 7. Location of major stratigraphic units in Waterton Lakes National Park.

system; the Cameron Creek valley; and the Blakiston Brook valley. The latter two valleys are quite narrow and confined between steep mountainsides. A diagrammatic cross section (Figures 6, 7, and 13) provides a generalized relationship of the main physiographic features.

The lowest elevation, near the Park entrance, is approximately 4,180 feet above sea level; the highest elevation is Mt. Blakiston, at about 9,050 feet. The majority of the Park lies above 4,300 feet. Steep mountainsides, hanging valleys, and the extreme folding and faulting of the bedrock result in abrupt changes in topography and elevation.

The topography classes are given in Table 2.

GEOLOGY

The main mountains of Waterton Lakes National Park are formed from Proterozoic, or Precambrian sedimentary rocks (GSC Map 1002A, 1951; MacKay 1952; Douglas 1952). These rocks are some of the oldest exposed sediments in the world, with exposures at Cameron Falls and many other places. The complete sequence of rocks is in the order of 13,000 feet. These rocks are composed of the Upper and Lower Purcell Groups containing 10 formations of red, green, and gray dolomites; green and red argillites, with some sandy and gritty dolomites, quartzites, conglomerates, and some basalt (Douglas 1952) (Figure 7). It is the red and green argillites that are prominent in the Park, especially along Blakiston Creek and Red Rock Canyon. It is this rock that probably gave the Cordilleran glacial till soil parent materials their characteristic pinkish color.

The Lewis Thrust (MacKay 1952) represents the eastward extension of the horizontal compressive forces of the earth's crust, which caused the older Proterozoic rocks to be forced over the younger Mesozoic rocks (Figures 4, 6, and 7). These younger underlying rocks belong mostly to the Belly River and Wapiabi formations and are mainly fine textured shales which give rise to a higher clay content in the soils on the eastern side of the Park. The Wapiabi shales, in particular, give rise to clayey soils and characteristic slumping of large blocks of land, especially along the south side of the North Fork Belly River (Figure 8). The Mesozoic rocks give rise to less spectacular landscape and lack the aesthetic appeal of the rugged mountainous territory of the Proterozoic rocks.

There are no glaciers in Waterton Lakes Park, but glacial features are evident in the many cirques (Figure 9), rock-basin lakes, U-shaped valleys, hanging valleys (Figure 10), waterfalls (Figure 11), moraines (Figure 12), drumlins, eskers, and outwash plains. The fault trench occupied by the Waterton Lakes system is about 8 miles long and one-half mile wide, and is a unique feature in itself. Numerous lakes such as Cameron, Alderson, Carthew, Bertha, Lineham, Rowe, Crypt, Lone Lake, Lost Lake, Goat Lake, Ruby Lake, and Twin Lakes occupy cirque positions. Frost, snow action, and water erosion have formed many postglacial features.

The surficial geology maps by Stalker (1959, 1962) provide land separations on the basis of surface features such as nonglaciated areas, valley glaciers and cirques, areas of Cordilleran till and outwash, alluvium, and an approximation of the contact line between the Cordilleran and Continental glaciations. The Continental glaciation just reaches into the Park in the vicinity of the Blood Indian Reserve Timber Limit A and at the extreme north end of the Park. This contact zone contains stones and pebbles derived from the Canadian Shield. These erratics have been observed at elevations of approximately 4,500 feet. Soils associated with continental till have a higher clay content than soils developed on Cordilleran materials.

DRAINAGE

The Waterton and the Belly are the two main rivers draining the Park. Their northerly flow empties into the Oldman River, and in turn into the Saskatchewan River system via the South Saskatchewan River.

Major perennial stream tributaries (Figure 13) are Cameron Creek, Blakiston Brook, Sofa Creek, Hell-Roaring Creek, and North Fork Belly River. Yarrow Creek is outside the Park and accepts drainage from the north slopes of the mountains along the northern perimeter. Likewise West Boundary Creek collects water from the south slopes along the International Border and discharges into Waterton Lake just south of the border. Minor perennial streams are Bertha Brook, Carthew Creek, Rowe Brook, Lineham Brook, Lone Brook, and Bauerman Brook. All the above streams, except Sofa Creek, originate from cirque lakes. Galway Creek, Lost Horse Creek, Coppermine Creek, and Red Rock Canyon stream do not originate from cirque lakes and because of smaller catchment areas their discharges are somewhat smaller and probably more erratic in flow.

Numerous intermittent streams flow down the mountainsides as a result of snowmelt and occasional heavy rainstorms.

The magnitude of one such storm in June 1964 provided records (D. L. Golding, File report on Waterton flood. Forest Hydrology Section, Canadian Forestry Service, Edmonton) indicating that 13.2 inches of rainfall occurred in one 24-hour period, with gauge heights showing that the level of Waterton Lake rose by 13.76 feet. Downstream damage to the town of Cardston was estimated in excess of $68,000.

Because of generally steep topography in the mountainous area, most of the Park is well drained. However, the east and northeast parts of the Park do have some restricted drainage resulting in Gleysolic and Organic soils. Such areas occur in depressions in the glacial till plains and at the lower elevations, or toe, of some of the alluvial fans; Blakiston fan, for example. Some areas, generally small in extent, are flooded as a result of beaver dams constructed on relatively low gradient streams. Seepage and water discharge cause small areas of poor drainage on some mountain slopes and on some steeper glacial till areas. Such areas are not generally extensive, except for some wet areas and springs along the North Fork Belly River and in the vicinity of Cameron Lake.

The major lake is really a lake system, composed of Waterton Lakes, Knight's Lake, and Maskinonge. There are a number of poorly drained soil areas along the Dardanelles and the two lower lakes. Since many recreation activities are water oriented, such wet soil areas adjacent to these lakes may have an impact on the type of land management required for their best use. The other lakes in the Park occupy cirques

Figure 9. A cirque lake.

Figure 10. U-shaped hanging valley; Lineham wall.

Figure 11. Waterfall; middle falls, Hell-Roaring Creek; note increased erosion below the falls.

Figure 12. Moraine features resulting from glacial till; near Kesler Lake. This area is in the general contact zone between the Continental and Cordilleran glaciations.

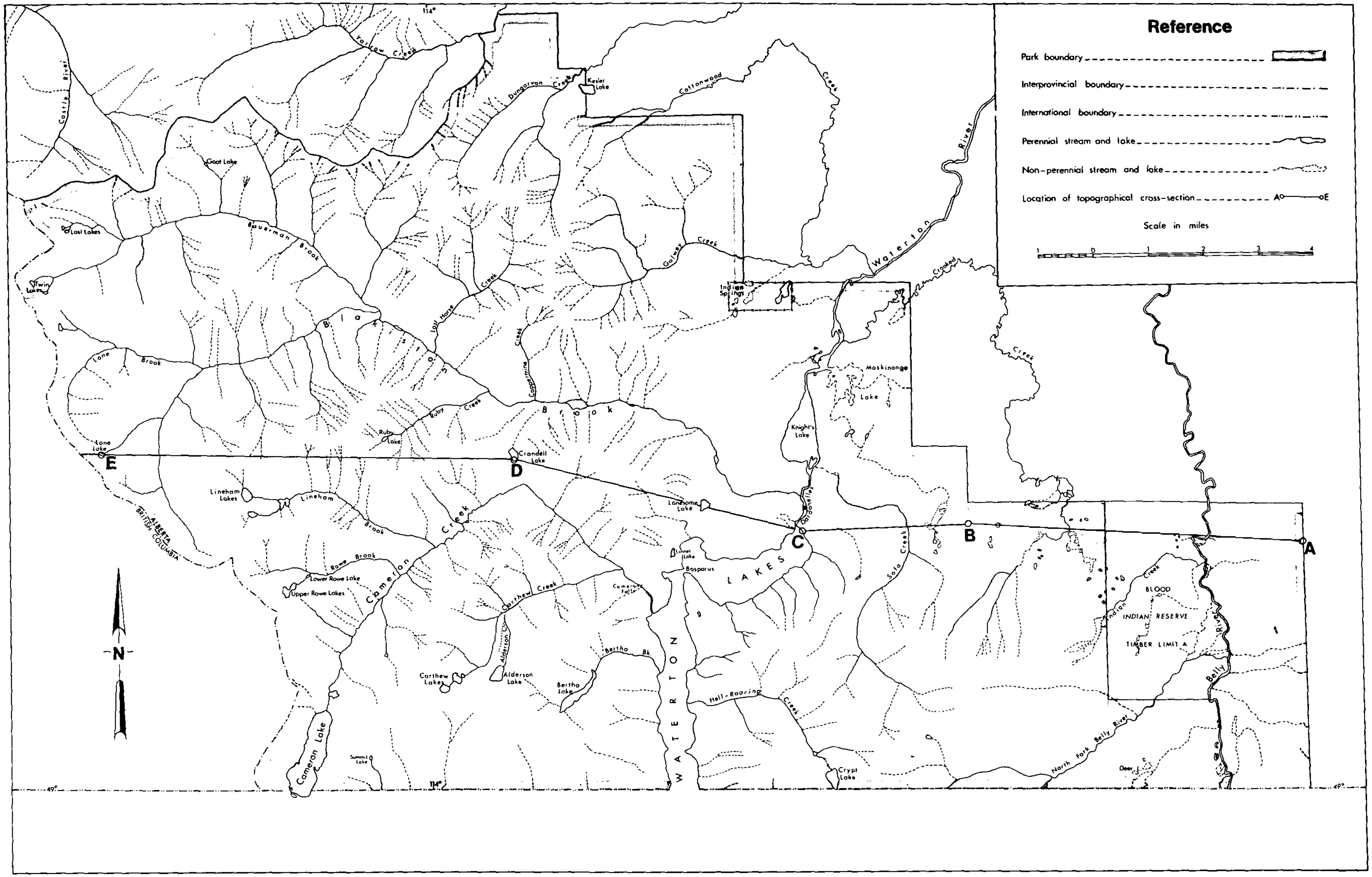

Figure 13. Drainage systems of Waterton Lakes National Park.

resulting from alpine glaciation. Except for Cameron Lake, they are relatively high in altitude and not very large. They include Crypt Lake, Bertha Lake, Alderson Lake, Carthew Lakes, Upper and Lower Rowe lakes, Lineham Lakes, Lone Lake, Twin Lakes, Lost Lake, Ruby Lake, and Goat Lake. Kesler Lake, Lonesome Lake, the Buffalo Paddock lakes, and some small lakes east of the fire tower result from the damming effects of glacial deposits. An exception appears to be Crandell Lake, which is formed in a col, and is essentially a rock basin lake. Again, because so many recreation activities are water oriented, land surrounding the lakes will be the areas subjected to the most intensive human use pressures.

The majority of the lakes and streams are aesthetically pleasing bodies of cold, clean mountain waters (Figure 14). Many of them have coarse and highly permeable soils adjacent to them (Figure 15). If such soils are improperly managed through overuse or wrong use, then serious pollution levels could occur and the clean attractiveness of these waters could be lost.

CLIMATE

The regional climate of Waterton Lakes Park is similar to that of the rest of Alberta to the extent that it is continental, with long, cold winters and short cool summers (Longley 1967). Poliquin (personal communication) comments that the general climate of the Park is affected by the maritime influence from the Pacific and also by the continental climate. Longley further points out that chinooks are more frequent in the Crowsnest area and southern Alberta than in the rest of Alberta; that the tops of hills are generally colder than the plains, although frost hollows are common in depressional areas; and that the Koeppen classification places most of Alberta in the cool temperate zone, although polar conditions occur on some of the mountain peaks. (*See* Table 1.)

Stringer (1969) and Longley (1967) both point out that the climate in the Park is different from that in other parts of the province in that the area has the highest springtime precipitation in Alberta, mostly in June. The growing season is completed by early September. Carway, on the International Border just east of the Park, has a mean of only 97 frost-free days.

Stringer (1969) emphasizes that the higher precipitation in the main Waterton valley (compared with similar prairies to the northeast) is offset by valley winds that increase evapotranspiration in the area. He also notes the higher incidence of winter chinooks in the main valley. Ogilvie (1962) refers to the inland extension of maritime influences from the Pacific by virtue of "storm-tracks," and that as a result Waterton has a summer-dry, winter-wet climate with slightly higher total precipitation and milder temperatures than other parts of the province. Klein (1957) substantiates the presence of "storm-tracks." Such "storm-tracks" are further verified by the occurrence of the June flood in 1964 and the paralyzing snowstorm of April 1967 (Janz and Treffry 1968).

Sanderson (1948) and Reinelt (1968) point out the moist subhumid to humid climate that occurs at higher elevations. This observation is substantiated in Waterton Lakes Park by the presence of strongly developed Podzol soils at the higher elevations in the west part of the Park (Figure 18).

VEGETATION

Forest types and vegetation have been mapped by Stringer (1969), Lopoukhine (1970), and Kuchar (1973). A fire hazard classification based on vegetation types has been prepared by Grigel, Lieskovsky, and Kiil (1971). The reader is referred to the above publications for detailed descriptions and maps.

A summary correlation of the soil map units with main vegetation is given in Table 2. Further soil–vegetation correlations could be obtained by using the map overlay method of McHarg (1969).

The map unit descriptions include vegetation as found at the pedon site on the sampled soils. They also provide a regional description of the vegetation as it occurs on the mapping unit (Figure 16, a and b). This information is available on request.

Table 1. Selected climatic data

Station	Elevation (ft A.S.L.)	Temperature (°F) Mean annual	January Max.	January Min.	July Max.	July Min.	Precip. (in.) Mean annual	% as snow	Wind, Percent frequency from noted directions N	NE	E	SE	S	SW	W	NW	Calm
Beaver Mines	4,218	39	27	7	76	44	24.3	50									
Caldwell—Hillspring	4,000	40	26	11	77	47	25.6	51	8	6	2	3	2	70	1	7	1
Cardston	3,826	41	28	9	78	49	18.1	36									
Carway	4,000	39	24	5	74	48	21.8	50									
Mountainview	4,325						22.9	48	7	12	2	2	*	66	7	3	1
Pincher Creek	3,758	40	27	9	77	47	20.7	40	1	5	25	2	*	5	57	5	0
Mountainview—Birdseye	4,300						26.4	51	10	8	5	*	*	66	6	<1	4
Waterton Park Headquarters	4,200	41	25	7	75	51	42.7	53	10	9	1	<1	3	64	4	2	6
Waterton—Belly River	4,500						38.8	54									
Waterton Lakes—River Cabin	4,200						34.0	54	8	10	2	1	4	63	3	1	8

*Less than 0.5%.
Note: Data taken from McKay, Curry, and Mann (1963).

Figure 14. Cold, clean, and attractive water near Boundary Bay, Waterton Lake.

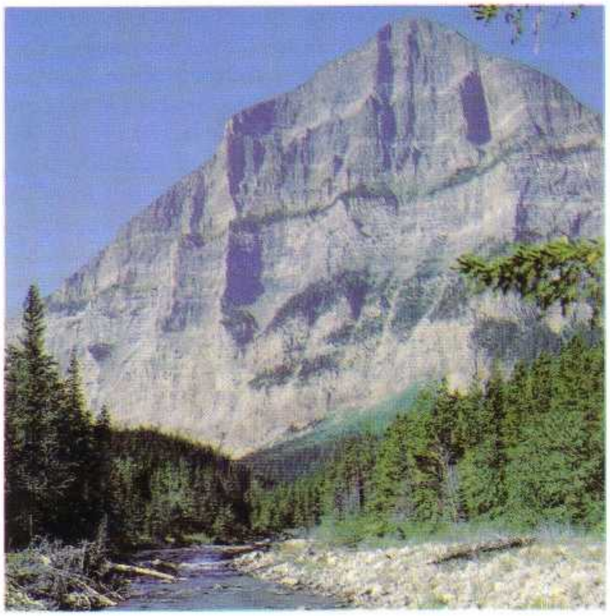

Figure 15. Creek flowing through an area of coarse textured soils.

Figure 16(a). Fescue – oat grass (Festuca-Danthonia) association on dry site. Note roadway reclamation. See map unit 21 for soil description.

Figure 16(b). Engelmann spruce – lodgepole pine association on a subhumid site.

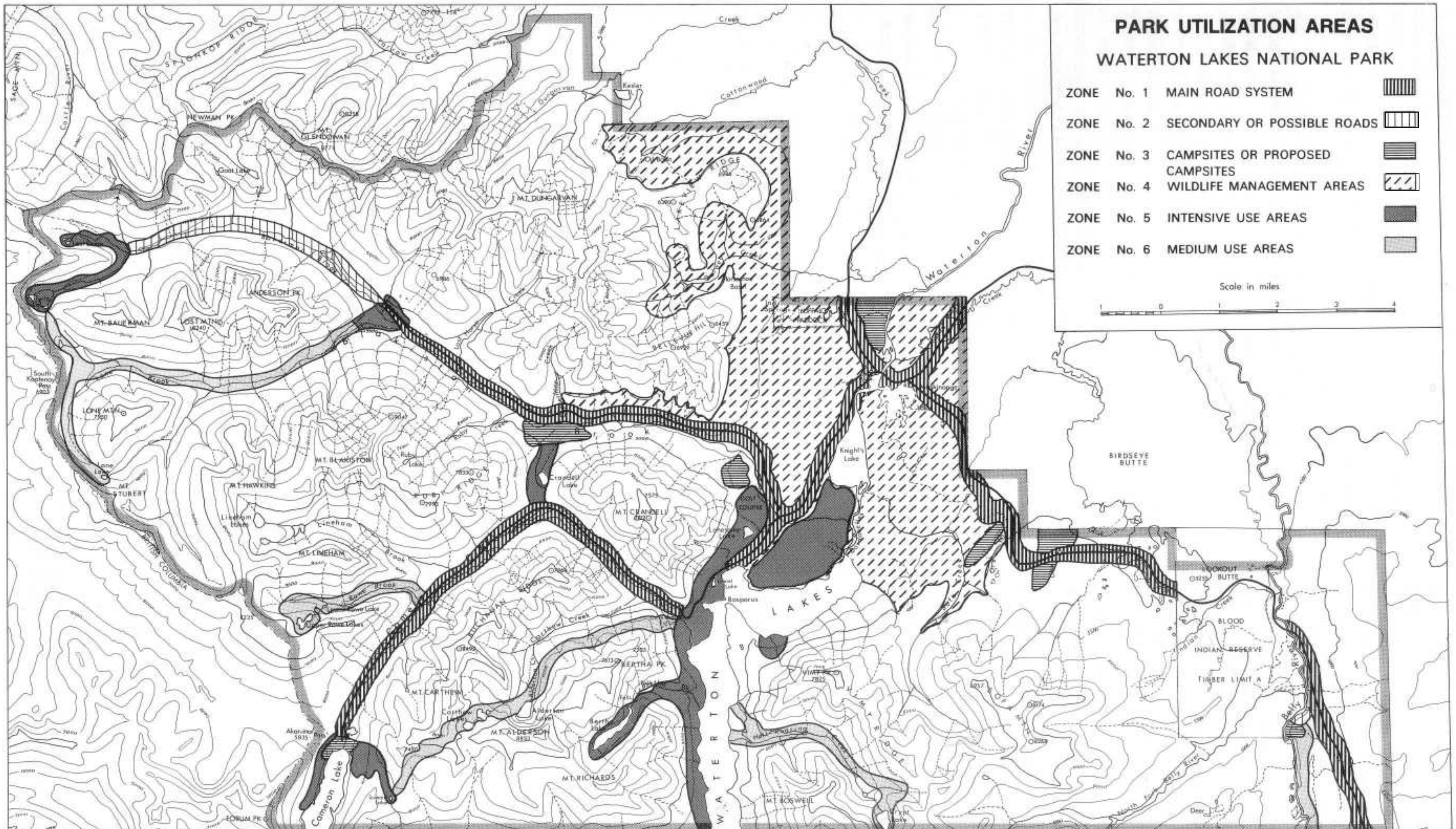

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Figure 17. Park utilization areas.

LAND USE PATTERNS

Although Waterton Lakes Park extends over more than 200 square miles, much of the land is mountainous rock outcrop, steep slopes, and cliffs. While it serves a nonconsumptive use for scenery and aesthetics, much of the area is not readily used by visitors. The reasons are assumed to be that many visitors are rather sedentary in habits and that most recreation activities are water oriented. As a result nearly all the visitor activity is concentrated on about 20 to 25 square miles of the Park, which combined with a high number of Park visitations in July and August, results in a very unequal land use pattern and load. The land use pattern is best indicated by Figure 17, which shows park utilization areas (personal communication from Dwayne Barruss, Naturalist, Waterton Park). An unequal pattern of land use means that the more intensively used land, other things being equal, will probably receive more wear and damage than the less intensively used land. These intensively used areas have priority for intensive study using soil interpretations to assist in their protection and management.

SOIL FORMATION

The soil-formation factors of parent material, climate, living organisms, topography, and time (Canada Department of Agriculture 1972) come into play in the genesis of every soil. The relative importance of each factor differs from place to place; sometimes one is more important, sometimes another. Detailed information pertaining to soil-formation factors are found in Buol et al. (1973), and Buckman and Brady (1969).

The interaction of these soil-forming factors, as observed in Waterton Lakes Park, has resulted in many different kinds of soil. For example, the older and more stable landforms (such as glacial till plains, and some of the older, stabilized alluvial fans) in the eastern part of the Park, with its lower rainfall and moderate moisture deficiency, have encouraged coniferous forest vegetation and the concomitant Gray Luvisolic (Gray Wooded) soils (e.g., descriptions of map unit 57). The parent materials are slightly alkaline in reaction and they are calcareous. The soils have a thin forest litter on the surface. The mineral soil surface (Ae) horizons are leached and grayish in color. The subsurface (Bt) horizon is enriched with clay. In general, these Gray Luvisolic soils are well drained, strongly acid in the surface horizons (Ae and Bt), and low in organic matter and exchangeable bases.

The lower elevations in the north-central portion of the Park appear to be the most arid in the area. Here, Chernozemic soils are found under largely prairie vegetation (e.g.,

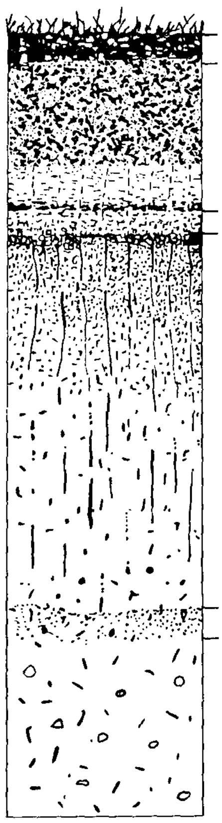


Figure 19. Diagram of a soil profile showing various horizons. Some profiles may not have all these horizons clearly developed. Where it is necessary to subdivide a horizon, digits are used; for example, the Bf horizon may be subdivided into Bf1, Bf2, etc.

Figure 18. General soil map of Waterton Lakes National Park.

descriptions of map units 50, 1, 4, 8, and others). These well drained soils have mineral surface horizons (Ah) that are dark colored and high in organic matter, with moderately high amounts of exchangeable bases. The amount of coarse fragments varies from 15 to 40% by volume.

The Brunisolic soils occur at moderately high elevations in the central portion of the Park, mainly along the southern portion of Waterton Lake. These soils occur in one transitional zone between the Luvisols (Gray Wooded soils) and Chernozemic soils on the east side of the Waterton Lakes and in another between the Chernozemic soils and Podzols farther west. The Brunisols generally support a coniferous forest containing some of the more drought resistant species such as Douglas-fir, and are well drained, yellowish brown soils that are often strongly acid (pH in $CaCl_2$, less than 5.5), low in organic matter, and often shallow in depth. Occasional mapping unit inclusions of soils with Bf or Bt horizons as defined by the Canada Soil Survey Committee (1970) occur. There is evidence of the presence of weathered volcanic ash intimately mixed with surface mineral materials.

Higher elevations and more humid climatic conditions occur in the western portion of the Park. The vegetation is dominantly subalpine coniferous forest. This area has soils that exhibit typical Podzolic morphology, having whitish colored Ae (leached) surface mineral horizons and strong brown to reddish brown Bf horizons that meet the present horizon criteria for a Podzolic Bf (Canada Soil Survey Committee 1970). These soils (e.g., description of map unit 64) are strongly acid, have moderately high amounts of organic matter, are well drained, and have 20 to 40% coarse fragments by volume. Presence of volcanic ash was also confirmed in some of these soils.

Regosolic soils (Figure 18) are scattered throughout the Park, on many kinds of materials, under grass and forest vegetation. These are chronologically young soils associated with relatively recent or unstable land surfaces. They are well drained, dull colored, and of variable textures. Disruption of the soil materials as a result of soil creep, soil erosion on steep topography, and deposition of this eroding material on fans, colluvial slopes, and terraces, together with slumping, results in extreme mixing of materials and prevents the development of soil horizon differentiation. Thus, the Regosolic soils are composed of heterogeneous materials, slightly acid to neutral (more acid in association with Podzols), and variable in amounts of organic matter and coarse fragments. They are, nevertheless, generally productive soils.

The Gleysols are soils that are water saturated for a significant portion of the year. High water tables along the edges of water bodies, depressions in the glacial till materials, and seepages at the toe of alluvial fans minimize the expression of the other soil-forming factors.

The grouping of soils shown in the general soils map (Figure 18) is designed to delineate and emphasize the dominant kinds of soil-forming factors found in the various regions of the Park.

Figure 19 is a schematic diagram of a soil profile. Schematic diagrams of soil profiles commonly found in the Park are also illustrated in Figure 18.

PART II

METHODOLOGY

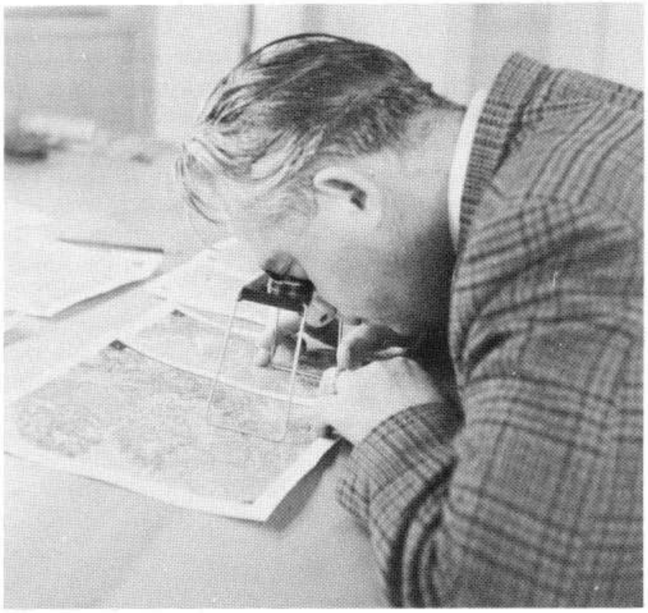


Figure 20. Interpretation of air photographs.

MAPPING

Aerial photographs taken July 1967 at a scale of 1:15,840 were used as the basic field tool for locating soil areas. An initial brief reconnaissance was used to set up a tentative legend, or key, to identify map units. The reconnaissance experience was then used to delineate tentative areas by interpretation of air photographs (Figure 20) and to name these areas according to the tentative legend. Field checking, using soil pits and any other available exposures, allowed refining of the aerial photographic interpretation, and the legend or key (Table 2). Definitive map unit concepts were developed for each map unit, with each unit being a composite of the information obtained from the aerial photographs (Figures 21 and 22), the legend or soils key, landforms and associated vegetation, soil profile morphology, chemical and physical analyses, and field analyses. When the map unit concepts were finalized, they were separated by field boundaries and located on soil maps. Representative pedons (soil profiles) were then described (see Part III) and sampled to characterize the map units. The location of each type pedon is recorded on Figure 23.

LANDFORMS

Major landforms generally have predictable kinds of materials, vegetation and/or climate, drainage (topography), and stability (time). Hence these separations are the logical first step in preparing a soils legend and map. These major landforms (Figure 24) can be subdivided and their covarying surficial geological characteristics incorporated into the legend as follows:

1) Glaciofluvial terraces, eskers, kames, and outwash channels, comprised of coarse gravels and sands. Map units 1 through 9 were reserved for this landform type.

2) River terraces and floodplains having moderately fine alluvium as parent materials, but in some locations minor areas of coarse textured materials. These landforms are postglacial in origin. Map units 10 through 19 were reserved for this landform type.

3) Alluvial fans, having a heterogeneous mixture of parent materials; extremely variable in texture, size of fan, steepness of slope, and time of deposition. All are postglacial in origin; some are so recent that they are still aggrading (Figure 25). Map units 20 through 49 were reserved for this landform type.

4) Moraines composed of medium to fine textured glacial till materials. The morainal landforms are mostly ground moraines, although there are minor amounts of drumlins, end moraines in cirques, and lateral moraines on valley sides. The moraine landforms contain more coarse fragments near the source, i.e., in cirques and at the upper end of creek valleys. The finest textured glacial till parent materials occur in the Belly River and Oil Basin areas where the Cordilleran and Continental ice sheets met. The influence of Continental ice is extremely limited. Map units 50 through 69 were reserved for the morainic landform type.

5) The Lower Valley landforms have weathered fine shales and clays as parent materials. They occur mostly in the Belly River area and are a mixture of Belly River and Wapiabi formations. These landforms are unstable, as evidenced by their slumping nature.

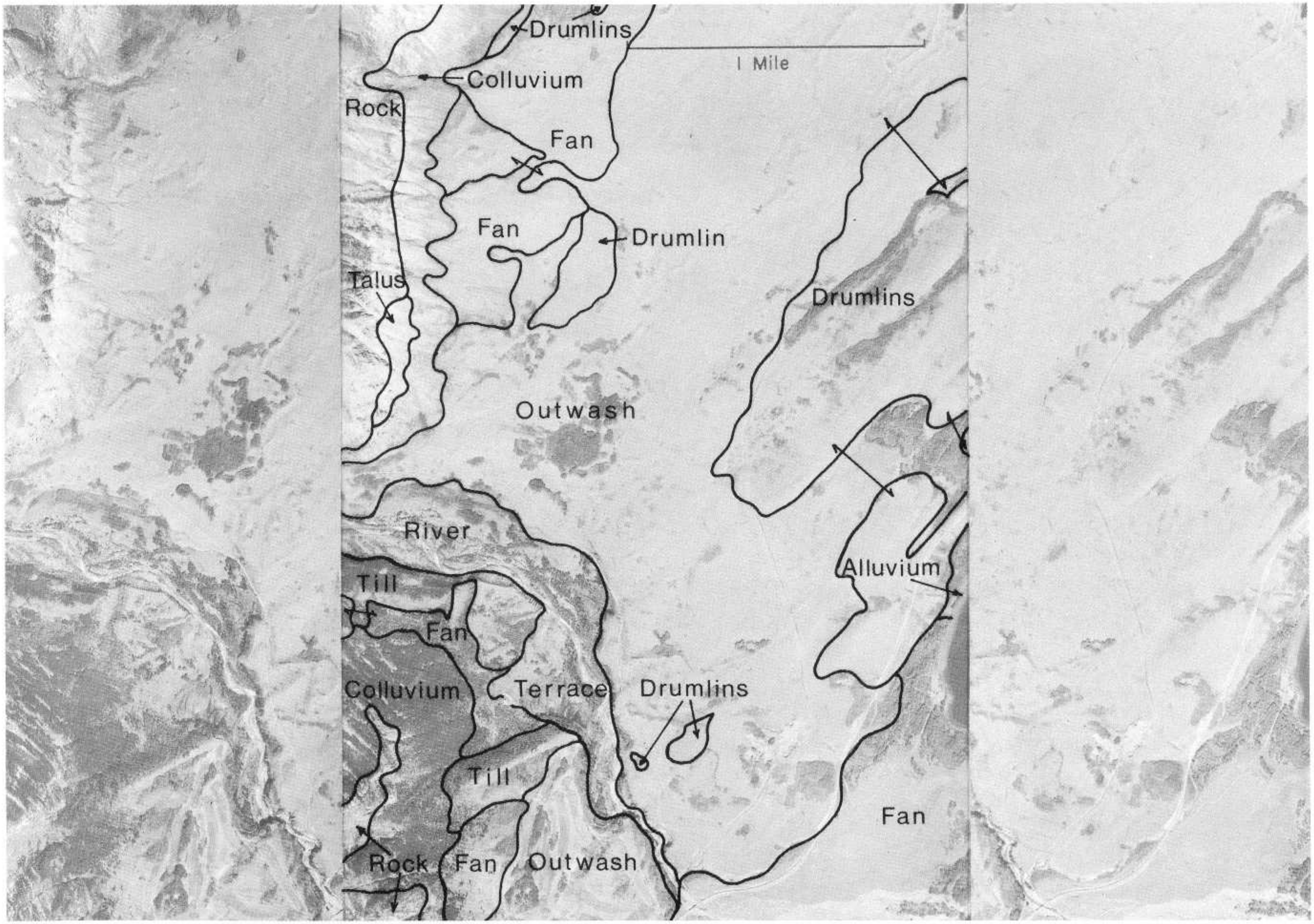


Figure 21. Stereo-triplet (Landforms).

Figure 22. Stereo-triplet (Soils).

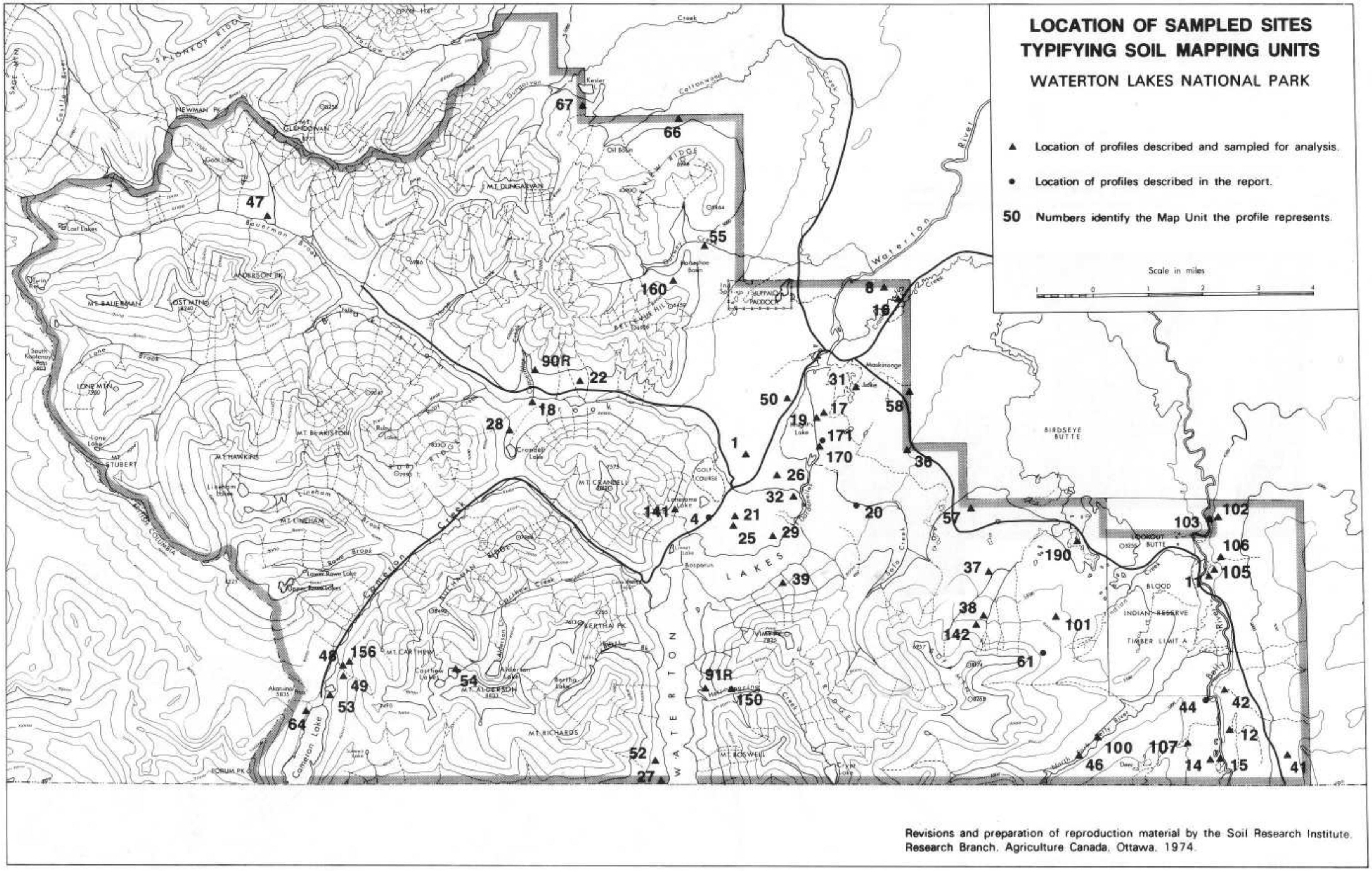


Figure 23. Sampling locations of type pedons chosen to represent soil map units.

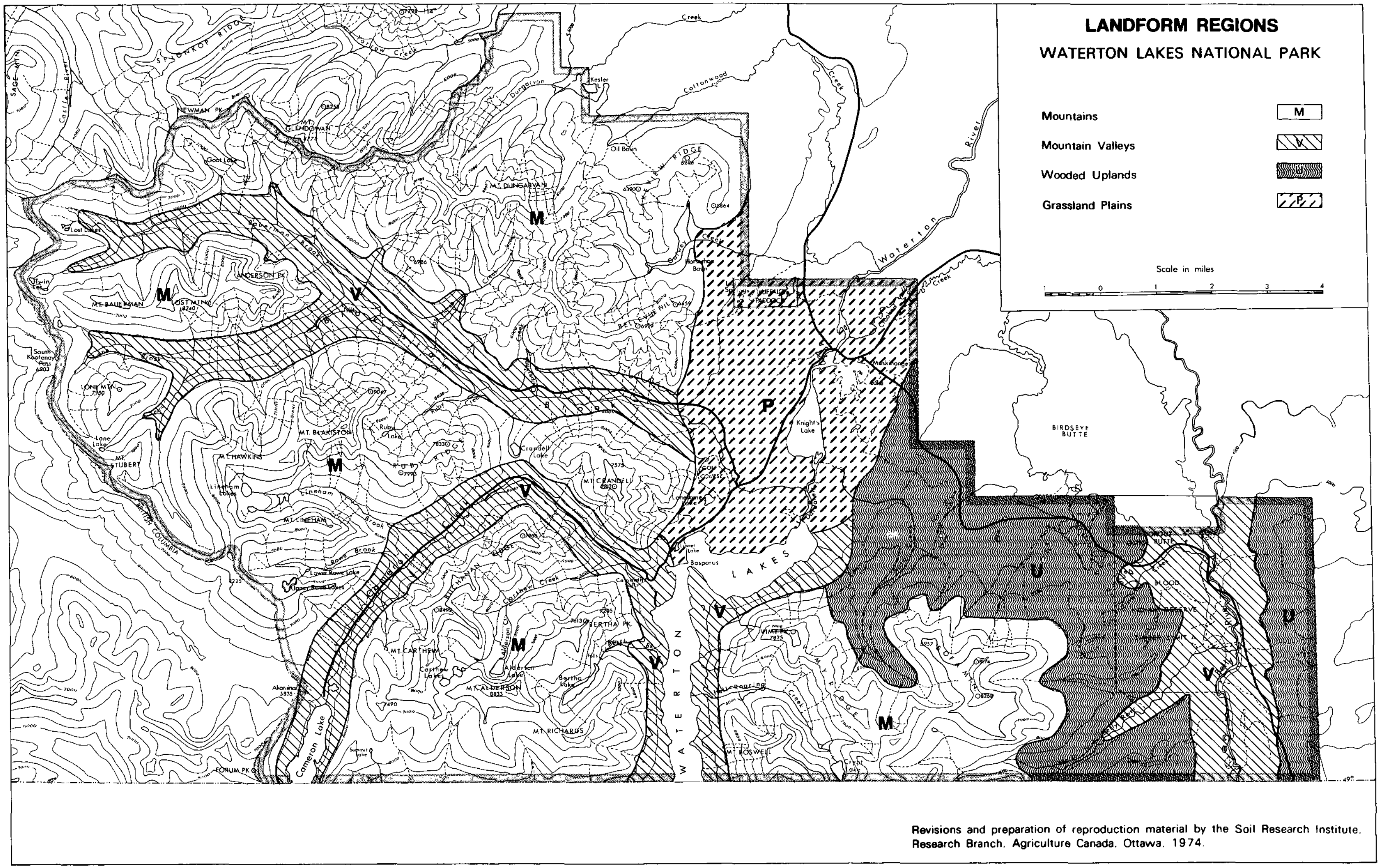


Figure 24. Landform regions.

Figure 25. Blakiston fan, showing current aggrading features of Blakiston Brook.

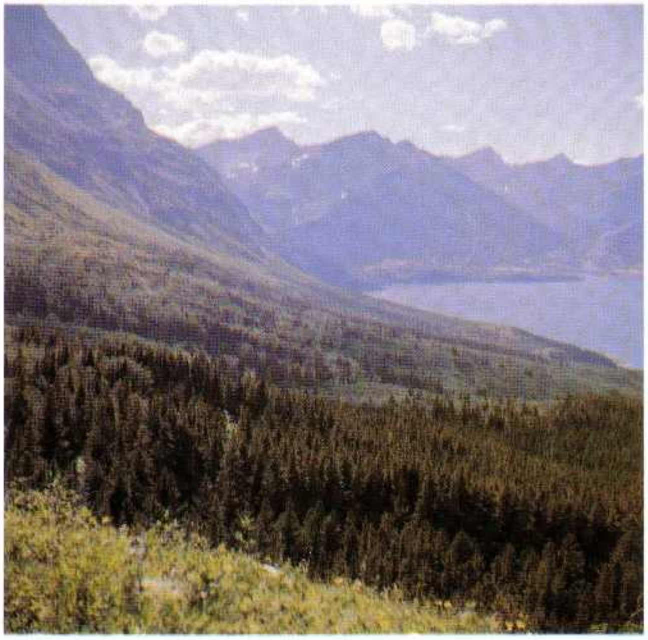


Figure 26. Long colluvial slopes characteristic of upper mountainsides.

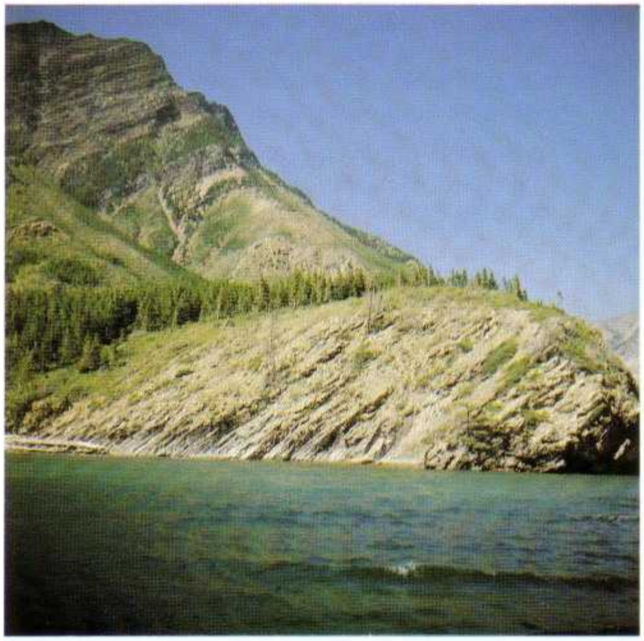


Figure 27. Rock outcrop also occurs at low elevations, in this instance resulting in a reduction of usable shoreline.

Figure 28. Talus; note some stabilization and sparse vegetative cover.

Map units 100 through 109 were reserved for this landform type.

6) Upper mountainsides; mostly of coarse colluvial parent materials (Figure 26). These mountainsides are the steeper and higher mountain slopes (the older rocks) resulting from the Lewis Thrust. Minor amounts of alluvium from intermittent streams are included. Map units 140 through 160 were reserved for this landform type.
7) Dunes of coarse sandy parent material occupy a small area on the southeast shore of Knight's Lake. Included in this landform is a small area immediately to the northeast of the dunes which has a surficial deposit of sand blown from the dunes. Map units 170 through 179 were reserved for this landform type.
8) Organic landforms having highly organic parent materials occur in a few locations, usually low-lying depressions. Map units 190 through 199 were reserved for this landform type.
9) Miscellaneous landforms include complexes of rock outcrop, broken rock, shallow residual and /or alluvial and /or colluvial materials. They generally occur at high altitudes. Shallow residual and /or alluvial and / or colluvial landforms were mapped as soil map units 90R and 91R. Rock landforms include the mountaintops of solid and /or broken rock, usually with little or no soil and supporting a limited amount of alpine vegetation. Many areas are snow covered for much of the summer. Also included are minor amounts of rock outcrops at lower elevations (Figure 27). The soil map unit Rock was used to identify these landforms. Talus landforms are those steep areas of broken rock, plus some fine materials, usually at the base of a mountain rock outcrop, and occurring on steep slopes (Figure 28). The soil map unit Talus was used to identify these landforms. Chute landforms are mountainside areas where deep accumulations of snow periodically slide down, removing most of the trees. They are generally steep, often V-shaped landforms. The parent materials are quite heterogeneous. The soil map unit Chute was used to identify these landforms.

Once the major soil lines were located by identifying the above landforms, these areas were further subdivided according to morphological features such as mottles (drainage), texture, stoniness, and other pertinent characteristics.

SOIL PROFILE MORPHOLOGY

Descriptions and classifications were made according to the criteria established by the System of Soil Classification for Canada (Canada Soil Survey Committee 1970). The soil descriptions included thickness and depth of horizons, soil colors (Munsell color notations), texture, structure, consistence, roots, pores, coarse fragments, horizon boundaries, and lime content as well as any other pertinent details. Site characteristics such as slope, aspect, vegetation, and elevation were also noted.

CHEMICAL AND PHYSICAL ANALYSES

Chemical and physical analyses were carried out according to the routine procedures used by the Alberta Institute of Pedology. These involved determination of:

1) *Soil reaction:* pH was determined with a Beckman model Zeromatic pH meter using a 2:1 0.01 M $CaCl_2$ solution to soil ratio (Peech 1965).
2) *Total nitrogen:* determined by the macro Kjeldahl-Wilforth-Gunning method (A.O.A.C. 1955). A mixture of HgO, $CuSO_4$, and K_2SO_4 (Kelpak) was used as a catalyst.
3) *Calcium carbonate equivalent:* inorganic carbon manometric method of Bascombe (1961).
4) *Organic carbon:* by difference between total carbon and inorganic carbon. Total carbon was determined by dry combustion using an induction furnace (Allison et al. 1965) with a gasometric detection of evolved CO_2 (Leco model 577-100).
5) *Exchange capacity:* by displacement of ammonium with sodium chloride (Chapman 1965).
6) *Exchangeable cations:* extraction by A.O.A.C. (1955) method and K, Mg, Na, Ca determined by atomic absorption spectrophotometry.
7) *Oxalate-extractable iron and aluminum:* by the McKeague and Day (1966) method. Iron was determined by atomic absorption spectroscopy and aluminum colorimetrically using aluminon.
8) *Particle size distribution:* by the pipette method of Kilmer and Alexander as modified by Toogood and Peters (1953).
9) *Liquid limit, plastic limit, and plasticity index:* by the method outlined by ASTM (1970).
10) *One-third and 15 bar moisture:* by the pressure plate and pressure membrane methods (U.S. Salinity Lab. 1954).
11) *Available nutrients:* determined by the methods used at the Alberta Soil and Feed Testing Laboratory. Available nitrogen (N) was estimated as nitrate-nitrogen extracted by 0.02 N $CuSO_4$ solution and determined photometrically using phenol-disulfonic acid. Available phosphorus (P) was extracted with a solution of 0.03 N NH_4F – 0.03 N H_2SO_4 and determined by the HNO_3-vanadate-molybdate colorimetric procedure (Dickman and Bray 1940). Available potassium (K) was extracted with N NH_4OAc solution and determined by flame photometry.

FIELD TESTS

1) *Bulk density:* by the soil core method. The samples were oven dried and weighed. Calculations were based on field moist, gravel-free volume. Values reported are the arithmetic mean of 5 determinations per horizon.

2) *Percolation:* by the method suggested by the Alberta Department of Manpower and Labor, Plumbing Inspection Branch (1972). This consists of digging a hole to the depth of interest and saturation for 24 hours before measuring the rate of drop of the water level in the hole.

3) *Infiltration:* by the double ring method (Figure 29) with a constant head apparatus as suggested by Adams et al. (1957).

Part IV presents further methodology in the form of guidelines for interpreting soil qualities for selected uses.

Figure 29. Field testing of water infiltration rates.

Figure 30. Landscape of map unit 4, indicating shallow depth of soil over bedrock.

Figure 31. Soil profile of map unit 8; note surface organic matter, lack of coarse fragments, and abundance of roots.

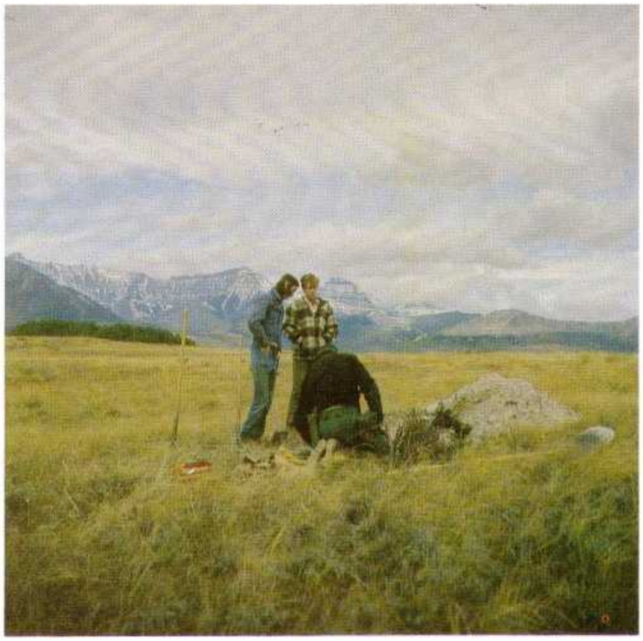


Figure 32. Fescue - oat grass association and landscape of map unit 8.

PART III

SOIL MAP UNIT DESCRIPTIONS

This section contains an identification key and generalized descriptions[1] of the soil map units used in the Park. The key identifies the soil map unit in relation to the soil maps and includes general information on the landforms, parent materials, soil classification, soil horizons, texture, topography, drainage, and vegetation. The generalized descriptions of the map units include some landscape and vegetation information, and indicate some of the dominant soil qualities of each unit. Some morphological and analytical information from a type location for each map unit is presented in tabular form.

Some map unit numbers and descriptions appear to be missing from the key. This is a result of the procedure, as described in the methodology section, whereby blocks of numbers were assigned to specific landforms. Correlation (grouping of closely related soils) also resulted in the deletion of some map units which were established during the course of the survey.

The descriptions indicate that the Waterton soils have a wide range of soil characteristics that affect soil quality. Soil characteristics refer to physical and chemical features such as particle size distribution, soil structure, stoniness, amount of lime, acidity, and amount of organic matter. Soil qualities refer to the inferred soil properties resulting from various combinations of physical and chemical characteristics and are designated by such terms as erodibility, productivity, permeability, and fertility. Soil limitation means an evaluation of the degree and kind of risk or hazard that a certain soil has for a specific, selected park use. For example: the kind of limitation for a playground may be steep topography; the degree of limitation may be severe if the slope is 30%, but less severe if the slope is 5%. An expanded discussion of soil limitations is found in Part IV.

Soil Map Unit 1 (Orthic Dark Brown and Orthic Black Chernozemic soils)

This unit is associated with the grassland area located on the coarse textured glaciofluvial outwash southwest of the buffalo paddocks. Very thin Ah horizons occur on the knolls; thicker, darker Ah horizons associated with more moisture occur in the depressions.

This map unit has soils with low available moisture storage, rapid profile drainage and permeability rate, and high evapotranspiration. It does not compact readily. A large volume of pedestrian or horse traffic may be expected to result in blowing dust and/or water erosion.

Horizon	Depth inches	Coarse fragments* %	Moist color†	Field texture	pH $CaCl_2$	Organic matter %
Ah	0–8	50	Dark grayish brown	Gravelly coarse sandy loam	5.2	8.7
Bm1	8–15	50	Brown to dark brown	Gravelly coarse sandy loam	5.1	5.3
Bm2	15–30	50	Brown to dark brown	Gravelly coarse sandy loam	6.5	2.3
Ck	30–40+	50	Dark reddish brown	Gravelly coarse sandy loam	7.3	

*Field estimate by volume.
†Except where otherwise noted, colors are moist colors.
[1]More complete information on profile morphology and other mapping unit parameters can be obtained from the authors.

Soil Map Unit 4 (Lithic Orthic Brown Chernozemic soils)

This unit consists of a small acreage of soils developed on shallow glaciofluvial outwash over bedrock. It occurs on the small rocky knobs (Figure 30) on the south edge of Blakiston fan and adjacent outwash. The grassland vegetation is similar to soil map unit 1.

The degree of limitation to the use of soil map unit 4 is more severe than for unit 1 because of the shallow depth to bedrock. The soil has low available moisture storage, rapid profile drainage and permeability, high evapotranspiration, and low compactibility. Large volumes of pedestrian or horse traffic may be expected to result in dust and erosion.

Horizon	Depth inches	Coarse fragments %	Moist color	Field texture	pH $CaCl_2$	Organic matter %
Ah	0–3½	50	Dark reddish brown	Gravelly loam	Not sampled	
Bm	3½–12	50	Brown	Gravelly loam	Not sampled	
C	12–15	50	Reddish brown	Gravelly sandy loam	Not sampled	
R			Rock consisting of an outcrop of resistant dolomite			

Soil Map Unit 8 (Orthic Dark Brown Chernozemic soils)

This unit consists of fine sandy loam to silt loam soils developed on glaciofluvial outwash terraces associated with grassland in the vicinity of Crooked Creek (Figures 31 and 32). Some minor gravelly inclusions occur. The soils are very calcareous with the lime coming nearly to the surface near the top of the slopes and receding to 30 inches or so near the bottom of the slopes. In some kettle holes the lime has been removed to below 8 feet indicating that runoff is collecting and is percolating downward, eventually ending up in the Waterton River to the west. The surface soil is fairly well supplied with organic matter.

This soil map unit has soil with a moderate available moisture storage capability, except for the very droughty minor gravel inclusions. The soil is well drained internally. Permeability is high, and compactibility is low. Large volumes of foot traffic may create dust and erosion problems.

Horizon	Depth inches	Coarse fragments %	Moist color	Field texture	pH $CaCl_2$	Organic matter %
Ah	0–4	<5%	Very dark grayish brown	Silt loam	6.0	7.8
AB	4–6	<5%	Brown	Very fine sandy loam	6.0	2.2
Bm	6–13	<2%	Dark yellowish brown	Very fine sand	5.9	1.5
BC	13–18	None	Yellowish brown	Very fine sand	7.3	
Ck1	18–28	None	Light gray*	Silt loam	7.7	
Ck2	28–41+	None	Light gray*	Silt	7.7	

*Dry color

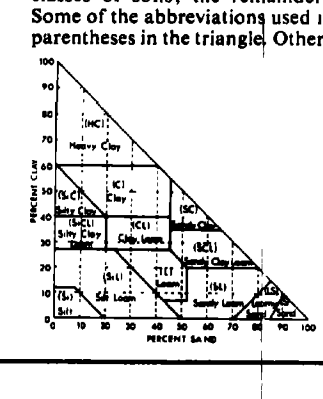
Table 2

Key to major characteristics of the soil map units

Soil map unit	Subgroup Classification	Parent material and texture	Landform(s)	Main horizons	Texture and coarse fragments	Internal soil drainage	Main topography classes	Main vegetation (see Appendix C for botanical names)	Other features
1	Orthic Dark Brown & Orthic Black Chernozemic soils	Very coarse textured gravelly and sandy outwash	Glaciofluvial terraces, eskers, kames, outwash plains	Ah, Bm, C	GSL, ~50% CF	Rapidly drained	Complex slopes varying rapidly from A to G	Fescue, oat grass	Mainly esker area
4	Lithic Orthic Brown Chernozemic soils			Ah, Bm, R	GSL, ~50% CF	Rapidly drained	AC, DE	Fescue, oat grass	Rock outcrops
8	Orthic Dark Brown Chernozemic soils			Ah, Bm, Cca	VFSL-SiL, <5% CF	Well drained	AC	Fescue, oat grass	Shallow to lime
11	Orthic & Cumulic Regosols	Alluvium, varying from 5 to 95% coarse fragments (>2mm) and from sand to loam in texture	Alluvial terraces, floodplains	(L-H), (Ah), C	<30 in. LS-SL, ~10% CF (with gravel below ~50 in.)	Well drained (except for spring flooding)	AC, DE	Balsam poplar mixed with white spruce	Very active alluvium of variable texture and CF
12	Orthic Regosol			L-H, Ah, C, IIC	Surficial deposit of loam over clay till	Moderately well drained	AC, DE	Mixed aspen & lodgepole pine	Very dense till at shallow depth causes perched water table
14	Rego Gleysol			L-H, (Ah), Cg	SiCL, Nil CF	Very poorly drained	AB	Willow, alder	Oxbows and depressions in river floodplains
15	Orthic & Cumulic Regosols			Ah, C	SiL, <5% CF	Moderately well drained	AB	Willow, balsam poplar	Slightly elevated areas on river floodplains
16	Rego Brown Chernozemic soils			Ah, Cca	SiL, <5% CF	Well drained	AC	Fescue, oat grass	Shallow to lime; associated with Dark Brown Chernozemic soils
17	Orthic Dark Brown Chernozemic soils			Ah, Bm, Cca	GSL, ~50% CF	Rapidly drained	AC	Fescue, oat grass	Weak Bm development
18	Orthic Eutric Brunisol			L-H, Ah, Bm, C	GSL, ~50% CF	Well drained	AC	Lodgepole pine	
19	Rego Black & Orthic Black Chernozemic soils			Ah, (Bm), C	GSL-L, 10% CF increasing with depth	Moderately well drained	AC, DE	Fescue, aspen	
20	Orthic Regosol	Alluvium, varying from 5 to 95% coarse fragments (>2mm) and from sand to loam in texture	Alluvial fans	C	Gravelly and cobbly, CF variable	Well drained (except for spring flooding)	AC (occasionally steeper)	Unvegetated	Very recent alluvium; annual flooding
21	Orthic Regosol			Ah, C	VGLS, >60% CF	Rapidly drained	AC (occasionally steeper)	Fescue, oat grass	Braided channels
22	Orthic Dark Brown Chernozemic soils			Ah, Bm, Ck	VGSL, >60% CF	Rapidly drained	AC, DE	Blue grass, brome grass & timothy	Found on areas infrequently flooded
25	Orthic & Cumulic Regosols			(L-H), Ah, C	SL, ~5% CF	Well drained	AC, DE	Aspen, fescue	Found on areas commonly disturbed by runoff
26	Rego Dark Brown Chernozemic soils			Ah, C	L, <5% CF	Well drained	AC	Timothy, brome grass	
27	Cumulic & Orthic Regosols			L-H, (Ah), C	GCoSL & GSL (variable), 20–50% CF	Well drained	AC, DE (occasionally steeper)	Lodgepole pine, alpine fir, spruces	
28	Orthic Eutric Brunisol			L-H, Ah, Bm, C	GSL, ~40% CF	Well drained	Found on relatively simple slopes varying from A to G	Lodgepole pine, Douglas-fir	Found on poorly defined fan-shaped landforms
29	Gleyed Cumulic Regosol			L-H, Ah, Cg	Stratified SiCL-SL, CF <5%	Imperfectly drained	Found mainly on simple AB slopes but also on steeper slopes	Balsam poplar, black cottonwood	Found on downslope margins of fans
31	Orthic Humic Gleysol			Ah, Bg, Cg	Stratified SiCL-L, <5% CF	Very poorly drained	AB	Sedges	Saturated except for brief periods in the fall
32	Orthic Humic Gleysol			Ah, Bg, Cg	SiL-L, <5% CF	Poorly drained	AB (occasionally steeper)	Willow, alder	Saturated for significant periods in the spring and summer
36	Orthic Gray & Dark Gray Luvisols			L-H, (Ahe), Ae, Bt, C	SL-L, <5% CF	Well drained	Found mainly on simple AC slopes but occasionally steeper	Lodgepole pine, white spruce, aspen	Dark Gray Luvisols associated with aspen and Gray Luvisols associated with mixed forest
37	Cumulic Regosol			L-H, Ah, C	SL, <5% CF	Moderately well drained	Found mainly on simple AC slopes but occasionally steeper	Balsam poplar, white spruce	Area receives runoff water from adjacent slopes
38	Orthic Regosol			Ah, C	GSL, ~40% CF	Well drained	Found on simple slopes varying from A through G	Fescue, oat grass & aspen, spruce	CF mainly fine gravel size; deep dark Ah
39	Cumulic Regosol			(L-H), Ah, C	GSL, ~40–60% CF	Well drained	Mainly E, F and G slopes	Douglas-fir, lodgepole pine	Transition between alluvial fan and colluvial slope
41	Orthic Regosol			L-H, C, IIC	<30 in. SiL with <5% CF over L till material with ~50% CF	Well to moderately well drained	Mainly DE with some steeper and some more gentle slopes	Lodgepole pine	Fine alluvial surficial deposit over till
42	Rego Dark Brown Chernozemic soils			Ah, C	SiL, <5% CF	Well drained	AC	Fescue, oat grass & aspen	>40 in. to gravel
44	Rego Humic Gleysol			L-H, Ah, Cg	GSL, ~50% CF	Very poorly drained	AC	Willow, poplar	Seepage area
46	Orthic Gray Luvisol			L-H, Ae, Bt, C	GSiL, ~40% CF	Well drained	Mainly DE, some steeper and some more gentle	Lodgepole pine	
47	Degraded Eutric Brunisol			(L-H), Ae, Bm, C	GSL, ~30% CF	Well drained	Slopes vary from A through F	Alpine fir, lodgepole pine	Fairly stable fans
48	Orthic Regosol			L-H, (Ah), C	GSiL-SL, ~40% CF (variable)	Moderately well drained	Mainly DE, but widely distributed from A through F	Alpine fir, spruce, lodgepole pine	Forested stony fans
49	Orthic Humo-Ferric Podzol			L-H, Ae, Bf, C	GSL-SiL, 30–60% CF	Well drained	Slopes vary from A through F	Alpine fir, lodgepole pine	Stable slopes
50	Orthic Dark Brown and Black Chernozemic soils	Glacial till, varying from 10 to 70% coarse fragments and from loam to clay loam in texture	Moraines	Ah, Bm, C	GL, ~40% CF	Well drained	Short, complex slopes varying from A through G	Fescue, oat grass	Some drumlin landforms
52	Orthic Eutric Brunisols			Ah, Bm, C	GSiL, ~40% CF	Well drained	Simple and complex slopes varying from A through H	Lodgepole pine, aspen	Some Lithic inclusions
53	Orthic Humic Gleysol			L-H, Ah, Bg, Cg	GSiL, ~40% CF (variable)	Poorly & very poorly drained	Mainly AD slopes, some steeper	Spruce, willow	Seepage areas and depressions
54	Orthic Regosol			Ah, C	~50% CF	Well drained	Mainly complex slopes varying from A through H	Alpine larch, alpine fir	Generally found at >6500 ft and with turfy Ah
55	Orthic Regosol			L-H, (Ah), C	SL, L, ~40% CF (variable)	Well drained	Mainly G and H slopes, with occasional more gentle slopes	Variable; bare to forested	Generally on steep or unstable slopes
57	Orthic Gray Luvisol			L-H, Ae, Bt, C	GL, >40% CF	Well drained	Simple and complex slopes varying from A through H	Lodgepole pine	High lime, stable till
58	Dark Gray Luvisol			L-H, Ah, (Ahe), Ae, Bt, C	SiL, 10–40% CF (variable)	Well and moderately well drained	Mainly A through E slopes some steeper	Aspen	Many pedons show abundant earthworm activity
61	Orthic Gray Luvisols & Orthic Regosols			(L-H), (Ae), Bt, C	VGSiL, >70% CF	Well drained	Simple E, F, G and H	Alpine fir, white spruce	Surface very stony and bouldery
64	Orthic Humo-Ferric Podzol			L-H, Ae, Bf, C	SiL & GSiL, ~40% CF over GL & GSL, ~50% CF	Well drained	Mainly simple and complex E, F, G and H slopes, occasionally less steep slopes	Alpine fir, lodgepole and whitebark pine, spruces	Found mainly in the mountainous western portion of the park
66	Orthic Eutric Brunisol			Ah, Bm, Ck	GCL, ~40% CF	Well drained	EF	Alpine fir, aspen, limber pine	Low lime, continental till
67	Orthic Black Chernozemic soils			Ah, Bm, C	CL, ~10% CF	Well to moderately well drained	Mainly complex A through F slopes	Aspen or fescue, oat grass	Low lime, continental till
100	Cumulic & Orthic Regosols	Weathered shale bedrock, mainly clay and clay loam in texture	Lower valleys (Glaciated valley with much of the drift removed)	(Ah), C	SiC, <5% CF	Well drained	Mainly simple slopes varying from A through H	Blue & brome grasses, timothy or saskatoon, fir & aspen (shrubby)	Grayish clays prone to slumping
101	Cumulic & Orthic Regosols			L-H, C	SiL-SiCL, <10% CF	Well to moderately well drained	Mainly simple slopes varying from A through H	Lodgepole pine, aspen	Dark grayish brown clays
102	Orthic Gray Luvisol			L-H, Ae, Bt, C	CL, CF none	Well drained	Mainly simple slopes varying from A through H	Lodgepole pine	Fairly stable landform
103	Lithic Regosols			L-H, (Ah), Ck	SiL, <10% CF	Well drained	GH	Spruce, aspen	Steep bedrock-controlled landform
105	Gleyed Cumulic Regosol			L, Ah, C, (Ahb), (Cb)	Stratified SiL-CL, <10% CF	Imperfectly drained	AD, EF	Aspen, poplar, Douglas-fir	Seepage areas and depressions
106	Orthic Gray Luvisol			L-H, Ae, Bt, C	SiCL-SiC, CF none	Well drained	Mainly simple slopes varying from A through G	Lodgepole pine, Douglas-fir	Fairly stable landform
107	Orthic & Cumulic Regosols			L-H, (Ah), C	SiC, CF none	Well drained	Mainly simple slopes varying from E through G	Lodgepole pine, white spruce	Soils developed on residual shale
141	Orthic Regosol	Coarse textured colluvium	Upper mountain sides (steepland)	L-H, (Ah), C	GSL, 20–70% CF	Well drained	Mainly G & H slopes, occasionally less steep	Douglas-fir, lodgepole pine, alpine fir	Mainly plate-shaped fine gravels
142	Orthic Regosol			Ah, C	GSL & GLS, 20–70% CF mainly fine gravels	Well drained	Mainly G & H slopes	Fescue, oat grass	>5000 ft elevation
150	Orthic Regosols & Degraded Eutric Brunisols			L-H, (Ah), C	GFSL, 30–50% CF (variable)	Well drained	Mainly F, G & H and occasionally less steep slopes	Lodgepole pine, Douglas-fir	
156	Orthic Humo-Ferric Podzols & Degraded Eutric Brunisols			L-H, Ae, Bm, C	GSL & GSiL, ~50% CF (variable)	Well drained	Mainly F, G & H and occasionally less steep slopes	Lodgepole pine, alpine fir	Stabilized fairly steep slopes
160	Orthic Gray Luvisol			L-H, Ae, Bt, C	GL, ~40% CF	Well drained	D, E, F & G slopes	Lodgepole pine	Stabilized fairly steep slopes
170	Orthic Regosol	Aeolian sand	Dunes	(Ah), C	LS, CF none	Rapidly drained	EF	Western snowberry, aspen	Partially vegetated sand dunes
171	Cumulic Regosol			(Ah), C, IIAhb, IIBmb, IIC	LS, CF none, shallow over GSL, ~30% CF increasing with depth	Rapidly drained	AD	Fescue, oat grass	Wind-blown sandy deposit <30 in. thick over alluvial paleosol
190	Silvo-Fibrisol	Organic; mainly nonspagnum mosses	Organic		Not applicable	Very poorly drained	AB	Sedges, willows	Water saturated
90R	Lithic Orthic Regosol	Rock outcrop, broken rock, residual, alluvial and/or colluvium	Miscellaneous Landforms, Complexes and Land Areas	(L-H), Ah, (C), R	Variable texture, CF 10–50% (variable)	Rapidly drained	Mainly G & H slopes, occasionally less steep slopes	Lodgepole pine, Douglas-fir, alpine fir	Texture and color quite variable
91R	Lithic Orthic Eutric Brunisol			(L-H), (Bm or Bfj), (C), R	GSiL, ~30% CF (variable)	Rapidly drained	Mainly F, G & H slopes, occasionally less steep slopes	Lodgepole pine, Douglas-fir	Yellowish brown, mellow
R	Not-soil	Rock outcrop, mountain tops, solid and broken rock							
Bp	Not-soil and Gleysolic soils	Beaver ponds & dams, very wet soils							
RD	Not-soil	Refuse disposal pit							
Talus	Not-soil	Broken rock plus fines							
Pit	Not-soil	Soil stripping excavations for topsoil, rock quarry, and/or road construction							
Chutes	Mainly Regosolic soils	Snowchutes on steep mountain-sides							

Soil textural classes

Percentages of clay and sand in the main textural classes of soils; the remainder of each class is silt. Some of the abbreviations used in the table are given in parentheses in the triangle. Other abbreviations include:



G—gravelly
VC—very coarse sand
C—coarse sand
F—fine sand
VF—very fine sand
CF—coarse fragments (2 mm to 10 in.)

Drainage classes

Rapidly drained
Well drained
Moderately well drained
Imperfectly drained
Poorly drained
Very poorly drained

For a more complete discussion of textural, drainage and topographic classes and of classification see the System of Soil Classification for Canada (Canada Soil Survey Committee 1970).

Topographic classes

Class*	Slope %
A	0.0–0.5
B	0.5–2
C	2–5
D	5–9
E	9–15
F	15–30
G	30–60
H	over 60

*No distinction was made between complex and simple slopes in the map symbols.

Map symbol convention

The number in the map symbol identifies the map unit and hence the kinds of soils within it. The letter beneath the number identifies the slope classes associated with this map unit. For example, the symbol $\frac{50}{AD}$ identifies a complex of Orthic Dark Brown and Orthic Black Chernozemic soils, developed on glacial till and having A to D slopes.

Soil Map Unit 11 (Orthic and Cumulic Regosols)

These soils are dominantly coarse textured gravelly sandy loams found on the recently deposited floodplains of major rivers and streams such as Belly River, Cameron Creek, and Lone and Blakiston brooks. The physiographic position of this soil map unit along the rivers and streams is such that flooding and water-table conditions are prevalent for part of the year. Although these soils become flooded and saturated in the early spring, their coarse textured characteristic permits the water to drain out rapidly once the flood level drops. Vegetation is balsam poplar and white spruce and lower story vegetation characteristic of low, moist sites, thus indicating that the roots are in contact with the water table. Free carbonates occur throughout this soil.

The low physiographic position of this unit subjects it to annual flooding hazards. Soils of this unit have coarse texture giving it low compactibility and high permeability. The relatively high amount of lime does not appear to be a detrimental quality for any foreseeable use of this soil unit except to the extent that it contributes to physiologic drought.

Horizon	Depth inches	Coarse fragments %	Moist color	Field texture	pH $CaCl_2$	Organic matter %
L-H	½		Relatively undecomposed leaf litter, variable thickness			
C1	0–7	5	Very dark grayish brown	Silt loam	7.2	6.6
C2	7–20	40	Very dark grayish brown	Gravelly coarse sandy loam	7.2	0.8
C3	20–30	10	Gray and grayish brown	Coarse sand	7.2	0.4
C4	30–40+	80*	Grayish brown	Gravelly coarse sand	7.4	

*Field estimate probably too high. Appendix A suggests gravelly rather than very gravelly coarse sand.

Soil Map Unit 12 (Orthic Regosol)

The soils of this map unit are unique in that they were found to occur only on the east side of the Belly River and near the International Border. They are also unique to the extent that the subsoil appears to be a "paleosol" of strongly weathered clay till covered relatively recently by loam to silt loam materials. The result is a subsoil horizon that impedes downward drainage of water through the profile, thus causing a perched water table to be present for a significant portion of the year. The subsoil may contain appreciable quantities of stones greater than 10 inches in diameter. The profile is strongly acid. The vegetation is mainly fire succession trembling aspen and lodgepole pine, although some white spruce and Douglas-fir seedlings have become established. Some balsam poplar occurs in the wetter areas.

The soil qualities of this map unit are largely controlled by the mixed characteristics of the soil profile. The surface soil is moderately well drained, but the subsoil is poorly drained. The poor subsurface drainage dominates the other soil qualities. Disturbance of the vegetation on this kind of soil runs the risk of establishment of an alder or willow thicket.

Horizon	Depth inches	Coarse fragments %	Moist color	Field texture	pH $CaCl_2$	Organic matter %
L-H	1–0		Relatively undecomposed organic matter, contains some yellow mycelia			
Ah	0–5	None	Very dark grayish brown to black	Loam	4.8	12.1
C	5–11	None	Grayish brown, dark gray to dark grayish brown	Loam to silt loam	4.9	1.5
Cg	11–17	None	Grayish brown	Silt loam	4.9	0.7
IIABgb	17–20	None	Mottled light brownish gray	Clay loam	4.8	0.9
IIBtgb1	20–30	None	Mottled brown	Clay	5.1	1.7
IIBtgb2	30–43	None	Mottled brown	Clay	5.1	2.1
IIBCgb	43–46+	None	Mottled brown	Clay	5.8	

Soil Map Unit 14 (Rego Gleysol)

The soils of this map unit are medium to fine textured and very poorly drained; they have developed on recent floodplain deposits, mainly along the Belly River and also about 2 miles east of the fire tower. These areas are located in the depressional and oxbow positions of the floodplain. Much of the area has a water table within inches of the surface for the entire season on some years. The water table fluctuates with the level of the water in the nearby river, or stream. The vegetation is mainly willow and alder, although some balsam poplar does occur.

The flood hazard and high water table conditions strongly limit the use of this map unit for many purposes. It is, of course, highly suited to semiaquatic uses.

Horizon	Depth inches	Coarse fragments %	Moist color	Field texture	pH $CaCl_2$	Organic matter %
L–H	8–0	Very dark gray, very well decomposed organic matter			6.9	
A & Cg	0–2	None	Mottled, very dark gray and dark gray	Loam	6.8	10.2
Cg	2–20	None	Strongly mottled gray	Silty clay loam	6.9	3.2

Soil Map Unit 15 (Orthic and Cumulic Regosols)

The soils of this map unit are medium to fine textured and weakly stratified. They are developed on recent floodplain deposits found along the larger streams and rivers. There are no layers which seriously impede water percolation, but because of landscape position these soils receive runoff and groundwater so that they are saturated for significant portions of the year. Many grassy areas occur, as do willow, alder, and occasional white spruce, aspen, and balsam poplar (Figure 33).

This unit has soils with fertility and vegetative productivity. Their use is limited by occasional flooding hazards and temporary imperfect profile drainage resulting from the fluctuating water table. A portion of this map unit was observed to be heavily used as an overflow campground in 1971. It was not used in 1972 and it was noted that the lush, grassy vegetation recovered to the extent that the previous year's use was not detectable.

Horizon	Depth inches	Coarse fragments %	Moist color	Field texture	pH $CaCl_2$	Organic matter %
Ah1	0–5	None	Very dark grayish brown	Silt loam	7.0	7.8
Ah2	5–10	None	Dark grayish brown	Silt loam	6.8	5.8
C1	10–26	None	Dark grayish brown	Silt loam	6.4	
C2	26–38+	None	Grayish brown	Silt loam	7.0	

Figure 33. Open and dominantly grassy vegetation on map unit 15. Note the level topography.

Figure 34. Soil profile of map unit 16.

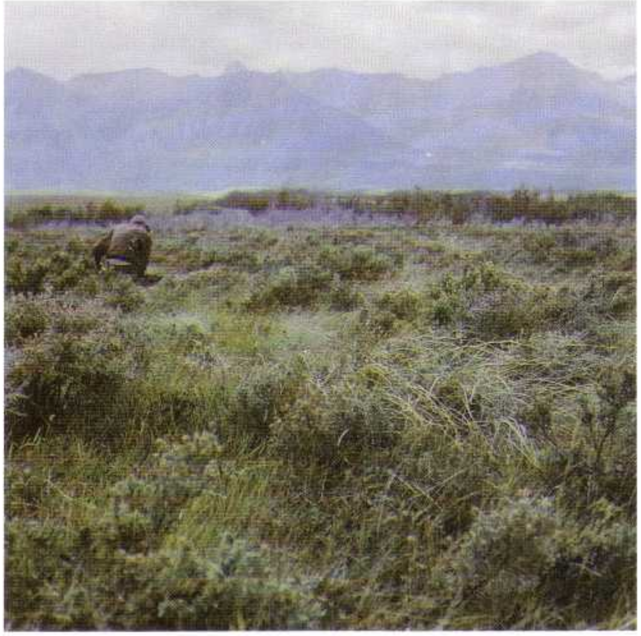


Figure 35. Vegetation and level topography of map unit 16.

Figure 36. Topography and droughty condition on map unit 17.

Soil Map Unit 16 (Rego Brown Chernozemic soils)

The soils of this map unit are very uniform, extensively water sorted silt loam texture with very few coarse fragments (Figure 34). They have formed on lightly colored, highly calcareous, recently deposited alluvial parent materials of the Crooked Creek floodplain. Flooding of these soils depends on the location and elevation of the particular segment of floodplain in question. Most areas are probably inundated at least once every 2 to 3 years. However, the water recedes quickly enough that vegetation is not indicative of wet soils and the absence of mottles in the soil profile indicates the soil drains as soon as the flood abates. These soils are in the direct path of the strong prevailing down-valley winds, and the soils and vegetation reflect the high evapotranspiration rates and exposure conditions. The majority of the area is characterized by sparse, low shrubs (e.g., shrubby cinquefoil), herbs, and various grasses (e.g., fescue) (*see* Figure 35). The perimeter of the mapping unit, slightly lower in elevation but with more moisture, is generally dominated by willows and alder.

Map unit 16 is located on the floodplain of Crooked Creek east of Waterton River and north of Maskinonge Lake.

This unit has soils with fairly desirable soil qualities. The limitations are the risk of flooding and the pollution hazard that exists by virtue of the fact that any polluting agent could easily pass through the soil and enter Crooked Creek and eventually the Waterton River.

Horizon	Depth inches	Coarse fragments %	Moist color	Field texture	pH $CaCl_2$	Organic matter %
Ah	0–4	2	Very dark grayish brown	Silt loam	6.8	10.2
Ck1	4–16	2	Dark grayish brown	Silt loam	7.1	
Ck2	16–40+	2	Dark grayish brown	Silt loam	7.5	

Soil Map Unit 17 (Orthic Dark Brown Chernozemic soils)

These soils are gravelly sandy loam in texture and have more than 50% coarse fragments. Being river terraces, these areas have relatively level topography. The fine gravels are mainly red and green argillites and sandstones. The parent materials are extremely stony. The grassy, shrubby vegetation reflects the droughtiness of this soil (Figure 36). This map unit occurs mostly on the east side of Knight's Lake and along the lower reaches of Blakiston Brook.

This soil map unit has excellent topographic characteristics. However, it is so coarse textured and has so many coarse fragments that its available moisture values are very low. It is a droughty soil with very rapid, or fast, water permeability rates to substantial depths from the surface. Its compactibility qualities are very low. Large volumes of traffic can be detrimental (in Figure 33, note the slow revegetation of old vehicle tracks on the east side of Knight's Lake).

Horizon	Depth inches	Coarse fragments %	Moist color	Field texture	pH $CaCl_2$	Organic matter %
Ah1	0–1		Very dark grayish brown and dark reddish brown	Loam	6.0	22.1
Ah2	1–10	20	Very dark brown and brown	Gravelly sandy loam	5.5	4.1
Bm	10–26	35	Dark yellowish brown	Gravelly sandy loam	6.9	3.4
Cca	26–31	95–99	Brown to dark yellowish brown	Very gravelly sand	6.9	
Ck	31–40+	70*	Light brown	Gravelly loamy coarse sand	7.2	

*Field estimate probably too high. Appendix A suggests gravelly rather than very gravelly loamy coarse sand.

Soil Map Unit 18 (Orthic Eutric Brunisol)

This map unit contains coarse textured soils with many gravel and cobble sized coarse fragments. These soils have developed on variable coarse textured, small alluvial terraces of valley streams. The soil development and landscape position suggests that these terraces are rarely flooded. Because of the lack of fine textured soil material, nutrients for good plant growth are probably limiting. The vegetation has a rather unthrifty lodgepole pine stand, with a limited number of shrubs, herbs, and grasses tolerant of a borderline forest community. The extent of this map unit is very small within the Park and is located along Blakiston Brook in the west half of the Park.

These soils are droughty because of their coarse texture and low available moisture storage. They also have low compactibility and low resistance to traffic, principally because of lack of organic matter in the soil, lack of moisture and nutrients, and resultant fragile vegetation. Also, the open, highly permeable nature of this soil permits rapid passage of pollutants which may enter Blakiston Brook. The Crandell Lake campground is located on these soils. The soil qualities suggest that some careful and intensive management is required.

Horizon	Depth inches	Coarse fragments %	Moist color	Field texture	pH $CaCl_2$	Organic matter %
L–F	½–0	Dark brown partly decomposed coniferous needles			4.8	
Ah	0–2	30	Brown	Gravelly sandy loam	4.6	3.5
Bm	2–14	50	Brown	Gravelly sandy loam	5.2	1.3
C	14–26+	70	Brown	Very gravelly sandy loam	7.0	

Soil Map Unit 19 (Rego Black and Orthic Black Chernozemic soils)[1]

The soils of this map unit are similar to those of soil map unit 17. Unit 19 has developed on a gravelly sandy loam river terrace with many coarse fragments. However, there are not as many coarse fragments as in unit 17. Soils of unit 19 are in a slightly lower position and have slightly less soil profile development. Some of these soils have been examined archaeologically. The parent material is stonier than the surface layers. The topography is generally level. The map unit is located near Knight's Lake, Waterton River, and Blakiston Brook. The vegetation consists mainly of tall grasses (2–3 feet tall) and aspen poplar.

The soils of this map unit are similar to those of map unit 17, except for a slightly better available moisture storage in the surface soil horizons. The limitations are mostly moderate, except for playground use (*see* Figure 12).

Rego Dark Brown Chernozemic soil:

Horizon	Depth inches	Coarse fragments %	Moist color	Field texture	pH $CaCl_2$	Organic matter %
Ah1	0–15	25	Very dark brown	Gravelly sandy loam	5.7	6.2
Ah2	15–37	30	Very dark grayish brown	Gravelly sandy loam	5.8	3.3
AC	37–43	45	Dark brown	Gravelly sandy loam	6.2	2.9
Ck	43–50+	80*	Brown	Gravelly coarse sandy loam	6.8	

*Field estimate probably too high. Appendix A suggests gravelly rather than very gravelly coarse sandy loam.

[1]The profile described is classified as a Rego Dark Brown Chernozemic soil, but many areas of this map unit are slightly darker in color and have Bm horizons, thus qualifying for Black Chernozemic soils.

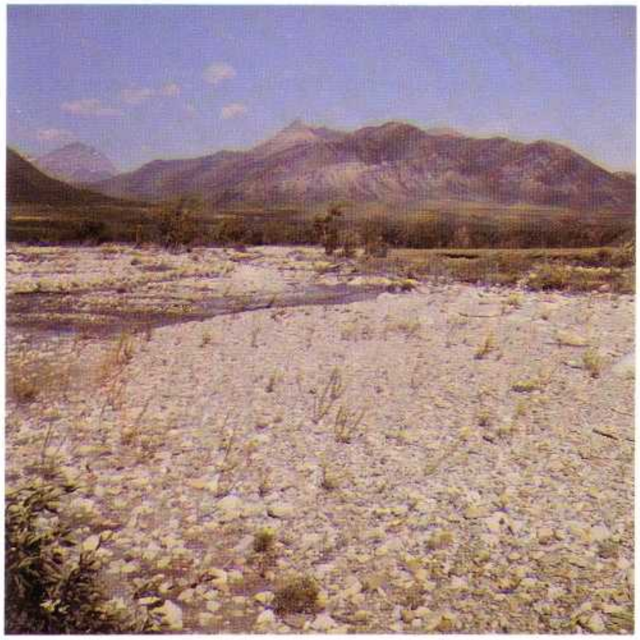


Figure 37. Active stream channel during low water period.

Figure 38. An "inclusion" of shallow sandy loam over the gravels of map unit 21. Usually the gravels occur to the surface.

Figure 39. Soil profile of map unit 27, with silty layer at 3 feet from the surface.

Figure 40. An area prone to windthrow is a hazardous location for establishment of some recreational uses; for example, camping.

Soil Map Unit 20 (Orthic Regosol)

This map unit is confined to the active portion of stream and river channels where vegetation does not become established and erosion removes most of the fine earth (<2 mm) fraction (Figure 37). This map unit is found throughout the Park, sometimes in stream channels occupied intermittently by water for short periods in the spring, and in channels that have continuous flows of water. On occasion the intermittent channels are found on 25–30% slopes.

Because the map unit is defined as being the active portion of stream channels, there is insufficient soil to describe.

The stream channels are subjected to seasonal wide variations in the amount of water they carry. Some portions of the channels are being scoured, or shifted, by the erosive forces of the stream itself; other portions, such as the lower part of Blakiston Brook (where it crosses Blakiston fan), are aggrading, or building up their stream channels. Such aggradation could result in stream overflow and flooding during periods of high flow.

Soil Map Unit 21 (Orthic Regosol)[1]

These are coarse textured gravelly sandy loam soils developed on low-angle alluvial fan deposits. They have a very high percentage of coarse fragments composed of sandstone, limestone, and red and green argillite cobbles. There is, however, an occasional inclusion of shallow sandy loam soil over the gravel (Figure 38). Most of the coarse fragments have lime coatings. There are no layers or horizons to impede downward movement of water to the water table. In early spring there may be very short periods of time when the water table rises to within 3 feet of the surface on some areas mapped as unit 21. Shallow meander scars and abandoned stream channels are evident on the surface. Grassy, prairie type vegetation is dominant (Figure 16, a), although some aspen groves do occur. Soil map unit 21 is located mainly on the fans of Blakiston Brook and Sofa Creek.

The soils of map unit 21 have very low available moisture storage, rapid water permeability rate, and low compactibility. Large volumes of traffic may result in dust and erosion. It should be noted that there is a risk of pollutants reaching the water table very quickly (Figure 38; Holland and Coen 1972, NOR-Y-20) and that this water table is contiguous with that of other soil units in lower positions on Blakiston and Sofa fan and also with Waterton Lake. The high pH indicates the occurrence of free lime and is of no particular significance for the probable uses of this soil.

Rego Dark Brown Chernozemic soil:

Horizon	Depth inches	Coarse fragments %	Moist color	Field texture	pH $CaCl_2$	Organic matter %
Ah	0–5	50	Dark brown	Gravelly sandy loam	7.1	5.1
Ck1	5–30	90	Grayish brown*	Very gravelly coarse sandy loam	7.7	
Ck2	30–35+	90	Grayish brown*	Very gravelly coarse sandy loam	7.1	

*Dry color

[1] Although the profile described is a Rego Dark Brown Chernozemic soil, much of the area has Ah horizons too thin for Chernozemic soils, hence the map unit classification of Regosol.

Soil Map Unit 22 (Orthic Dark Brown Chernozemic soils)

The soils of this map unit are very similar to those of map unit 21 to the extent that they are coarse textured gravelly sandy loams, with many cobbles and small boulders within 40 inches of the surface. They have formed on gravelly and cobbly alluvial fan deposits with south-facing slopes. The difference between the two units is that unit 22 has a somewhat more mature soil profile development, the surface horizon is deeper and has more organic matter, a B horizon occurs, and lime has been leached from the surface. The vegetation consists dominantly of shrubs, herbs, and fescue grasses. It occurs mainly along Blakiston Brook near Red Rock Canyon.

These soils are very similar to those of map unit 21, especially with respect to low available moisture storage and droughtiness. They do not compact readily and large volumes of traffic may cause dust and erosion problems. It is probably slightly better for production of vegetation than is unit 21.

Horizon	Depth inches	Coarse fragments %	Moist color	Field texture	pH $CaCl_2$	Organic matter %
Ah	0–12	>40	Dark reddish brown	Gravelly loam	6.3	6.9
Bm	12–28	>70	Dark reddish gray*	Very gravelly coarse sandy loam	7.3	2.9
Ck	28–36+	>80	Reddish brown*	Very gravelly coarse sandy loam	7.6	

*Dry color

Soil Map Unit 25 (Orthic and Cumulic Regosols)

The soils in this unit are generally coarse textured sandy loams but have little gravel and essentially no stones or cobbles within 30 inches of the surface. They occur on the lower portions of fairly large alluvial fans such as Blakiston. The coarse sand sizes and gravels are dominated by red and green argillites and sandstones with some limestone fragments. There are no dense or compact layers. The variation in texture with depth due to varying sedimentary conditions provides for some layers with finer textures and greater water-holding capacity than the adjacent soils in map unit 21. The soils of map unit 25 are located on the Blakiston and Sofa Creek fans. The vegetation is dominantly aspen and associated shrubs.

These soils have better available moisture storage than map units 21 or 22 and this is reflected in the dominance of aspen vegetation. The surface layers do not compact readily. Large volumes of traffic may be expected to cause moderate dust and erosion problems. Their moderate level of soil qualities means that unit 25 is a better soil for use than some (e.g., units 21, 22, 17, 19) but that they still have a number of limitations that preclude very intensive use for a prolonged period of time.

Horizon	Depth inches	Coarse fragments %	Moist color	Field texture	pH $CaCl_2$	Organic matter %
Ah	0–1½	<5	Dark brown	Sandy loam	6.7	8.1
C1	1½–6	<1	Dark brown	Sandy loam	7.2	5.6
C2	6–11	30	Very dark grayish brown	Gravelly sandy loam	7.4	1.9
C3	11–45+	<1	Brown	Silt loam	7.3	

Soil Map Unit 26 (Rego Dark Brown Chernozemic soils)

The soils of this map unit are well sorted and fairly uniform medium to coarse textured. They are developed on the finer textured toe, or lower portion, of alluvial fans. The depth to coarse gravelly sandy materials is fairly shallow. The soil profile is well drained; the water table may be within 3 to 4 feet, depending on the time of year. The vegetation is mainly grasses, probably because of the strong prevailing down-valley winds and subsequent very high evapotranspiration rates. The map unit is located on the lower portion of Blakiston fan.

This map unit has good soil qualities for most Park uses anticipated at this time. Its limitation is its small area and its location of being adjacent to poorly drained soils. It is subject to occasional extreme floods; for example, the flood of 1964.

Horizon	Depth inches	Coarse fragments %	Moist color	Field texture	pH $CaCl_2$	Organic matter %
Ah	0–12	0	Dark reddish brown	Sandy loam	6.4	9.3
C1	12–29	5	Dark brown	Sandy loam	7.0	
Ck1	29–42	0	Brown	Sandy loam	7.1	
Ck2	42–46+	20	Reddish gray	Gravelly sandy loam	7.2	

Soil Map Unit 27 (Cumulic and Orthic Regosols)

The soils of this map unit are coarse sandy loam in texture with abundant coarse fragments (Figure 39), most of which are of fine gravel size. They are developed on relatively low angle alluvial fans located along the shore of Waterton Lake, Bertha Lake, and Cameron Lake. These fans are generally not extensive in area and often have finer textured silt loam layers in them. The vegetation on unit 27 fans reflects differences of elevation and climatic effects. The unit 27 fans along Waterton Lake are dominated by lodgepole pine and Douglas-fir forests. The unit 27 areas adjacent to Bertha Lake are mainly alpine fir forests and along Cameron Lake they are mainly dense forests of Engelmann spruce and alpine fir. Many of the trees on these fans are overmature and unsound, thus posing a potential blow-down and windthrow hazard (Coen, Holland, and Nagy 1972, NOR-Y-17).

The soil qualities of map unit 27 may be summated as moderate for some uses. They have rapid drainage and high permeability, and low compactibility. They withstand moderate amounts of traffic before dust and erosion problems become objectionable. In general, they are moderately high in vegetative productivity but are loose enough that trees have a high windthrow hazard (Figure 40). The areas along Waterton Lake have the lowest productivity, those along Cameron Lake the highest. The silt loam layers are probably beneficial to the extent that they elevate the available moisture storage.

Horizon	Depth inches	Coarse fragments %	Moist color	Field texture	pH $CaCl_2$	Organic matter %
L–H	2–0	Relatively undecomposed and slightly decomposed leaves, needles, and rotten wood			4.4	
C1	0–1	<10	Brown	Loam	Not sampled	
C2	1–7	50	Dark reddish brown	Gravelly sandy loam	5.8	3.4
C3	7–15	20	Dark reddish brown	Gravelly coarse sand	6.0	0.6
C4	15–17½	5	Reddish brown	Silt loam	6.0	1.4
C5	17½–35	10	Reddish brown	Gravelly coarse sand	6.1	0.5
C6	35–44+	60	Reddish brown	Gravelly coarse sand	6.0	0.3

Soil Map Unit 28 (Orthic Eutric Brunisol)

This unit has coarse textured soils with a fairly high amount of coarse fragments mainly of gravel and cobble size. They have formed on broad poorly defined alluvial fan landforms that are fairly coarse textured materials dominated by red and green argillites in the fine gravel fraction. Because of the fissile nature of the sedimentary materials forming these fans, the soils are loose and easily erodible. The vegetation is dominated by conifers such as lodgepole pine, Douglas-fir, alpine fir, and occasionally aspen. Shrubs and herbs are varied and numerous; grasses are scarce. Map unit 28 is of limited extent and occurs adjacent to Waterton and Cameron lakes and along Blakiston and Bauerman brooks.

The main limitations to use of these soils are the low available moisture, and the loose, open, and porous nature of the soil materials and hence their high erodibility potential.

Horizon	Depth inches	Coarse fragments %	Moist color	Field texture	pH $CaCl_2$	Organic matter %
L–H	½–0		Black, well decomposed organic litter		4.3	
Ah	0–4½	30	Brown	Gravelly sandy loam	4.9	4.1
Bf	4½–15	30	Strong brown	Gravelly sandy loam	5.2	1.7
C	15–30+	45	Brown	Gravelly loamy coarse sand	5.1	

Soil Map Unit 29 (Gleyed Cumulic Regosol)

The soils of this map unit are coarse to fine sandy loam and silt loam in texture with few cobbles within 40 inches of the surface. Fine gravel components are mainly red and green argillites. These soils are developed on the toe, or lower slopes, of large, low-angle alluvial fans. The lower portion of the soil profile is imperfectly drained because of a fluctuating water table. The largest areas of these map units occur on the lower margins of Blakiston Brook and Sofa Creek fans. Vegetation is dominantly balsam poplar and black cottonwood, with some aspen poplar. Minor amounts of willow and swamp birch are also found. Shrub and ground vegetation is generally luxuriant.

The main limiting factor in the use of this unit is its imperfect drainage caused by a fluctuating water-table condition.

Horizon	Depth inches	Coarse fragments %	Moist color	Field texture	pH $CaCl_2$	Organic matter %
L	¼–0	Undecomposed deciduous leaves				
Ck1	0–2	None	Light brownish gray, few fine distinct mottles	Very fine sandy loam	7.3	
Ahb	2–4	None	Reddish brown	Silt loam	7.1	15.1
Ck2	4–10	None	Dark brown	Sandy loam and fine sandy loam	7.5	
Ckg1	10–18	None	Grayish brown, few fine faint mottles	Sandy loam	7.5	0.3
Ckg2	18–29	None	Brown, medium distinct mottles	Silt loam	7.6	0.4
Ckg3	29–35+	20	Brown, medium distinct mottles	Gravelly sandy loam	7.0	0.3

Soil Map Unit 31 (Orthic Humic Gleysol)

This map unit is dominated by medium loam to silt loam soils developed on alluvial fan materials along the edges of water bodies where spring flooding is frequent. The soil is saturated until late spring or early summer. The water table is high enough in the spring that it restricts the growth of balsam poplar and in many cases willows. Numerous sedges are present. Geographically these soils are located mainly along the margins of lower Waterton Lake, Knight's Lake, the Dardanelles, and Maskinonge Lake.

The main factor limiting the use of this unit is its very poorly drained condition. In June 1971, it was covered with 6 to 12 inches of water. In August the water table was about 3 feet below the soil surface.

Horizon	Depth inches	Coarse fragments %	Moist color	Field texture	pH $CaCl_2$	Organic matter %
Ahgk	0–6	<1	Very dark brown, few fine distinct mottles	Loam	7.7	19.9
Bgk	6–16	<1	Dark gray, many medium distinct mottles	Silt loam to silty clay loam	7.8	2.1
BCgk	16–30	<2	Gray, few medium mottles	Silt loam	7.9	
Cgk	30–35+	<2	Gray, many medium prominent mottles	Silt loam	7.8	

Soil Map Unit 32 (Orthic Humic Gleysol)

These medium textured, fine sandy loam to loam soils are poorly drained, and developed on alluvial fan margins adjacent to rivers and lakes. The parent material is saturated much of the year and wet most of the year. The water table is very close to the surface, being at or near the surface in June and within 15 inches throughout the season in many years. Willows and mountain alder are abundant; sedges are common and shrubs and herbs are abundant. These soils are located mainly on both sides of the Dardanelles, and adjacent to the shores of lower Waterton Lakes and Knight's Lake. They are similar to those of map unit 31, except for a lesser degree of water saturation.

The main limitation of these soils is their poorly drained condition. The poor drainage masks all the other soil qualities; for example, these soils are quite permeable but the water table is so close to the surface that the permeability is of little practical significance.

Horizon	Depth inches	Coarse fragments %	Moist color	Field texture	pH $CaCl_2$	Organic matter %
Ahg	0–5	None	Dark reddish brown, common fine faint mottles	Loam	7.2	10.6
Bg1	5–7	<5	Reddish gray, common fine distinct mottles	Very fine sandy loam	7.3	3.4
Bg2	7–21	<5	Brown, common fine distinct mottles	Silt loam	7.1	2.2
Cg	21–30+	5	Dark brown, few fine distinct mottles	Very fine sandy loam	7.6	

Soil Map Unit 36 (Orthic Gray and Dark Gray Luvisols)[1]

The soils of this map unit are coarse to medium textured sandy loam and loams, developed on alluvial deposits that are old, or were ice margin deposits. They have fairly mature well-developed profiles. Those areas that are mainly under aspen and associated vegetation have considerably more organic matter in the surface horizons and are not quite so acid as those areas that are under coniferous vegetation (mostly lodgepole pine, with considerable Douglas-fir, and some white spruce). These soils are located mainly in the northeast portion of the Park.

This unit has moderate limitations and moderate attributes for all envisaged Park uses, except those involving slope. Steep slopes impose limitations for some uses.

Dark Gray Luvisol:

Horizon	Depth inches	Coarse fragments %	Moist color	Field texture	pH $CaCl_2$	Organic matter %
L–H	1½–0	Very dark brown, fluffy, relatively well decomposed deciduous leaves			6.8	
Ahe	0–3	<2	Very dark brown	Sandy loam	6.8	16.4
Ae	3–6	<2	Grayish brown	Sandy loam	6.8	3.8
Bt	6–18	<2	Dark grayish brown	Loam	6.9	1.4
C1	18–38	<2	Light olive brown	Sandy loam	7.0	
C2	38–43+	None	Light olive brown	Sandy loam	6.9	

[1]The Orthic Gray Luvisols and Dark Gray Luvisols are approximately equal in areal extent. The description is of a Dark Gray Luvisol.

Soil Map Unit 37 (Cumulic Regosol)

The soils of this map unit are comprised of medium and coarse textured materials formed on gently sloping alluvial fans. There are only occasional coarse fragments. These soils occur in a landscape position that favors the collection of water from higher slope positions. The frequent movement of water through and beneath the profile promotes the development of a black, organic-rich Ah horizon that is often fairly thick. The vegetation is mostly balsam and aspen poplar, and white spruce, with an occasional alpine fir and lodgepole pine. The undercover is dense and varied. Alder, willow, thimbleberry, and many other shrubs occur. This map unit occurs mainly between Sofa Mountain and Highway 6, although some isolated areas are also found near Cameron Lake and in the Horseshoe Basin – Oil Basin area.

This unit has moderate qualities for most uses. It should be noted that soil compactibility is low, and that the soil material is loose and porous; hence any severe disturbance will result in an unstable soil condition. Its connection with the water table in the lower soil horizons and the severe limitations due to wetness and slope are to be noted.

Horizon	Depth inches	Coarse fragments %	Moist color	Field texture	pH $CaCl_2$	Organic matter %
L–H	6–0	Well decomposed organic material with a fairly high amount of mineral soil			6.0	
Ah*	0–5	2	Black	Sandy loam to loam	6.2	8.9
C	5–18	2	Dark gray	Sandy loam	6.0	
Ahb	18–21	2	Dark reddish brown	Sandy loam	6.1	2.6
Cg	21–24	2	Dark reddish gray	Sandy loam	6.2	

*The Ah is often up to 30 inches thick.

Figure 41. Loose, easily eroded soil of map unit 38.

Figure 42. Gully erosion on trail across map unit 38.

Figure 43. Soil profile of map unit 42, showing low amount of coarse fragments and high rooting volume.

Figure 44. Soil profile of map unit 46; note pale color of the Ae horizon.

Soil Map Unit 38 (Orthic Regosol)

This map unit is dominantly coarse textured gravelly sandy loam and loam soils developed on cobbly and stony, loose alluvial fans. The cobbles, stones, and boulders contain about 50% limestones, 20% sandstones, and the rest are red and green argillites. The red and green argillites dominate the gravel size fraction. Boulder size and quantity vary considerably over very short distances. These soils are found at elevations above 5,000 feet generally at the base of a steep slope and are scattered throughout the mountainous landform region. The soils are generally well drained, but about 5% of these fan areas have imperfectly to poorly drained soil, particularly at the toe of the fans located along the Twin Lakes to Lone Lake section of the Tamarack Trail. It is suspected that most, or all, of map unit 38 soils are receiving areas for snowslides and avalanche materials. The evidence of snowslides is in the decided lack of forest on these fans and the observation of freshly damaged trees on the edges of these fans in the spring of 1972. Probably the damaging effects of the snowslides are occasional rather than annual. Vegetation is characteristically open grassy and shrubby areas with few to no trees. Those trees that are present are not too vigorous aspen, balsam poplar, white spruce and/or Engelmann spruce. The grasses and shrubs are common to abundant.

The low available moisture storage qualities of this unit are offset to a considerable extent by the location of these soils in a cool and relatively moist mountain environment. Because of coarseness, these soils have low compactibility qualities (Figures 41 and 42). The remaining limitations and attributes are moderate, although it is suspected that an occasional snowslide and small avalanche hazard does exist.

Horizon	Depth inches	Coarse fragments %	Moist color	Field texture	pH $CaCl_2$	Organic matter %
Ah1	0–8	20	Dark reddish brown	Sandy loam to loam	6.2	5.6
Ah2	8–12	40	Dark reddish brown	Gravelly sandy loam	6.9	1.3
C1	12–28	50	Reddish brown	Gravelly loam	7.0	
C2	28–32+	50	Reddish brown	Gravelly sandy loam	7.3	

Soil Map Unit 39 (Cumulic Regosol)

These coarse textured soils contain a very high percentage of coarse fragments. They have formed on relatively loose alluvial and/or colluvial materials at the toe of long slopes, occasionally appearing to be a group of coalescing fans. The vegetation usually consists of a mixed forest of white spruce, lodgepole pine, alpine fir, and Douglas-fir, with some aspen. The tree growth assists in controlling creep and erosion. Numerous shrubs and herbs occur, along with some grasses.

The main soil qualities affecting the use of these soils are the low available moisture and the loose, unstable nature of these materials once they are disturbed.

Horizon	Depth inches	Coarse fragments %	Moist color	Field texture	pH $CaCl_2$	Organic matter %
F–H	2–0	Moderately well to well decomposed organic material			6.1	
Ah	0–1		Very dark brown	Sandy loam	6.1	31.0
C1	1–11	30–40	Weak red	Gravelly coarse sandy loam	6.6	
Ahb	11–12		Very dusky red	Sandy loam	Not sampled	
C2	12–26	60	Weak red	Gravelly sandy loam	6.9	

Soil Map Unit 41 (Orthic Regosol)

The medium textured soils of this map unit are developed from a shallow surficial alluvial fan deposit over glacial till. Below the surficial loamy deposit the material is a fine textured hard and compact till with considerable numbers of rocks and boulders. Map unit 41 is generally found in draws and small catchment basins. The occurrence of finer till material at shallow depths provides a restriction to vertical water movement and may promote considerable lateral flow. Some seepage spots were noted west of No. 6 highway. This soil unit is located mainly in the Belly River area in the eastern portion of the Park. The main forest vegetation is lodgepole pine with some white spruce. Shrubs such as *Shepherdia* and thimbleberry are common, but grasses and mosses are few.

Production of forest and associated vegetation is moderately high. The soils in this map unit have moderate limitations and attributes except for slope. The main point to be remembered for use of these soils is their mixed morphology; that is, the shallow loam and silt loam soil materials over the compact clay loam glacial till. Such mixed morphology could be of concern if these soils were to be used for some purpose requiring rapid water percolation and high water storage in the lower subsoil horizons.

Horizon	Depth inches	Coarse fragments %	Moist color	Field texture	pH $CaCl_2$	Organic matter %
L–H	2–0	Decayed wood, twigs, needles and leaves				
C1	0–5	5	Dark brown	Loam	6.9	
C2	5–17	5	Brown	Silt loam	6.9	
IIC1	17–33	50	Brown	Gravelly clay loam	7.1	
IIC2	33–40+	50	Light olive brown and yellowish brown	Gravelly clay loam	7.3	

Soil Map Unit 42 (Rego Dark Brown Chernozemic soils)

This map unit is dominantly deep medium textured loam to silt loam soils (Figure 43) developed on relatively low angle alluvial fans associated with the finer sediments of the Belly River area. There are few cobbles and stones within the top 40 inches. The soil material sometimes becomes gravelly below 40 inches, and very occasionally it becomes gravelly within the top 40 inches. Variations in texture with depth are not unusual and are the result of the stratified alluvial materials on which these soils are formed. No layers restrictive to water and root movement are encountered within the top 40 inches of the surface. In general it is not evident that there are any severe restrictions to water movement below 40 inches, but there are some small areas included in this map unit that show imperfect drainage and burial of former soil surfaces. Characteristic vegetation is typified by parkland-like communities of grasses and aspen. Various shrubs provide about a 25% ground cover. There may have been some vegetation disturbance on the area southeast of the Waterton River. Most of the unit 42 soils are located in the Belly River area.

These soils have a number of moderately favorable soil qualities that accumulate to make them desirable for a number of Park uses. Mainly, they are soils that can readily be managed. Moderate moisture retention, deep profiles, with relatively high rooting volumes, moderate compactibility, fairly high organic matter content, and good topography are all favorable attributes. This unit has the kinds of soils that can more readily be irrigated, fertilized, planted, used for reception of septic effluent, or otherwise managed. If properly handled they are expected to be some of the better soils for intensive use.

Horizon	Depth inches	Coarse fragments %	Moist color	Field texture	pH $CaCl_2$	Organic matter %
Ah	0–8	None	Very dark brown	Loam	6.2	7.4
C1	8–24	None	Very dark grayish brown	Silt loam	5.9	
C2	24–47	None	Dark yellowish brown	Silt loam	6.1	
C3	47–51+	40–60	Dark yellowish brown	Gravelly clay loam	6.5	

Soil Map Unit 44 (Rego Humic Gleysol)

The soils of this map unit are coarse textured, with many cobble and gravel sized coarse fragments and are found at the toe of some coarse textured and poorly drained alluvial fans in the Belly River area. The poor drainage is caused by seepage coming to the surface near the water table occurring at the contact of alluvial fan material with the floodplain of the Belly River. Only two areas were found. The vegetation is a very dense cover of willow and alder with many shrubs and herbs. A few small patches of balsam poplar were observed. Occasionally there are a few aspen and/or white spruce.

The very poor drainage on this soil unit is the soil quality that dominates all other qualities and its use is therefore limited.

Horizon	Depth inches	Coarse fragments %	Moist color	Field texture	pH $CaCl_2$	Organic matter %
Ah	0–4		Very dark grayish brown	Loam	Not sampled	
Cg	4–20	50	Light gray	Gravelly sandy loam	Not sampled	

Soil Map Unit 46 (Orthic Gray Luvisol)

The soils of this map unit are medium to fine sandy loam and loam in texture, developed on alluvial fans with moderate amounts of coarse fragments. They have formed on relatively stable fans that are fairly steeply sloping. The relatively well developed Gray Luvisol profile (Figure 44) is indicative of landform stability. It is a minor map unit in terms of its area. Geographically it is located mainly in the area of the North Fork Belly River. The vegetation is mainly lodgepole pine with minor amounts of aspen. Shrubs and herbs form a relatively abundant ground cover.

The soil qualities of this map unit are moderate throughout nearly all of the soil characteristics. No severe limitations are apparent, except for slope. Probably the steeper topography of these fans, as compared with other larger low-angle fans, is its greatest liability.

Horizon	Depth inches	Coarse fragments %	Moist color	Field texture	pH $CaCl_2$	Organic matter %
L–F	½–0	Very dark grayish brown partly decomposed organic material			4.5	
Ae	0–3	10	Light brown	Sandy loam	5.7	2.6
Bt	3–15	40	Brown	Gravelly clay loam	6.5	5.6
Ck	15–25+	40	Pale brown	Gravelly loam	7.1	

Soil Map Unit 47 (Degraded Eutric Brunisol)

The soils of this map unit are coarse gravelly sandy loam in texture, developed on alluvial fans with a moderate amount of coarse fragments and a fairly stony surface. These are relatively stable fans (Figure 45) found in isolated pockets along the edges of major valleys. Map unit 47 is located almost entirely in the western part of the Park where the more mountainous topography results in a greater amount of rainfall and available moisture. The vegetation is mainly lodgepole pine with small quantities of Douglas-fir and aspen poplar. The varied shrub and herb layer forms a fairly abundant ground cover.

The main soil qualities affecting the use of map unit 47 are the low available moisture storage, its high permeability rate, and its low compactibility. Some of these areas have steep topography.

Horizon	Depth inches	Coarse fragments %	Moist color	Field texture	pH $CaCl_2$	Organic matter %
L–H	2–0	Very dark grayish brown partially decomposed organic matter with many white and yellow mycelia			4.4	
Ae	0–1	25	Light brown grading to pinkish gray	Gravelly sandy loam	4.2	4.4
Bm	1–12	30	Strong brown	Gravelly sandy loam	5.3	1.3
C	12–25+	25	Brown	Gravelly sandy loam	5.5	

Figure 45. Soil profile of map unit 47.

Figure 46. Luxuriant vegetative undergrowth on map unit 48.

Figure 47. Map unit 50 near top of slope.

Figure 48. Profile of map unit 50 in a lower slope position.

Soil Map Unit 48 (Orthic Regosol)

This map unit contains coarse textured soils with many coarse fragments in the soil and on the surface. The soils are found on small coarse textured alluvial fans that are not extensive in acreage. The lack of soil horizon development indicates that the profiles are subject to natural geologic disturbances. The vegetation found on these coarse materials suggests some seepage water in the plant root zone. The vegetation is mainly lodgepole pine plus white spruce and alpine fir. Occasional Douglas-fir and aspen poplar are also found. Numerous shrubs and herbs with luxuriant growth are found (Figure 46). The soils of this map unit are mainly west of Waterton Lake, along the Cameron and Bauerman – Blakiston Creek valleys.

Most of the soil qualities of this map unit are rated moderate for most Park uses. Its topography may be too steep for some uses. The open, porous nature of the soil should be noted for some uses, e.g., sewage disposal.

Horizon	Depth inches	Coarse fragments %	Moist color	Field texture	pH $CaCl_2$	Organic matter %
L–F	2–0	Relatively undecomposed leaf and needle litter			4.6	
C1	0–18	30	Dark reddish gray	Gravelly silt loam	4.7	
C2	18–30+	40	Dark reddish gray	Gravelly sandy loam	5.1	

Soil Map Unit 49 (Orthic Humo-Ferric Podzol)

The soils of this unit are dominantly coarse textured, containing abundant coarse fragments. They are formed on coarse textured alluvial fans that, according to soil profile development, have had a relatively long period of stability and have not recently been disturbed by soil creep or water erosion. They are the only alluvial fans in the Park with strongly developed Podzolic soils. The occurrence of these soils in the more mountainous region of the western half of the Park corresponds with the higher rainfall there. The main forest vegetation is alpine fir, white spruce, and occasionally lodgepole pine and alpine larch. A rich and varied understory of shrubs occurs. The areas of this map unit are small in size and are not extensive in distribution. They are located along the margins of Cameron Creek valley and its tributaries.

The soil qualities are moderate. Probably the steep topography on some of these fans and the open, porous nature of the soils are the strongest limitations to use.

Horizon	Depth inches	Coarse fragments %	Moist color	Field texture	pH $CaCl_2$	Organic matter %
L–H	½–0	Moderately well decomposed organic matter			3.8	
Ae	0–4	35–40	Pinkish gray	Gravelly sandy loam	4.1	5.0
Bf	4–12	35–40	Yellowish red and brown	Gravelly loam	5.3	5.9
Aeb	12–16	45	Brown	Gravelly sandy loam	4.7	1.3
Bfb	16–20	45	Strong brown	Gravelly very fine sandy loam	5.2	1.6
C	20–35+	50	Weak red	Gravelly sandy loam	4.6	

Figure 49. Topography and vegetation variations on map unit 50.

Figure 50. Trails oriented straight up and down slopes can result in damage and gullying even on relatively erosion resistant soils.

Figure 51. A long narrow "inclusion" of poorly drained soil borders much of Summit Lake. Because of limitations of map scale, the mapping unit is not always pure, or finite; such variations are called "inclusions."

Figure 52. Soil profile of map unit 58.

Soil Map Unit 50 (Orthic Dark Brown and Black Chernozemic soils)

The soils in this map unit are medium textured with many gravel and cobble sized fragments. They have formed from compacted, water-impervious, pinkish glacial till of Cordilleran origin. The fine gravels (2-5 mm) are dominantly red and green argillites with some sandstone and limestone. Surface boulders are of common occurrence and the topography of these soils varies from A to G slopes. In several instances, these soils are found on moderately well defined drumlins, particularly in the area west of Knight's Lake. In general, where the till mantles the entire landscape the depressions are filled with permanent or seasonal ponds. Thus, the map unit has some inclusions of poorly drained soils in the vicinity of these water bodies. Soils on the tops of the knobs and drumlins are often as shallow as 10 inches. In general, the soils become thicker downslope, reaching 25 to 30 inches maximum depth, and are darker in color indicating a higher accumulation of organic matter (Figures 47 and 48). The soils on the lower slopes also have a somewhat finer surface texture and fewer coarse fragments. Because of the very dense compacted till parent material, these soils have restricted water permeability. The associated vegetation is mainly dryland grasses such as fescues and oat grasses, and shrubs. Scrubby aspen poplar are found on the lower slopes and generally deeper and moister soils and on the north lee side of hills where snow collects and where the trees are less exposed to the strong down-valley winds (Figure 49). Most of the soils in map unit 50 are located in the north-central part of the Park.

Because of the topographic variations, the soils of map unit 50 have a range of soil qualities. Those areas that occur on the tops of knolls or drumlins generally have shallow soils, with low available moisture storage, low rooting volume, low water permeability, and high evapotranspiration losses because of the exposure to the strong down-valley winds. The soils on the lower slopes have moderate soil qualities of available moisture storage, rooting volumes, compactibility, and evapotranspiration values. Also, the soil qualities of the solum, or developed soil profile, are considerably different from those of the parent material. For example, the soil materials of the solum are moderately compactible and permeable to water, whereas the till parent material itself is already in a dense compact condition as a result of its deposition by ice and subsequent unweathered state. Thus, the parent material is impervious, or at least only very slowly pervious, to water percolation.

Horizon	Depth inches	Coarse fragments %	Moist color	Field texture	pH $CaCl_2$	Organic matter %
Ah1	0–3½	25	Very dark grayish brown	Gravelly loam	6.3	15.9
Ah2	3½–6	25	Dark brown	Gravelly loam	5.6	4.0
Bm	6–17	40	Brown	Gravelly sandy loam to loam	6.3	1.5
Ck	17–24+	40	Light reddish brown*	Gravelly loam	7.7	

*Dry color

Soil Map Unit 52 (Orthic Eutric Brunisols)

The strong brown soils of this map unit are medium textured loams with a moderate amount of coarse fragments. They are formed on generally light colored glacial till of Cordilleran origin. In many instances the till parent material is of shallow depth and some of the soil profiles are lithic inclusions (less than 20 inches deep to bedrock). The parent material is dense and compact, thus offering resistance to water percolation and also offering resistance to water erosion. These Brunisolic soils are between Gray Luvisols in the eastern portion of the Park and the Podzol soils found in the western, mountainous portion. Occasional mapping unit "inclusions" of soils with Bf or Bt horizons occur (see soil formation). Map unit 52 is mainly located on the east and west sides of the upper waters of Waterton Lake, along the sides of the lower Cameron Creek valley and Blakiston Brook, north of Sofa Mountain, and the Bellevue Hill and Lakeview Ridge areas. The vegetation has a number of diverse associations. Lodgepole pine is dominant along Waterton Lake, but small amounts of Douglas-fir also occur. Areas north of Sofa Mountain, northwest of the Buffalo Paddocks, and in the Oil Basin – Cloudy Ridge area have stunted growth of limber pine and alpine fir. Aspen poplar cover a significant (40%) portion of these areas. The understory shrubs and herbs are common to abundant and quite varied.

The main points of consideration on these soils are the low available moisture, the shallow depth of soil, the compact and impervious nature of the till parent material, and its resistance to erosion (Figure 50). Map unit 52 has a moister environment than unit 50.

Horizon	Depth inches	Coarse fragments %	Moist color	Field texture	pH $CaCl_2$	Organic matter %
L–F	1–0	Dark brown, moderately decomposed pine needles with many white mycelia			4.3	
Ah	0–1		Dark brown	Gravelly loam	5.0	14.0
Bf	1–10	20	Strong brown	Gravelly loam	5.4	3.8
C	10–30+	30	Light brown	Gravelly sandy loam	4.8	

Soil Map Unit 53 (Orthic Humic Gleysol)

These soils, of medium to coarse texture, are found in depressions and seepage areas on Cordilleran glacial till. The parent material is sufficiently impermeable so as to aggravate the poor drainage tendency in some landscape positions. Individual areas of map unit 53 are not large in extent; collectively they cover less than 20% of the till acreage. Some of these map areas have long, narrow shapes (Figure 51). Map unit 53 is geographically located throughout the Park wherever poorly drained soils have developed on glacial till parent materials. Vegetation is usually dominated by spruce, although willows and alder are also common.

The main soil qualities to consider on this map unit are the poor profile drainage and the compact and impervious nature of the glacial till parent material. These qualities may be a distinct advantage for certain wetland plants and animals. They also offer an advantage for pond building for certain purposes. The strongly acid pH indicates that water is probably moving through the soil laterally. Thus, the rooting zone is strongly acid and carbonates are not accumulating.

Horizon	Depth inches	Coarse fragments %	Moist color	Field texture	pH $CaCl_2$	Organic matter %
L	½–0	Dark brown slightly decomposed moss layer			5.1	
Ahg	0–3½	5	Very dark gray	Loam	5.0	1.5
Bg	3½–7	5	Dark reddish brown, common medium distinct mottles	Loam	5.1	7.9
BCg	7–10	50	Dark brown, common medium distinct mottles	Gravelly silt loam	5.2	3.6
Cg	10–20+		Reddish gray, many medium distinct and prominent mottles	Fine sandy loam	5.1	

Soil Map Unit 54 (Orthic Regosol)

The soils of this map unit are medium to coarse textured and often have many coarse fragments, especially of cobble and boulder sizes. They have formed on the local lateral and end moraines bordering and closing, or encircling, the cirques at high elevations of about 6,500 ft a.s.l. The boulders show very little rounding and the tills are very heterogeneous, strongly reflecting the adjacent rock outcrops. Map unit 54 is geographically located throughout the western portion of the park in the cirque basins at higher elevations. The soils do not form an extensive acreage. Vegetation is characterized by short, slow-growing stands of alpine fir. Alpine larch and juniper are common, and herbs and grasses are also common.

The main limitations to the use of map unit 54 soils are their cold, inhospitable environment because of location at high elevation, their extreme stoniness, and their very strongly acid condition in the rooting zone. Many of their other limitations are moderate, thus suggesting their suitability for moderate but not intensive land uses.

Horizon	Depth inches	Coarse fragments %	Moist color	Field texture	pH $CaCl_2$	Organic matter %
Ah	0–1½	15	Very dark grayish brown	Loam	4.8	18.1
C	1½–15+	50	Reddish brown	Gravelly loam	4.5	3.7

Soil Map Unit 55 (Orthic Regosol)

This map unit is dominated by medium and coarse textured soils formed on medium textured calcareous Cordilleran glacial tills that are actively eroding. Thus, they are generally located on the steep part of stream-channel walls and occasionally on steep till slopes. Because of the steepness of the topography where these soils are found, these soils are in an unstable condition and profile development is severely retarded. Texture and amount of coarse fragments are quite variable, as is the vegetation. Aspen poplar and white spruce are predominant in the Belly River area; white spruce and Douglas-fir in the Sofa Creek area; alpine fir and white bark pine near Cameron Lake; and lodgepole pine and aspen poplar in the Horseshoe and Oil basin areas. The map unit does not make up a particularly large acreage, but is located throughout most of the Park.

The main soil limitations to consider are the low available moisture storage (mainly because of the high amount of runoff and exposure to high evaporation losses), the steep topography (mostly G and H slopes), and the unstable soil condition resulting from its location in the landscape. Since erosion is continually removing the upper soil, the rooting zone is calcareous and mildly alkaline.

Horizon	Depth inches	Coarse fragments %	Moist color	Field texture	pH $CaCl_2$	Organic matter %
L–F	1–0	Very dark grayish brown partially decomposed leaf and needle litter			6.5	
Ck1	0–6	10	Reddish brown	Sandy loam	7.1	2.9
Ck2	6–24	45	Reddish brown	Gravelly sandy loam	7.2	1.2
Ck3	24–30	45	Reddish brown	Gravelly sandy loam to gravelly silt loam	7.4	0.2
Ck4	30–40+	45	Pinkish gray	Gravelly sandy loam	7.3	0.5

Figure 53. Aspen forest and luxuriant undergrowth on map unit 58.

Figure 54. Gravels exposed on the surface of map unit 61.

Figure 55. Toppling of trees by "blowdown" is nature's way of cultivating soil, but can be hazardous for certain Park uses.

Figure 56. Extremely slow growth (2 feet in approximately 30 years) of alpine fir on map unit 64. Located near Twin Lakes, the slow growth results from the effect of cold climate at high altitude rather than soil limitations.

Soil Map Unit 57 (Orthic Gray Luvisol)

The soils of this map unit are mainly coarse to medium textured, formed on dense, hard and compact, pinkish calcareous Cordilleran glacial till. Many cobbles and boulders occur in these soils, and fine gravels composed of red and green argillites are of common occurrence. The till is very similar to the parent materials found in map units 50 and 52 except in the Belly River area. There the till is more brownish in color, has a slightly higher clay content, and appears to be less dense and hard. The landforms are characterized by generally long simple slopes, thus giving rise to only minor inclusions of poorly drained soils throughout the well-drained map unit 57. Soils on the top of the till ridges and on steeper sideslopes are generally somewhat shallower than those of the lower slopes. The parent materials are very impermeable and the Bt horizons (see profile descriptions) have accumulated sufficient clay to impede downward water percolation. The dominant tree vegetation is lodgepole pine, although some white spruce and Douglas-fir also occur. The shrub and herb layer varies with the density of the forest stand. Soils of map unit 57 are located mostly in the eastern portion of the Park, but do extend to the vicinity of Red Rock Canyon mainly on the south side of Blakiston Brook. Soil map unit 57 covers an extensive area of the Park and is one of the major soil types encountered.

The topographic nature of the till has resulted in shallow soils in the higher positions and thicker soils on the lower slopes. Thus there is a range of soil qualities on this map unit that are similar to that described for map unit 50. For example, lower available moisture storage occurs on the shallow soils and moderate moisture availability on the deeper ones. The characteristics of the profile and the parent till are quite different and again are similar to those described for unit 50. Map unit 57 differs in that it is a Luvisolic soil. This means that it is in a moderately moist climatic environment and has been subjected to downward movement and leaching of clays. The organic matter values are low and the rooting zone is strongly acid. Also, the accumulation of clay in the Bt horizon impedes downward percolation of water and downward movement of roots. Hence, while some of the restrictions are similar to those of unit 50, the management required is different.

Horizon	Depth inches	Coarse fragments %	Moist color	Field texture	pH $CaCl_2$	Organic matter %
L–F	1–0	Dark brown undecomposed organic matter				
Ae1	0–3	20	Grayish brown	Gravelly very fine sandy loam	4.3	2.5
Ae2	3–5½	20	Light yellowish brown	Gravelly silt loam	4.3	2.0
Bt1	5½–17½	40	Brown to strong brown	Gravelly silty clay loam	4.9	1.2
Bt2	17½–26	40	Strong brown	Gravelly silty clay loam	6.8	1.3
Ck	26–32+	40	Brown	Gravelly silt loam	7.3	

Soil Map Unit 58 (Dark Gray Luvisol)

This map unit is composed of medium to fine textured soils with relatively few coarse fragments (Figure 52). They have formed on dark colored Continental and/or Cordilleran glacial till. Not only are these soils developed on parent materials in a zone of mixing of the two tills, but they occur in a transition zone between the prairie and coniferous forest vegetation. Aspen poplar forests (Figure 53) are generally found to be associated with grasses toward the west and lodgepole pine and spruce at higher elevations to the east. Numerous shrubs and herbs also occur. This map unit occurs north of the registration office and in the Oil Basin cabin area.

The soil qualities are similar to those of map units 50 and 57.

Horizon	Depth inches	Coarse fragments %	Moist color	Field texture	pH $CaCl_2$	Organic matter %
L–H	2–0	Relatively undecomposed organic matter			6.2	
Ahe	0–6	5	Grayish brown and light gray	Silt loam	5.1	2.2
Bt1	6–12	5	Yellowish brown	Silty clay loam	5.5	1.6
Bt2	12–20	5	Yellowish brown	Silty clay loam	5.7	1.2
Ck1	20–25	7	Dark grayish brown	Silt loam	7.1	
Ck2	25–50+	5	Pale olive	Silt loam	7.3	

Soil Map Unit 61 (Orthic Gray Luvisols and Orthic Regosols)

The soils of this map unit are medium to coarse textured, with a very high content of gravel, cobbles, and boulders within the soil and on the surface (Figure 54). These soils are formed on Cordilleran glacial till comprised of angular, broken materials transported only very short distances. Some map units are on windy, exposed areas. Patches of bare soil with a continuous cover of gravel sized stones is a common occurrence. In such areas there is often no A horizon. The vegetation is often not continuous over the landscape. Some areas have a shrubby and mossy vegetation and many areas have stunted alpine fir, white spruce, and/or Engelmann spruce. Limber pine, Douglas-fir, and shrubs and grasses also occur. Most of map unit 61 is located at the base of the northeast corner of Sofa Mountain and occasionally in the Horseshoe Basin area and constitute a minor acreage of land.

Map unit 61 differs from the other map units on tills (except for unit 54) to the extent that the surface soil is very stony and bouldery, and the percentage of coarse fragments is high. This soil is similar to the other soils developed on tills in that the parent till is hard, compacted, and impermeable. These soils have low available moisture storage, high amount of runoff, and elevational exposure to cold and wind. In addition, the rooting volume is very low. Because of the limited acreage, these soils were not sampled for laboratory analysis. They are, however, some of the poorer soils for intensive Park use.

Horizon	Depth inches	Coarse fragments %	Moist color	Field texture	pH $CaCl_2$	Organic matter %
L	½–0	Black slightly decomposed leaves			Not sampled	
Ae	0–2	50	Brown	Gravelly silt loam	Not sampled	
Bt	2–9	80	Yellowish brown	Very gravelly silty clay loam	Not sampled	
C	9–20+	80	Pale brown	Very gravelly silt loam to gravelly sandy loam	Not sampled	

Soil Map Unit 64 (Orthic Humo-Ferric Podzol)

These soils generally have medium textures (silt loam) in the upper 12 to 18 inches over coarser, gravelly and sandy horizons derived from glacial till. The texture difference appears to result from postglacial loess and/or postglacial volcanic ash deposits overlying the Cordilleran till. There has been mixing of the underlying till (probably through tree-fall) with the overlying finer textured deposit so that stones are found throughout the upper material as well. The density of the upper, finer textured soil is much less than the till below and will greatly influence the response of these soils to any superimposed use. In general, these soils are found at relatively high elevations (usually above 5,000 feet), where precipitation is comparatively higher than on the prairies at lower elevations. As a result they have the most prominent horizons of any soils in the Park. The distinct gray layer near the surface and the bright reddish horizon below, plus the chemical criteria, indicate very distinctive Podzols. Map unit 64 occurs in the western sector of the Park and covers an extensive acreage. The vegetation is quite variable, depending on elevation and stand history. Except for areas of blowdown (Figure 55) or burn, there is generally a good cover of large trees (Figure 16,b). At the higher elevations, about 6,500 feet, map unit 64 soils support alpine fir (Figure 56) and alpine larch, as well as a dense and varied shrub cover. Alpine fir is common to all areas of unit 64 but varying amounts of white-bark pine, lodgepole pine, white spruce, and Engelmann spruce also occurs. The stands are generally tall and of large diameter, and overmature.

These soils have a number of attributes that cause map unit 64 to be of considerable value to the Park. Mainly, these units receive substantially greater amounts of precipitation than the eastern sections of the Park. The soil profile is more deeply weathered, providing a fairly high rooting volume, friable consistence, and high available moisture. The disadvantage of the soils of this map unit is indicated by the evidence of a high potential erosion hazard as seen along the Akamina Pass road and a few other small areas of obvious recent disturbance. Organic matter values are fairly high. Extremely acid surface horizons and strongly acid parent materials occur.

Horizon	Depth inches	Coarse fragments %	Moist color	Field texture	pH $CaCl_2$	Organic matter %
L–H	1–0	Very dark grayish brown slight and undecomposed organic material				
Ae	0–1	5	Gray	Silt loam	3.4	4.0
Bf1	1–5	40–50	Dark reddish brown to dark red	Gravelly loam	4.4	10.6
Bf2	5–11	40–50	Yellowish brown	Gravelly loam	4.9	4.5
C1	11–28	50–60	Yellowish brown	Gravelly loam to gravelly sandy loam	4.3	
C2	28–38+	50–60	Yellowish brown	Gravelly sandy loam	4.6	

Soil Map Unit 66 (Orthic Eutric Brunisol)

These soils are fine textured with moderate amounts of coarse fragments. They have formed on a thin mantle of Continental glacial till and exhibit a bedrock controlled landform. Occasional rock outcrops occur. Map unit 66 occurs mainly to the north of Lakeview Ridge, but is not an extensive map unit. The vegetation is characterized by scrubby stunted aspen poplar stands with some limber pine, alpine fir, Douglas-fir, and numerous shrubs and herbs.

The soils of this map unit have mostly moderate qualities. The area is much drier climatically than is map unit 64. The location of map unit 66, its elevation, shallowness (about 2 feet to rock), and low available moisture are probably its greatest limitations for Park use.

Horizon	Depth inches	Coarse fragments %	Moist color	Field texture	pH $CaCl_2$	Organic matter %
Ah	0–1		Very dark grayish brown	Loam to clay loam	6.6	5.0
Bm	1–11	20	Dark brown	Clay loam	6.6	3.2
Ck	11–26+	40	Yellowish brown	Gravelly clay loam	7.3	


Figure 57. Soil profile of map unit 67.


Figure 58. Grassy areas of map unit 67.


Figure 59. Deciduous forest and luxuriant undergrowth of map unit 67.


Figure 60. Grassy areas within a coniferous forest generally help to locate map unit 100.

Soil Map Unit 67 (Orthic Black Chernozemic soils)

These are fine textured soils, with occasional well-rounded coarse fragments in the soil and on the surface (Figure 57). They have developed on fairly dark colored fine textured glacial tills that contain rocks from the Canadian Shield and are therefore assumed to be of Continental origin. The more mellow, less stoney Continental tills in this area have a lower lime content, and may be less stable than the Cordilleran tills. Soil map unit 67 is located in the Prairie–Woodland transition zone and is vegetated with grasses and deciduous trees, mostly aspen poplar, and some balsam poplar (Figures 58 and 59). Numerous shrubs, herbs, and grasses also occur. Map unit 67 is located along the north boundary of the Park in the Kesler Lake and Lakeview Ridge areas. It is not an extensive map unit.

Map unit 67 has soil qualities exhibiting ample moisture and favorable physical conditions for good vegetative growth on northern aspects, and moderate moisture limitations on other aspects. Observations of trail conditions suggest that these soils are less stable than those developed from Cordilleran tills.

Horizon	Depth inches	Coarse fragments %	Moist color	Field texture	pH $CaCl_2$	Organic matter %
Ah	0–9	5	Very dark brown	Loam	5.8	15.0
Bm	9–17	5	Dark brown	Clay loam	5.2	3.2
BC	17–38	5	Dark brown	Clay	5.2	
C	38–46+	5	Dark gray to very dark gray	Clay	6.0	

Soil Map Unit 100 (Cumulic and Orthic Regosols)

These soils are fine textured (clays) with very few coarse fragments, formed on dark colored fine materials probably derived from locally weathered Belly River shales (Figure 8). These fine textured materials are subject to large rotational slumps which often disturb the surface soil and in some areas mix the 10-30 foot mantle of glacial till with the shales. Thus, a rather complex soil pattern has evolved. Shallow burial of one or more Ah horizons is evident in the profiles examined. This burial appears to be a repetitive process and probably has occurred repeatedly since the last glaciation. The majority of these soils have a mixed vegetation, probably because of the unstable nature of these landforms. Patches of white spruce and aspen poplar are found within dominantly grassy areas (Figure 60) that often support luxuriant growth of snowberry, cow parsnip, false hellebore, and thimbleberry. Map unit 100 is located east of Sofa Mountain in the Belly River area of the Park.

The soils in map unit 100 possess sufficient moisture to produce luxuriant growth of grasses, shrubs, and herbs. The unstable nature of these soils causes much slumping (Figure 61), which together with the slipperyness and low permeability resulting from the high clay content, suggests many severe use limitations. However, these soils probably provide a valuable source of forage to elk migrating through the Belly River valley on their way to and from winter ranges.

Horizon	Depth inches	Coarse fragments %	Moist color	Field texture	pH $CaCl_2$	Organic matter %
C1	0–7	None	Very dark grayish brown	Clay	5.4	5.9
C2	7–11	None	Very dark grayish brown	Clay	5.6	6.6
Btb1	11–23	None	Very dark grayish brown, and dark grayish brown	Clay	5.9	3.8
Btb2	23–40	None	Dark grayish brown, few very fine distinct mottles	Clay	6.1	2.4
BCb	40–48+	None	Dark gray and very dark gray, few fine distinct mottles	Clay	6.3	

Figure 61. Map unit 100 tends to slump, and then erode.

Figure 62. Soil profile of map unit 101.

Figure 63. The well-developed root mat is effective in stabilizing the steep slopes of map unit 142.

Figure 64. Soil profile of map unit 156.

Soil Map Unit 101 (Cumulic and Orthic Regosols)

These fine textured soils have few coarse fragments and are formed on dark colored, fine textured materials which were probably derived from the weathering of Belly River shales (Figure 62). The soil characteristics are very similar to those of map unit 100, except that map unit 101 is located mainly within draws and other local areas of erosion, or wash, that results in a silt loam surface texture rather than the clay of map unit 100. The erosion and deposition of this fine material often result in burial of the till and other soil materials. Shallow burial of Ah and L-H horizons is common. Many springs and seepage areas originate on these soil units and many of them are probably frequently "washed" by running water. Some areas have lodgepole pine forest, others have aspen poplar. White spruce was also observed. Shrubs, herbs, and grasses vary considerably in abundance and growth depending on the overstory species, and the aspect and slope characteristics of the landform. Map unit 101 occurs mainly in the Belly River area east of Sofa Mountain, north of Sofa Mountain, and small areas in the Oil Basin region.

High quantities of available moisture, well drained soils, and relatively high rooting volumes are the reasons this unit produces luxuriant vegetation growth. The limitations are similar to those of unit 100, but not to the same degree of severity. Unit 101 soils are more stable, although erodibility potential is high, especially if subjected to large volumes of traffic.

Horizon	Depth inches	Coarse fragments %	Moist color	Field texture	pH $CaCl_2$	Organic matter %
L–H	1–0	Partially decomposed organic matter comprised of rotting needles and twigs			5.4	
C1	0–4	2	Brown	Silt loam	5.2	5.5
Ahb	4–10	2	Dark brown	Silt loam	5.8	5.2
C2	10–16	2	Dark grayish brown	Clay loam	5.9	1.8
C3	16–23	2	Brown	Clay	5.9	1.1
C4	23–29	5	Weak red	Clay loam	6.3	
C5	29–40 +	10	Weak red	Clay loam	6.7	

Soil Map Unit 102 (Orthic Gray Luvisol)

This unit has dominantly fine textured soils with very few coarse fragments. These soils are formed on dark colored fine textured materials of either eroded local lacustrine or weathered shale origin. Most of these fine textured materials are susceptible to large rotational slumps. However, the well developed Gray Luvisol soils of map unit 102 suggest that these map units have been stable for a considerable length of time. The forest is mainly tall and thrifty lodgepole pine with occasional small areas of aspen poplar and white spruce. Shrubs and herbs are varied and thrifty; some grasses are present. Map unit 102 occurs mainly east of the Belly River.

The soil qualities of map unit 102 are moderate to good for most Park uses. A few areas have limited use because of steep topography. The characteristics of the Gray Luvisolic Bt horizons impose soil limitations to the extent that they restrict root penetration and probably create a perched water table near the surface for short periods of time in the spring.

Horizon	Depth inches	Coarse fragments %	Moist color	Field texture	pH $CaCl_2$	Organic matter %
L–H	2–0	Slightly to moderately decomposed organic material				
Ae1	0–5	None	Light gray	Silt loam	5.4	3.1
Ae2	5–9	None	Light brownish gray	Silt loam	5.3	1.6
AB	9–13	None	Grayish brown	Silt loam		
Bt1	13–22	None	Dark grayish brown	Silt loam	5.3	2.0
Bt2	22–37	None	Dark grayish brown	Clay loam	5.6	0.7
BC	37–46	None	Yellowish brown	Clay loam	6.3	
Ck	46–59	None	Brown and light grayish brown	Silt loam	7.6	

Soil Map Unit 103 (Lithic Regosols)

The soils of this map unit are medium textured with varying amounts of limestone fragments within the upper 20 inches of soil. These shallow soils have formed in a silt loam mantle of variable thickness overlying a relatively unweathered limestone bedrock. Map unit 103 is located mainly east of Belly River, and occurs on steep slopes intimately mixed with other Lithic and Regosolic soils. The steep slopes and relatively constant downslope movement of soil material prevent appreciable soil horizon development with the result that lime often occurs to the surface. The mixed forest is generally quite open and often scrubby, with domination of white spruce and trembling aspen. Shrub vegetation is characterized by an association of spirea, thimbleberry, and saskatoon. The herb layer contains meadow rue, fireweed, and grasses.

The shallow depth of soil, steep slopes, and downslope movement of material limit these soils for many uses.

Horizon	Depth inches	Coarse fragments %	Moist color	Field texture	pH $CaCl_2$	Organic matter %
L-F	½–0	Relatively undecomposed leaf litter				
AC	0–1	5	Dark grayish brown	Silt loam	7.5	7.5
Ck	1–10	5	Very dark grayish brown	Silt loam	7.7	
R	10–25+	Fractured limestone bedrock containing about 90% coarse fragments and 10% silt loam				

Soil Map Unit 105 (Gleyed Cumulic Regosol)

This map unit is dominated by medium textured soils with few coarse fragments. The soils are formed on local alluvial deposits where accumulations of fine textured materials have been carried in from adjacent shale parent materials and/or their derivatives. Seepage and depressional areas are subject to water saturation for significant portions of the year. The forest varies from sparse to dense mixtures of aspen poplar, white spruce, Douglas-fir, and lodgepole pine. Shrubs are numerous and varied, mountain maple, willow, and alder being common. Numerous herbs and grasses occur. Most of the unit 105 soils occur east of the Belly River.

This soil has severe limitations for many Park uses, the main ones being its poor drainage and fluctuating water-table condition. These same conditions are beneficial for wetland environments.

Horizon	Depth inches	Coarse fragments %	Moist color	Field texture	pH $CaCl_2$	Organic matter %
L	½–0	Slightly decomposed conifer needles				
Ah	0–3	None	Very dark grayish brown	Loam	6.9	21.3
C	3–6	None	Grayish brown	Silt loam	7.4	
Ahb	6–11	None	Black and very dark grayish brown	Loam to clay loam	7.3	7.8
Cg1	11–26	None	Light olive brown	Mottled silt loam	7.2	
Ahbg	26–29	None	Black grading to very dark grayish brown	Mottled clay loam	6.8	7.1
Cgk	29–32	None	Grayish brown	Mottled clay loam	6.9	
Cg2	32–37+	None	Brown	Mottled silt loam	7.0	

Soil Map Unit 106 (Orthic Gray Luvisol)

These fine textured soils have few coarse fragments, and are developed on dark colored fine textured materials of either eroded local lacustrine or weathered shale origin. These underlying fine textured materials are similar to those described for map unit 100. The susceptibility to large rotational slumps that occurred in map unit 100 is not evident in map unit 106 as the Gray Luvisol development of the soil profile indicates that this landform is fairly stable. The vegetation is strongly dominated by thrifty mature stands of lodgepole pine. Less dense forested areas have Douglas-fir mixed into the lodgepole pine stand. Occasional rather open areas are dominated by aspen poplar. Numerous shrubs, herbs, and grasses also occur. Most of this map unit occurs east of the Belly River.

Map unit 106 has a number of favorable soil qualities. Only moderate limitations occur for most uses. The increase in clay at 14 to 25 inches from the surface appears to have little effect on rooting volume, probably because of the strongly developed soil structure in the profile. The higher content of clay in the lower soil horizons may cause a perched water table for short periods in the spring or after fairly heavy rainfalls.

Horizon	Depth inches	Coarse fragments %	Moist color	Field texture	pH $CaCl_2$	Organic matter %
L–H	1–0	Slightly to moderately decomposed organic matter				
Ae1	0–4	None	Light gray	Silt loam	4.8	2.0
Ae2	4–7	None	Grayish brown	Silt loam	5.1	2.8
Bt1	7–14	None	Grayish brown	Clay loam	5.1	1.3
Bt2	14–25	None	Dark brown	Clay	4.8	1.3
BC	25–60	None	Very dark grayish brown	Clay	4.8	
C	60–74+	None	Yellowish brown	Clay loam	5.3	

Soil Map Unit 107 (Orthic and Cumulic Regosols)

These are very fine textured soils with very few coarse fragments. They have formed on grayish, fine textured materials apparently derived from slightly weathered residual shales. Most of the strong soil structure appears to be inherited from the parent shales. Unit 107 is similar to unit 100 in many respects but is developed under forest and is somewhat more stable than 100. Thus, the vegetation on unit 107 has fairly well developed forest cover of lodgepole pine with some white spruce. Douglas-fir regeneration was observed. Shrubs and herbs are numerous; mosses and grasses are few in number. Most of the unit 107 soils are found in the Belly River area east of Sofa Mountain.

The soil qualities of unit 107 are similar to those of unit 106 except that water permeability is somewhat slower. Both map units have strongly acid soils.

Horizon	Depth inches	Coarse fragments %	Moist color	Field texture	pH $CaCl_2$	Organic matter %
L–H	1–0	Very dark grayish brown partly decomposed leaf litter with many white mycelia			4.4	55.9
C1	0–8	None	Brown	Silty clay loam	4.6	1.7
C2	8–13	None	Grayish brown	Silty clay	4.8	1.6
C3	13–20	None	Grayish brown, common medium distinct mottles	Clay	4.6	
C4	20–40+	None	Gray and strong brown, few fine distinct mottles	Clay	4.6	

Soil Map Unit 141 (Orthic Regosol)

This map unit contains coarse textured soils with variable amounts of coarse fragments making up as much as 70% of the material. These units are on variously colored colluvial materials, depending on the kind of source rock. The soils are loose and porous, and have steep topography, thus giving rise to constant downslope creep of soil material. These soils have dominantly coniferous forests of alpine fir and white bark pine at higher elevations and lodgepole pine at the lower elevations. Some alpine larch occurs at high elevations and Douglas-fir occurs at some low elevations. An extremely varied shrub, herb, and grass layer occurs depending on exposure, moisture, elevation, and the nature of the forest stands. Map unit 141 occurs on mountain slopes located throughout the mountainous region of the Park and is one of the more extensive and varied map units encountered.

The use of these soils is limited by a number of soil features. These soils are loose and noncoherent, porous, and on steep topography. Hence, erosion risk is high, moisture availability is generally low, and a low rooting volume occurs. However, their use for trails was observed to be less hazardous than first anticipated. These soils have high value for protection forest, and aesthetic values.

Horizon	Depth inches	Coarse fragments %	Moist color	Field texture	pH $CaCl_2$	Organic matter %
L–H	2–0		Well decomposed to slightly decomposed leaf material		5.4	
C1	0–23	50	Dark brown	Gravelly loamy coarse sand	6.0	
C2	23–32+	50	Grayish brown	Gravelly loamy coarse sand	6.1	

Soil Map Unit 142 (Orthic Regosol)

This unit has coarse textured soils that often contain many cobbles, boulders, and broken red and green argillites. The soils are formed on coarse textured colluvium found on steep mountainsides. This colluvium does not include the talus or chute landforms. The argillites are usually of fine gravel size. Coarse gravels and large sized angular limestone fragments are common, and minor amounts of sandstone fragments also occur. The parent material is very loose and is usually close to the surface, the reason being that the steepness of the mountain slopes results in soil instability, and the geologic erosional forces are actively removing the surface soil. These soils, therefore, tend to develop indistinct thin A horizons and have numerous rock outcrops as inclusions. They occur on the steep nonforested mountainsides, generally at the higher elevations. The grassy vegetation also contains many herbs, but shrubs are of minor occurrence. If trees are present at all, they are usually extremely stunted, and/or broken from exposure to the climatic elements. This map unit forms an extensive acreage in the mountain landform area of the Park.

These soils have a number of soil qualities that severely limit some land uses. They have steep slopes, always over 30%, and some over 60%. Available moisture is low, compactibility is low, the depth of soil profile development is shallow. The looseness of the soil and steepness of the slopes produce unstable conditions causing a high erosion potential, especially if the vegetation should become overgrazed, burned, or otherwise severely disturbed. The hiking and riding trails that crossed this map unit indicated that resistance to erosion by traffic was better than expected, probably because of a well developed root mat (Figure 63) and a fairly good organic matter content, and because rapid permeability results in low runoff.

Horizon	Depth inches	Coarse fragments %	Moist color	Field texture	pH $CaCl_2$	Organic matter %
Ah	0–4	40	Dark brown*	Gravelly sandy loam	6.6	6.3
C1	4–29	40	Dark brown*	Gravelly sandy loam	6.8	4.2
C2	29–35+	40	Dark reddish brown	Gravelly sandy loam	6.7	3.9

*Dry color

Soil Map Unit 150 (Orthic Regosols and Degraded Eutric Brunisols)

This map unit contains coarse textured soils with abundant gravel sized coarse fragments. Cobbles are of common occurrence in the soil and on the surface, but large coarse fragments are less common. Because of the fairly steep colluvial slopes on which these soils are formed, there is considerable tendency for soil creep. Soil accumulation on the upslope side of old trees and buried soil surfaces provide evidence of the prevalence of downslope soil creep. The soil development and vegetation suggest a somewhat greater moisture supply than for map units 141 and 142. Lodgepole pine is the dominant forest tree, although Douglas-fir occurs, along with alpine fir and alpine larch at the higher elevations. Shrubs and herbs are varied and numerous; grasses are scarce. This map unit is located on mountainsides, particularly on the east side of Waterton Lake in the vicinity of Hell-Roaring Creek.

This unit has limitations similar to those of unit 142. Unit 150 has slightly more available moisture than unit 142, is slightly more stable, and is strongly acid. The presence of the buried Bf horizon suggests the probable presence of volcanic ash in this soil.

Horizon	Depth inches	Coarse fragments %	Moist color	Field texture	pH $CaCl_2$	Organic matter %
L–F	1–0	Very dark gray partly decomposed organic matter			5.1	
Ah	0–5	25	Dark brown	Gravelly sandy loam	5.5	3.5
C	5–12	25	Brown	Gravelly sandy loam	5.5	2.1
Bfb	12–22	30	Strong brown	Gravelly loam	5.5	2.9
Cb	22–40+	50	Light yellowish brown	Gravelly coarse sandy loam	5.7	0.7

Soil Map Unit 156 (Orthic Humo-Ferric Podzols and Degraded Eutric Brunisols)

This map unit has coarse textured soils with relatively abundant quantities of coarse fragments. Unit 156 is formed on steep and very steep colluvial slopes derived from local bedrock. The good forest and vegetative cover associated with this map unit are probably related to increased available moisture. As a result of the vegetation these soils have less downslope creep than units 141 and 142, and some well developed Podzols occur (Figure 64). Lodgepole pine and alpine fir are common at lower elevations, with white bark pine and alpine larch occurring above 6,500 feet. Engelmann spruce also occurs. Shrubs and herbs are numerous and varied, indicating the increased precipitation level. There are extensive areas of this map unit along the steep mountainsides of the more humid mountainous area west of Waterton Lake.

The soil qualities are similar to those of all units on colluvial slopes in the Park, except that the precipitation is higher and thus soil development and forest growth are better. The soils are loose, open, and highly porous, and have steep topography.

Horizon	Depth inches	Coarse fragments %	Moist color	Field texture	pH $CaCl_2$	Organic matter %
L–F	1½–0	Slightly decomposed organic litter			4.5	
Ae	0–4	40	Reddish gray	Gravelly sandy loam	4.3	3.8
Bf	4–16	40	Yellowish red	Gravelly sandy loam	5.1	3.8
C	16–30+	50	Reddish brown	Gravelly sandy loam	4.9	

Soil Map Unit 160 (Orthic Gray Luvisol)

These coarse textured soils have developed on colluvial materials containing a large amount of coarse fragments. They have formed from loose but fairly stable colluvium high in weathered limestone fragments, and with somewhat less steep slopes than adjacent mountainside colluviums. The greater stability of these slopes is indicated by the mature Gray Luvisol profile development in this soil. The vegetation is mostly lodgepole pine. Some areas have significant amounts of alpine fir, although limber pine and Douglas-fir also occur. Shrubs, herbs, and grasses are numerous and varied. This map unit is not extensive and is located in the Horseshoe Basin area of the Park.

The limiting soil qualities are very similar to those described for map unit 142. However, unit 160 is generally less steep and therefore more stable. Lime is readily available to plant roots, as indicated by the soil pH in the lower horizons.

Horizon	Depth inches	Coarse fragments %	Moist color	Field texture	pH $CaCl_2$	Organic matter %
L–H	2½–0	Very dark gray and black relatively well decomposed litter			4.8	
Ae	0–3	40	Pale brown	Gravelly loam	5.2	3.4
Bt1	3–8	40	Yellowish brown	Gravelly clay loam	5.5	2.9
Bt2	8–15	40	Yellow	Gravelly clay loam	6.0	2.7
Ck	15–40+	40	Yellowish brown	Gravelly clay loam	7.0	

Soil Map Unit 170 (Orthic Regosol)

The soils of this map unit are coarse textured with essentially no coarse fragments. They have formed on light colored wind-blown sand. The dunes are partially stabilized with a reasonably good growth of shrubby vegetation, mainly saskatoons, plus some scrubby aspen poplar. However, the lack of soil profile development indicates that there is probably some accretion occurring annually. Map unit 170 is geographically located in a single area at the southeast corner of Knight's Lake.

The soil of these sand dunes has severe limitations for most uses. Because of their exposed, windy situation these dunes are not entirely stable and some shifting is an almost daily phenomenon, at least during windy summer weather. They are unique by virtue of being the only dune area in the Park.

Horizon	Depth inches	Coarse fragments %	Moist color	Field texture	pH $CaCl_2$	Organic matter %
C	0–50+	None	Brown	Loamy coarse sand	6.4	

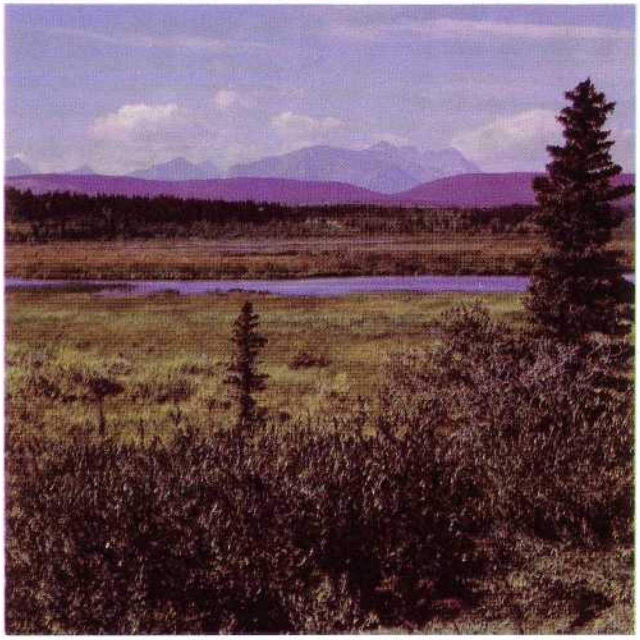


Figure 65. Vegetation and landscape of soil map unit 190.

Figure 66. Vegetation and landscape of soil map unit 190.

Figure 67. Exposed rock surface and vegetation of map unit 90R.

Figure 68. Vegetation of part of map unit 91R.

Soil Map Unit 171 (Cumulic Regosol)

The soils of this map unit are coarse textured with very few coarse fragments in the upper part of the profile and many coarse fragments in the lower part. They have formed on a thin mantle of wind-blown sand deposited over river terrace alluvium. This river terrace alluvium is very similar to the major soils comprising map unit 17. The depth of the overlying surficial deposit decreases to the northeast as the distance from the sand dunes increases.

The vegetation is mainly bluebunch fescue, parry oat grass, and others. Shrubs such as rose and snowberry also occur, and a few scrubby aspen poplar are on the margins of the map unit. This unit is also a single land area near the southeast corner of Knight's Lake.

The soils of this map unit have severe limitations for many Park uses. They are droughty, and because of their open, porous nature are a pollution risk if any large amounts of sewage are disposed in them. Being adjacent to the dunes (unit 170), map unit 171 is obviously also in an exposed windy location, hence preservation of the vegetation is necessary to protect the soil from wind erosion. Being grassy and well drained, the soils of map unit 171 are preferred by small mammals such as ground squirrels. The area is also part of the wintering range for ungulates.

Horizon	Depth inches	Coarse fragments %	Moist color	Field texture	pH $CaCl_2$	Organic matter %
C	0–16	None	Dark brown	Loamy sand	Not sampled	
IIAhb	16–26	15	Dark reddish brown	Sandy loam	Not sampled	
IIBmb	26–36	25	Dark reddish brown	Gravelly sandy loam	Not sampled	
IICb	36–40+	90	Dark yellowish brown	Very gravelly loamy sand	Not sampled	

Soil Map Unit 190 (Silvo-Fibrisol)

The soils of this map unit are made up of relatively undecomposed organic remains. Mosses dominate, but about 20 to 40% of the organic remains may be comprised of sedges and shrubs. Sphagnum mosses were not identified. These soils are slightly acid to neutral in reaction and are saturated throughout the season, and in most areas are greater than 60 inches deep to mineral material. There are few areas within the Park where appreciable amounts of Organic soils are found. The largest area is about 1 mile east of the fire tower south of Highway 6. This area was taken as the type area (Figures 65 and 66). However, a small area also was mapped north of Cameron Lake and was found to be slightly more oxidized. Small areas of Organic soils were also mapped in the Galwey Creek area and the Belly River area. The vegetation is usually dominated by mosses (not sphagnum). Shrubs such as willow and alder are common, as are herbs such as sedges.

Because these soils are highly organic and very wet, their use is severely limited except for the aquatic and semi-acquatic ones.

Horizon	Depth inches	Wet color	Organic composition	Bulk density
Of1	0–14	Brown and dark brown	70% unrubbed fiber; 30% rubbed	0.2
Of2	14–35	Reddish brown and dark reddish brown	95% unrubbed fiber; 70% rubbed	0.1
Of3	35–52+	Dark reddish brown, yellowish red, and dark reddish brown	90% unrubbed fiber; 40% rubbed	0.1

Figure 69. Examples of broken rock and consolidated rock in the map unit Rock as seen from Carthew Summit.

Figure 70. The map unit Rock occasionally occurs at relatively low elevations. Note the stunted trees and shrubs growing in cracks in otherwise consolidated bedrock.

Figure 71. Talus; with minor amounts of vegetation becoming established.

Figure 72. Rock quarry; such land areas are difficult to reclaim for other uses.

Soil Map Unit 90R (Lithic Orthic Regosol)

This map unit is a complex of rock outcrop (Figure 67) interspersed with coarse textured soils having variable amounts of coarse fragments. The soils have formed on shallow deposits (less than 20 inches) of unconsolidated material of various origins. The rock outcrops vary from resistant dolomites to fine and medium sandstones to fissile red shales. The unit generally occurs at the higher elevations and usually on the steeper slopes. At intermediate and lower slopes the dominant trees are lodgepole pine, Douglas-fir, and alpine fir. Whitebark pine, alpine larch, and alpine fir occur at elevations above 6,500 feet. Shrubs, herbs, and grasses are numerous and extremely varied in their location and abundance.

The shallow depth of soil materials and the generally steep topography limit these soils for many uses. Their location at relatively high elevations is a limitation to some uses. Also, their coarse texture and open, porous nature produce low amounts of available moisture. It should be remembered that a large proportion of these areas are rock outcrop.

Horizon	Depth inches	Coarse fragments %	Moist color	Field texture	pH $CaCl_2$	Organic matter %
Ah	0–1	10	Dark gray	Sandy loam	5.5	6.9
C	1–12	>10	Dusky red	Gravelly sandy loam to loamy sand	5.6	
R	12+	Red shale				

Soil Map Unit 91R (Lithic Orthic Eutric Brunisol)

The shallow soils of this map unit are medium textured with moderate amounts of coarse fragments. They have formed on shallow deposits (generally less than 20 inches) of what appears to be ground-up and weathered limestone bedrock left by glaciation. The brown and strong brown B horizons often extend to the bedrock contact. The soils are very friable and mellow and probably have a low bulk density. The shape of the landform is entirely bedrock controlled. Numerous small areas of rock outcrop are scattered throughout the unit, in some areas covering 50% or more of the land surface. The forest cover is mainly lodgepole pine, although mixed stands of lodgepole pine and Douglas-fir also occur (Figure 68). Shrubs, herbs, and grasses are varied and numerous. The map unit is located at the higher elevations along the east valley wall of the southern part of Waterton Lake.

The shallow depth of soil materials and the generally steep topography limit these soils for many uses. Their location at relatively high elevations is another limitation to some uses. It should also be remembered that a large proportion of these areas are rock outcrop.

Horizon	Depth inches	Coarse fragments %	Moist color	Field texture	pH $CaCl_2$	Organic matter %
L–F	2–0	Dark reddish brown partly decomposed organic material			4.8	
Bm	0–5	20	Yellowish red to reddish brown	Gravelly loam	5.7	4.6
C	5–14	40	Strong brown	Silt loam	6.2	
R	14+	Resistant light colored dolomite				

MISCELLANEOUS MAP UNITS

Map Unit Rock

This map unit is comprised of consolidated rock of all kinds found within the Park. It also includes extensive areas of fractured and broken rock such as that which occurs on the top of Mount Hawkins and Carthew Summit (Figure 69). Often the mountaintops and rock outcrops are bare. However, in several instances there are stunted trees growing in cracks and shallow pockets of soil (Figure 70). In alpine areas vegetation may cover 10 to 20% of the surface and the area will still be mapped as Rock because of the small amount of soil, or "nonrock" material. In general, if the fractured rock is not subject to continued gravitational movement the areas are mapped as Rock. If the fractured rock is moving downslope at an appreciable rate, it is mapped as Talus.

Figure 73. Mountainside with a number of Chutes indicating active snowslide conditions during the winter.

Figure 74. Partial regrowth on an older Chute.

Figure 75. Recent damage to forest vegetation by 1972 snowslide in a Chute.

Figure 76. Damage to a picnic shelter located at the bottom of a Chute.

Map Unit Bp

This map unit is comprised of beaver ponds, beaver dams, and very poorly drained soils associated with beaver activity. If the beavers have recently vacated a site it may be partially drained, but still mucky and wet. In other cases recently constructed dams change previously well drained soils to soils inundated with water. The soils may vary from Organic to Gleysols and Gleyed Regosols. Much of the surface of areas mapped as Bp is flooded and thus covered with water.

Vegetation associated with this map unit is dominantly grasses, sedges, and shrubs. Shrub species such as river alder and willows are common. Herbs such as water sedge, beaked sedge, arrow-leaved colt's-foot, marsh reed grass, and tall white orchid are common.

The parent materials associated with those soils found on map unit Bp are not restricted in number, or defined. However, the most common parent material is alluvium of varying textures. Occasionally the water levels will be raised by beaver dams sufficient to encroach upon some of the tills on either side of the stream channels.

Map Unit RD

This map unit identifies areas used as refuse disposal areas or pits. The abandoned gravel pit north of the golf course is the only area mapped as RD. There may be smaller areas within the Park where refuse is dumped, but these are small enough to be mapped as inclusions in other map units.

Map Unit Talus

This map unit is comprised of fractured rock which is actively moving downslope, mainly as the result of gravitational forces. The rock debris generally has a slope equal to the angle of repose. Thus, the landform is a typical scree or talus. In many cases the rate of weathering of the cliffs which feed the talus is fast enough to prevent appreciable vegetative growth. However, in other cases the rate of accretion and movement is slow enough that the surface may have a greenish appearance in late spring when observed from a distance (Figures 28 and 71). Vegetation gets a foothold in small pockets of fine materials that have probably accumulated through frost action on weathered rock. There is, often, a continuum between rock, talus, and colluvium. For the purposes of this report, when accretion and movement are slow enough for the surface to support appreciable vegetation the landform is considered to be colluvium; otherwise, the gravitational slopes are considered to be Talus.

Map Unit Pit

This map unit identifies areas where soil has been removed or excavated for topsoil, rock quarries (Figure 72), and/or road construction. Several areas of the park have been stripped of their topsoil. Other areas have been excavated for gravel used in roads and/or building construction. A number of borrow pits were made when the Chief Mountain highway (No. 6, south) was constructed.

Map Unit Chute

This map unit identifies areas where periodic snowslides remove the trees and render the denuded soil more susceptible to erosion in the spring and summer (Figure 73). There is often an abrupt change in soils found in the chutes to those found in the adjacent forested areas. Most chutes are characterized by Regosols. There are some, however, which have sufficient B horizon development to be considered Brunisols. Some chutes have thick accumulations of humified organic matter over the mineral material. Others (or soils of the same chute) have the mineral material exposed at the surface. Since these are areas of winter snow accumulation, and generally also areas where rivulets flow, chutes are often more moist than adjacent soils.

About the only consistent feature of the vegetation in chutes is its stunted, scrubby, twisted nature (Figure 74). Green alder and willows are very common in chutes. Scrubby poplars are common at lower elevations and scrubby alpine fir are common at higher elevations. Most species vary in accordance with the vegetative and climatic zones of the Park.

Because of apparent wide variations in snow accumulations and rapid changes in temperature, snowslides in chutes can result in variable amounts of damage; thus, chutes are considered to have severe limitations for many Park uses (Figures 75 and 76).

PART IV

INTERPRETATION OF SOIL MAPPING UNITS FOR SELECTED PARKS USES

The interpretative information is provided in tabular form, giving probable limitations of the map units for selected Park uses. The criteria used to evaluate the kind and degree of limitations are given in Tables 3, 5, 7, 9, 11, 13, and 15, and were largely adapted from unpublished guides used by the United States Department of Agriculture, Soil Conservation Service. Similar guides are to be found in Montgomery and Edminister, 1966; Soil Conservation Guide, 1967; and Brocke, 1970. In establishing the limits given in the criteria, a management level commensurate with a pleasant environment for the proposed uses was assumed. Appendixes A and B provide much of the analytical information and engineering data used to assess the limitations.

Soil limitation ratings were used to evaluate the mapping units, and hence the soils, for selected uses. These ratings express relative degrees of hazards, risks, or limitations for potential uses for natural or essentially undisturbed soils. The long-term effects of the potential uses on the behavior of the soil are considered in the rating. Ratings of slight, moderate, severe, and unsuitable are used as follows to designate the degree of soil limitations for each use listed in Tables 4, 6, 8, 10, 12, 14, 16, and 18.

1) *Slight soil limitations:* These soils have properties favorable for the rated use. Soil limitations are minor and can easily be overcome. Good performance and low maintenance can be expected on these soils.
2) *Moderate soil limitations:* These soils have properties moderately favorable for the rated use. Limitations can be overcome or modified with special planning, design, or maintenance. During some seasons, the performance of the structure or other planned use may be somewhat less desirable than for soils with a slight limitation. Some soils with this rating may require treatment such as drainage, runoff control to reduce erosion, extended sewage absorption fields, extra excavation, or some modification of certain soil features through soil manipulation. Construction plans may need to be modified from those normally used for soils with slight limitations. These may include special foundations, extra reinforcement of structures, sump pumps, or other auxiliary equipment or procedures.
3) *Severe soil limitations:* These soils have one or more unfavorable soil properties for the rated use. Limitations are difficult and costly to modify or overcome, requiring major soil reclamation, special design, or intense maintenance. They have one or more adverse features such as steep slopes, bedrock near the surface, a flood hazard, or other features (*see* Tables 4 to 10). Some soils rated severe can be improved by reducing or removing the soil feature that limits its use. In most situations it is difficult and costly to alter the soil or the design of the facility to compensate for soil limitations that are severe.
4) *Unsuitable:* These soils have such unfavorable soil properties that either they cannot physically be used for the rated use, or it is economically impractical to do so. For example, a talus slope is considered to be unsuitable as a location for a baseball playing field.

The soils were rated according to their limitations for playgrounds, camping areas, picnic areas, trails, septic tank absorption fields, permanent buildings with basements, permanent buildings without basements, and local roads (Tables 4, 6, 8, 10, 14, and 16). Susceptibility to erosion was also assessed (Table 18). Major campgrounds and back country camp-sites differ in design setting and management, but require similar soil attributes. The interpretation of mapping units for camping areas should provide the basic soils information necessary to evaluate either proposed use. The criteria and interpretations used for local roads can also be applied to parking lots. Soils criteria for visitor centers, depending upon their design, are probably a combination of interpretations for local roads and for permanent buildings. Hiking trails and riding trails were not treated separately. The design for riding trails is necessarily more stringent, and a given limitation will be somewhat more difficult to overcome. The main soils parameter of importance in planning ski areas is probably its susceptibility to erosion. The clearing of vegetation would result in baring some of the soil and at least one of the major parameters can be evaluated by assessing the susceptibilities of the soil to erosion. The other main parameter would be rate of revegetation, which is very dependent on climate and altitude as well as soil. Proposed dock areas can be evaluated by the interpretation of soils for picnic areas, parking lots, and possibly permanent buildings depending upon the proposed design.

Figure 77. Relatively undisturbed land on the west side of Cameron Lake campground.

Figure 78. The impact of use caused by severe vegetation and soil disturbance in the Cameron Lake campground. A narrow roadway is all that separates the two areas shown in Figures 77 and 78.

When using the soil limitation or suitability ratings, the following must be considered.

1) Interpretations are based on predictions of soil behavior under defined conditions of use and management.
2) Soil ratings do not include site factors such as nearness to towns or highways, water supply, or aesthetic values.
3) Soil ratings are based on natural undisturbed soil.
4) Soil suitability or limitation ratings are usually given for the entire soils but for some uses soil limitations are given for an individual soil horizon or other earthy layer, because of its overriding importance. Ratings rarely apply to soil depths greater than 3 to 4 feet, but in some kinds of soils reasonable estimates can be given for soil material at greater depths. It should be noted here that the term "soil" has been used throughout the report in the pedologic sense and differs in concept from that commonly used by engineers.
5) Severe soil ratings do not imply that a site cannot be changed to remove, correct, or modify the soil limitations. The use of soils rated severe depends on the kind of limitation, whether or not the soil limitation can be altered successfully and economically, and the scarcity of good sites.
6) Interpretations do not eliminate the need for on-site evaluations by qualified professionals. The need for or importance of on-site studies depends on the use to be made of the soil, the kinds of soil, and the soil problems involved. It is also necessary to assess the impact of land use (Figures 77 and 78) to determine whether the problem is physical (soil limitation), biological (vegetation fragility), or management (simply too many people using too little space).
7) Limitations to use for septic tank effluent disposal are indicated for those soils where a pollution hazard exists. Because of the number of variables affecting such ratings, the degree of pollution hazard is not indicated.

The information in Tables 4, 6, 8, 10, 12, 14, 16, and 18 presents the nature and degree of soil limitations on selected Park uses. If a moderate or severe limitation occurs in a given map unit lesser limitations were not specified. Limitations as a result of slope were not subdivided once the limitation became severe for the specified use. It follows, however, that the steeper the slope the more severe the limitation and this fact should be considered in using the tables.

Table 3. Guide for assessing soil limitations for playgrounds

This guide applies to soils to be used intensively for playgrounds for baseball, football, badminton, and other similar organized games. These areas are subject to intensive foot traffic. A nearly level surface, good drainage, and a soil texture and consistence that give a firm surface generally are required. The most desirable soils are free from rock outcrops and coarse fragments.

Soil suitability for growing and maintaining vegetation is not a part of this guide, except as influenced by moisture, but is an important item to consider in the final evaluation of site.

Item affecting use	Degree of soil limitation[7]		
	None to slight	Moderate	Severe
Wetness (Wet)[1]	Rapidly, well, and moderately well drained soils; water table below 30 in. during season of use	Moderately well and imperfectly drained soils; water table below 20 in. during season of use	Imperfectly, poorly, and very poorly drained soils; water table above 20 in. during season of use
Flooding (Flood)	None during season of use	May flood once in 2 yr during season of use	Floods more than once in 2 yr during season of use
Permeability[2] (Perm)	Very rapid to moderate inclusive	Moderately slow and slow	Very slow
Slope (Slope)	0–2% (AB)	2–5% (C)	5–9% (D)
Useful moisture[3] (Moist)	Water storage capacity >5 in. and/or adequate rainfall and/or low evapotranspiration	Water storage capacity 2–5 in. and/or moderate rainfall and/or moderate evapotranspiration	Water storage capacity <2 in. and/or low rainfall and/or high evapotranspiration
Surface soil texture[4] (Text)	SL, FSL, VFSL, L, SiL[5]	CL, SCL, SiCL, LS[5]	SC, SiC, C, sand, and loamy sand subject to blowing, organic soils
Depth to bedrock (Rock-D)	Over 40 in.	20–40 in.	Less than 20 in.
Coarse fragments on surface[6] (CF)	Relatively free from fragments	Up to 20% coarse fragments	20%+coarse fragments
Stoniness[6] (Stony)	Stones greater than 50 ft apart	Stones 50–5 ft apart	Stones less than 5 ft apart
Rockiness[6] (Rock)	Rock exposures greater than 300 ft apart and cover less than 2% of the surface	Rock exposures 300–100 ft apart and cover about 2–10% of the surface	Rock exposures less than 100 ft apart and cover greater than 10% of the surface

1The abbreviations in brackets are used in Table 4 to indicate the nature of the limitation.

2Infiltration tests show that, in most of the soils found in Waterton Lakes Park, there is little limitation in permeability with regard to playgrounds (Appendix A).

3This item attempts to evaluate the adequacy of moisture for vegetative growth. It incorporates the concept of supply through rainfall, loss through evapotranspiration, and storage within the rooting zone. In soils where the water table is within rooting depth for a significant portion of the year, water storage capacity may not significantly influence vegetation growth.

4Surface soil texture influences soil ratings as it affects foot trafficability, surface wetness, dust, and maintenance.

5If dust is a problem, rate soil one class lower (from *slight* to *moderate* or *moderate* to *severe*).

6See also definitions in *The System of Soil Classification for Canada* (Canada Soil Survey Committee 1970), pp. 213–214. Coarse fragments include both gravels and cobbles.

7A fourth degree of soil limitation is also defined for the purposes of Table 4—Unsuitable: Slopes greater than 9%; permanently wet soil; soil subject to floods every year, or more often; rock outcrop too frequent to permit playground location.

Table 4. Interpretation of soil characteristics for playgrounds
(Based on Table 3, Guide for assessing soil limitations for playgrounds)

Map unit	Degree and nature of limitation: Slight	Moderate	Severe	Unsuitable
1/AC		Slope Stony		
1/AD			Slope CF Moist	
1/DE, 1/EF, 1/F, 1/FG, 1/G, 1/GH		Stony	CF Moist	*Slope*[2]
4/AC		Slope	CF Moist Stony Rock	
4/DE			Stony CF Moist	*Slope* Rock
8/AC		Slope	Moist	
11/AC			Flood Wet CF	
11/DE			Flood Wet	*Slope*
12/AC		Slope Wet	Perm	
12/DE		Wet	Perm	*Slope*
14/AB			Flood	*Wet*
15/AB		Flood Wet		
16/AC		Flood		
17/AC, 17/AD			Moist CF	
18/AC		Moist	CF	
19/AC		CF		
19/AD		CF	Slope	
19/DE		CF		*Slope*
20/AC, 20/AD			Rock CF	*Flood*
20/FG			Rock CF	*Slope* Flood
21[6]/AC			CF Moist	
21[6]/F			CF Moist	*Slope*
22[6]/AC		Stony	CF Moist	
22[6]/DE, 22[6]/E, 22[6]/EF		Stony	CF Moist	*Slope*
25/AC		Moist		
25/DE, 25/EF, 25/G		Moist		*Slope*
26/AC	Nil			
27/AC		Slope Moist	CF	
27/AD		Moist	Slope CF	
27/DE, 27/E, 27/EF, 27/F		Moist	CF	*Slope*
28[6]/AC		Moist Stony Slope	CF	
28[6]/D		Moist Stony	CF Slope	
28[6]/E, 28[6]/EF, 28[6]/GH		Moist Stony	CF	*Slope*
29/AB, 29/AC		Wet		
29/CD		Wet	Slope	
29/DE, 29/E		Wet		*Slope*
29/EF, 29/G		Wet CF		*Slope*
31/AB			Flood	*Wet*
32/AB, 32/AC			Flood	*Wet*
32/AD, 32/CD		Slope	Flood	*Wet*
36[6]/AC		Slope		
36[6]/DE, 36[6]/EF, 36[6]/G				*Slope*
37/AC			Wet	
37/DE, 37/EF, 37/F			Wet	*Slope*
37/G, 37/GH		Wet		*Slope*
37/H				*Slope*
38[6]/AC		Slope CF Moist Wet[1]		
38[6]/AD, 38[6]/CD, 38[6]/D		CF Moist Wet[1]	Slope	
38[6]/DE, 38[6]/E		Moist	CF	*Slope*
38[6]/EF, 38[6]/F, 38[6]/FG, 38[6]/G, 38[6]/GH		Moist	CF Stony	*Slope*
39[6]/AC		Slope Moist	CF	
39[6]/EF, 39[6]/FG, 39[6]/G, 39[6]/GH		Moist	CF Stony	*Slope*
41/AC		Slope		
41/DE, 41/EF, 41/FG				*Slope*
42/AC	Nil			
44/AC			Flood	*Wet*
46/AC		Slope	CF	
46/DE, 46/EF			CF	*Slope*
47[6]/AC		Slope Stony	CF	
47[6]/DE, 47[6]/EF		Stony	CF	*Slope*
48[6]/AC		Slope	CF Stony	
48[6]/AD			CF Stony Slope	
48[6]/DE, 48[6]/EF, 48[6]/FG			CF Stony	*Slope*
49[6]/AC		Slope	CF	
49[6]/DE, 49[6]/EF			CF	*Slope*
50/AD, 50/CD		Moist	Stony CF Slope	
50/DE, 50/EF, 50/FG, 50/G		Moist	CF Stony	*Slope*
52/AD		Moist Stony Rock	Slope CF	
52/DE, 52/EF, 52/EG, 52/FG, 52/G, 52/GH, 52/H		Moist Stony Rock	CF	*Slope*
53/AC		CF		*Wet*
53/DE, 53/EF, 53/FG			CF	*Wet* Slope
54/AD			CF Stony Slope	
54/DE, 54/EF, 54/FG, 54/GH, 54/H			CF Stony	*Slope*
55/AD			Slope CF Stony	
55/DE, 55/EF, 55/FG, 55/G, 55/GH, 55/H			CF Stony	*Slope*

Table 4. Interpretation of soil characteristics for playgrounds (cont'd)

Map unit	Degree and nature of limitation: Slight	Moderate	Severe	Unsuitable
57/AC		Slope	CF	
57/AD, 57/CD, 57/D			Slope CF	
57/DE, 57/E, 57/EF, 57/F, 57/FG, 57/G, 57/GH			CF	*Slope*
58/AC		CF Slope		
58/AD		CF	Slope	
58/DE, 58/EF, 58/G		CF		*Slope*
61/EF, 61/FG, 61/G, 61/GH			CF Rock Stony	*Slope*
64/AC		CF Slope		
64/AD, 64/CD, 64/D		CF	Slope	
64/DE, 64/EF, 64/F, 64/FG, 64/G, 64/GH, 64/H		CF		*Slope*
66/EF			Stony CF	*Slope*
67/AD		Moist[1]	Slope	
67/DE, 67/EF, 67/FG		Moist[1]		*Slope*
100[3]/AC		Slope	Text	
100[3]/DE, 100[3]/EF, 100[3]/FG, 100[3]/G, 100[3]/H			Text	*Slope*
101[3]/AD		Text	Slope	
101[3]/DE, 101[3]/EF, 101[3]/F, 101[3]/FG, 101[3]/G, 101[3]/GH		Text		*Slope*
102/AC		Text Slope		
102/DE, 102/EF, 102/FG, 102/G		Text		*Slope*
103/GH		Rock-D		*Slope*
105/AD				*Wet*
105/DE, 105/EF			Wet	*Slope*
106/AC		Text Slope		
106/DE, 106/F, 106/FG, 106/G		Text		*Slope*
107[3]/E, 107[3]/EF, 107[3]/FG, 107[3]/G		Text		*Slope*
141[6]/DE, 141[6]/EF, 141[6]/F, 141[6]/FG, 141[6]/G, 141[6]/GH, 141[6]/H			Stony CF	*Slope*
142[6]/DE, 142[6]/EF, 142[6]/F, 142[6]/FG, 142[6]/G, 142[6]/GH, 142[6]/H			Stony CF	Slope
150[6]/DE, 150[6]/EF, 150[6]/FG, 150[6]/G, 150[6]/GH, 150[6]/H		Stony	CF	*Slope*
156[6]/DE, 156[6]/EF, 156[6]/F, 156[6]/FG, 156[6]/G, 156[6]/GH, 156[6]/H		Stony	CF	*Slope*
160[6]/DE, 160[6]/EF, 160[6]/G			CF	*Slope*
170/EF			Moist Text	*Slope*
171/AD		Text Moist		
190/AB			Flood Text	*Wet*
90R[6]/EF, 90R[6]/FG, 90R[6]/G, 90R[6]/GH, 90R[6]/H			CF	*Slope* Rock-D
91R[6]/FG, 91R[6]/G, 91R[6]/GH, 91R[6]/H			CF	*Slope* Rock-D
Talus/G, Talus/GH, Talus/H				*Slope*
Rock				*Rock*
BP			Flood	*Wet*
RD[4]				[4]
Pit[4]				Perm[4] Text[4]
Chute[5]			Wet[1]	Slope[1]

Footnotes

[1]This limitation occurs occasionally within the map unit but should not be expected throughout the area. Field checks on selected sites are necessary to ascertain whether this limitation applies to the given map unit.

[2]The limitations listed in italics under "Unsuitable" are considered to be the most significant ones for evaluating the appropriate map units for use as playgrounds.

[3]These map units are located on materials subject to large rotational slumping or excessive creep.

[4]These are miscellaneous land units representing cultural features. Unless the present use is abandoned these areas are unsuitable for any other use.

[5]Chute areas are subject to periodic snowslides or avalanches which result in a severe limitation for most uses.

[6]These soils are very susceptible to water erosion whenever runoff occurs, particularly if the vegetative cover is damaged. Fortunately, however, permeability is very high and seldom is water added fast enough to have surface flow. When a stream is diverted or some similar phenomenon occurs which provides surface flow, the results can be catastrophic.

Table 5. Guide for assessing soil limitations for camp areas

This guide applies to soils to be used intensively for tents and small camp trailers and the accompanying activities of outdoor living. It is assumed that little site preparation will be done other than shaping and leveling for tent and parking areas. The soil should be suitable for heavy foot traffic and for limited vehicular traffic.[1] Soil suitability for growing and maintaining vegetation is not a part of this guide, except as influenced by moisture, but is an important item to consider in the final evaluation of site.

Item affecting use	Degree of soil limitation[9]		
	None to slight	Moderate	Severe
Wetness (Wet)[2]	Rapidly, well, and moderately well drained soils; water table below 30 in. during season of use	Moderately well and imperfectly drained soils; water table below 20 in. during season of use	Imperfectly, poorly, and very poorly drained soils; water table above 20 in. during season of use
Flooding (Flood)	None	None during season of use	Floods during season of use
Permeability[3] (Perm)	Very rapid to moderate inclusive	Moderately slow and slow	Very slow
Slope (Slope)	0–9% (AD)	9–15% (E)	15–30% (F)
Useful moisture[4] (Moist)	Water storage capacity >5 in. and/or adequate rainfall and/or low evapotranspiration	Water storage capacity 2–5 in. and/or moderate rainfall and/or moderate evapotranspiration	Water storage capacity <2 in. and/or low rainfall and/or high evapotranspiration
Surface soil texture[5] (Text)	SL, FSL, VFSL, L, SiL	CL, SCL, SiCL, LS, and sand other than loose sand	SC, SiC, C, loose sand subject to severe blowing, organic soils
Coarse fragments on surface[6] (CF)	0–20%	20–50%[7]	>50%
Stoniness[8] (Stony)	Stones greater than 25 ft apart	Stones 25–5 ft apart	Stones less than 5 ft apart
Rockiness[8] (Rock)	No rock exposures	Rock exposures greater than 30 ft apart and cover less than 25% of the area	Rock exposures less than 30 ft apart and cover greater than 25% of the surface

1For information on roads and parking lots see Tables 15 and 16.

2The abbreviations in brackets are used in Table 6 to indicate the nature of the limitation.

3Infiltration tests show that in most, if not all, of the soils in the Park there is little if any limitation to permeability with regard to camp areas (Appendix A).

4This item attempts to evaluate the adequacy of moisture for vegetative growth. It incorporates the concept of supply through rainfall, loss through evapotranspiration, and storage within the rooting zone. In soils where the water table is within rooting depth for a significant portion of the year, water storage capacity may not significantly influence vegetation growth.

5Surface soil texture influences soil ratings as it affects foot trafficability, dust, and soil permeability.

6Coarse fragments include both gravels and cobbles.

7Some gravelly soils may be rated as slight if the content of gravel exceeds 20% by only a small margin providing (a) the gravel is imbedded in the soil matrix, or (b) the fragments are less than ¾ inch in size. See the definition for gravels in *The System of Soil Classification for Canada* (Canada Soil Survey Committee 1970), pp. 213–214.

8Very shallow soils are rated as having a severe soil limitation for rockiness and/or stoniness. See also definitions of rockiness and stoniness in *The System of Soil Classification for Canada* (Canada Soil Survey Committee 1970), pp. 213–214.

9A fourth degree of soil limitation is also defined for the purposes of Table 6—Unsuitable: Slopes greater than 30%; permanently wet soils; floods every year, or oftener; rock outcrop too frequent to permit location of camp areas.

Table 6. Interpretation of soil characteristics for camp areas
(Based on Table 5, Guide for assessing soil limitations for camp areas)

Map unit	Degree and nature of limitation			
	Slight	Moderate	Severe	Unsuitable
1 1/AC,AD		CF Stony	Moist	
1/DE		Slope Stony CF	Moist	
1 1/EF,F		Stony CF	Slope Moist	
1 1/FG,G, 1/GH		Stony CF	Moist	*Slope*
4/AC		CF	Stony Rock Moist	
4/DE		CF Slope	Stony Rock Moist	
8/AC		Moist		
11 11/AC,DE				*Flood Wet*
12/AC		Wet	Perm	
12/DE		Slope Wet	Perm	
14/AB			Flood	*Wet*
15/AB		Flood		
16/AC		Flood		
17 17/AC,AD		CF	Moist	
18/AC		CF Moist		
19/AC	Nil			
19 19/AD,DE		Slope		
20 20/AC,AD			Rock CF	*Flood*
20/FG			Rock CF	*Flood Slope*
21[6]/AC		CF	Moist	
21[6]/F		CF	Moist Slope	
22[6]/AC		CF Stony	Moist	
22[6] 22[6]/DE,E		Slope CF Stony	Moist	
22[6]/EF		CF Stony	Slope Moist	
25/AC	Moist			
25/DE		Moist Slope		
25/EF		Moist	Slope	
25/G		Moist		*Slope*
26/AC	Nil			
27 27/AC,AD		CF Moist		
27 27/DE,E		CF Moist Slope		
27 27/EF,F		Moist CF	Slope	
28[6] 28[6]/AC,D		Moist Stony CF		
28[6]/E		Moist Stony Slope CF		
28[6]/EF		Moist Stony CF	Slope	
28[6]/GH		Moist Stony CF		*Slope*
29 29/AB,AC, 29/CD				*Wet*
29 29/DE,E		Slope		*Wet*
29/EF		CF	Slope	*Wet*
29/G		CF		*Wet Slope*
31/AB			Flood	*Wet*
32 32/AB,AC, 32 32/AD,CD			Flood	*Wet*
36[6]/AC	Text			
36[6]/DE		Slope		
36[6]/EF			Slope	
36[6]/G				*Slope*
37/AC		Wet		
37/DE		Wet Slope		
37 37/EF,F		Wet	Slope	
37 37/G, GH, 37/H				*Slope*
38[6] 38[6]/AC,AD, 38[6] 38[6]/CD,D		Moist Wet[1]		
38[6] 38[6]/DE,E		Moist Slope CF		
38[6] 38[6]/EF,F		Moist CF Stony	Slope	
38[6] 38[6]/FG,G, 38[6]/GH		Moist CF Stony		*Slope*
39[6]/AC		Moist CF		
39[6]/EF		Moist CF Stony	Slope	
39[6] 39[6]/FG,G, 39[6]/GH		Moist CF Stony		*Slope*
41/AC	Wet[1]			
41/DE		Slope		
41/EF			Slope	
41/FG				*Slope*
42/AC	Nil			
44/AC			Flood	*Wet*
46/AC		CF		
46/DE		CF Slope		
46/EF		CF	Slope	
47[6]/AC		CF Stony		
47[6]/DE		CF Slope Stony		
47[6]/EF		CF Stony	Slope	
48[6]/AC		CF Stony		
48[6] 48[6]/AD,DE		CF Slope Stony		
48[6]/EF		CF Stony	Slope	
48[6]/FG		CF Stony		*Slope*
49[6]/AC		CF		
49[6]/DE		CF Slope		
49[6]/EF		CF	Slope	
50 50/AD,CD		CF Stony Moist		
50/DE		CF Stony Moist Slope		
50/EF		CF Stony Moist	Slope	
50 50/FG,G		CF Stony Moist		*Slope*
52/AD		CF Stony Rock Moist		
52/DE		CF Stony Rock Moist Slope		
52/EF		CF Stony Rock Moist	Slope	
52 52 52/EG,FG,G, 52 52/GH,H		CF Stony Rock Moist		*Slope*

Table 6. Interpretation of soil characteristics for camp areas (cont'd)

Map unit	Degree and nature of limitation			
	Slight	Moderate	Severe	Unsuitable
53/AC				*Wet*
53/DE		CF Slope		*Wet*
53 53/EF,FG		CF		*Wet Slope*
54/AD			CF Stony	
54/DE		Slope	CF Stony	
54/EF			CF Stony Slope	
54/FG, 54 54/GH,H			CF Stony	*Slope*
55/AD		Stony CF		
55/DE		CF Stony Slope		
55/EF		Stony CF	Slope	
55 55/FG,G, 55 55/GH,H		Stony CF		*Slope*
57 57/AC,AD, 57 57/CD,D		CF		
57 57/DE,E		CF Slope		
57 57/EF,F		CF	Slope	
57 57/FG,G, 57/GH		CF		*Slope*
58/AC	Wet[1] Text			
58/AD	Text			
58/DE		Slope		
58/EF			Slope	
58/G				*Slope*
61/EF			Slope Rock CF Stony	
61 61/FG,G, 61/GH			CF Rock Stony	*Slope*
64/AC	Text			
64 64 64/AD,CD,D		Text		
64/DE		Slope		
64 64/EF,F			Slope	
64 64/FG,G, 64 64/GH,H				*Slope*
66/EF		CF	Stony Slope	
67/AD		Moist[1]		
67/DE		Moist[1] Slope		
67/EF		Moist[1]	Slope	
67/FG		Moist[1]		*Slope*
100[3]/AC			Text	
100[3]/DE		Slope	Text	
100[3]/EF			Text Slope	
100[3] 100[3]/FG,G, 100[3]/H			Text	*Slope*
101[3]/AD		Text		
101[3]/DE		Text Slope		
101[3] 101[3]/EF, F		Text	Slope	
101[3] 101[3]/FG,G, 101[3]/GH		Text		*Slope*
102/AC		Text		
102/DE		Text Slope		
102/EF		Text	Slope	
102 102/FG,G		Text		*Slope*
103/GH		Rock-D		*Slope*
105/AD				*Wet*
105/DE		Slope		*Wet*
105/EF			Slope	*Wet*
106/AC		Text		
106/DE		Text Slope		
106/F		Text	Slope	
106 106/FG,G		Text		*Slope*
107[3]/E		Text Slope		
107[3]/EF		Text	Slope	
107[3] 107[3]/FG,G		Text		*Slope*
141[6]/DE		Slope Stony CF		
141[6] 141[6]/EF, F		CF Stony	Slope	
141[6] 141[6]/FG,G, 141[6] 141[6]/GH,H		CF Stony		*Slope*
142[6]/DE		Slope CF Stony		
142[6] 142[6]/EF, F		CF Stony	Slope	
142[6] 142[6]/FG,G, 142[6] 142[6]/GH,H		CF Stony		*Slope*
150[6]/DE		Slope CF		
150[6]/EF		CF	Slope	
150[6] 150[6]/FG,G, 150[6] 150[6]/GH,H		CF		*Slope*
156[6]/DE		Slope CF		
156[6] 156[6]/EF, F		CF	Slope	
156[6] 156[6]/FG,G, 156[6] 156[6]/GH,H		CF		*Slope*
160[6]/DE		Slope CF		
160[6]/EF		CF	Slope	
160[6]/G		CF		*Slope*
170/EF			Slope Moist Text	
171/AD		Text Moist		
190/AB			Flood Text	*Wet*
90R[6]/EF			Slope CF Rock	
90R[6] 90R[6]/FG, G, 90R[6] 90R[6]/GH, H			CF Rock	*Slope*
91R[6] 91R[6]/FG, G, 91R[6] 91R[6]/GH, H		CF	Rock	*Slope*
Talus/G, *Talus Talus*/GH, H				*Slope*
Rock				*Rock*
BP				*Wet Flood*
RD[4]				4
Pit[4]				4
Chute[5]			Wet[1]	*Slope*

Footnotes

[1]This limitation occurs occasionally within the map unit but should not be expected throughout the area. Field checks on selected sites are necessary to ascertain whether this limitation applies to the given map unit.

[2]The limitations listed in italics under "Unsuitable" are considered to be the most significant ones for evaluating the appropriate map units for use as camp areas.

[3]These map units are located on materials subject to large rotational slumping or excessive creep.

[4]These are miscellaneous land units representing cultural features. Unless the present use is abandoned these areas are unsuitable for any other use.

[5]Chute areas are subject to periodic snowslides or avalanches which result in a severe limitation for most uses.

[6]These soils are very susceptible to water erosion whenever runoff occurs, particularly if the vegetative cover is damaged. Fortunately, however, permeability is very high and seldom is water added fast enough to have surface flow. When a stream is diverted or some similar phenomenon occurs which provides surface flow, the results can be catastrophic.

Table 7. Guide for assessing soil limitations for picnic areas

This guide applies to soils considered for intensive use as park-type picnic areas. It is assumed that most vehicular traffic will be confined to access roads.[1] Soil suitability for growing and maintaining vegetation is not a part of this guide, except as influenced by moisture, but is an important item to consider in the final evaluation of site.

Item affecting use	Degree of soil limitation[7]		
	None to slight	Moderate	Severe
Wetness (Wet)[2]	Rapidly, well, and moderately well drained soils; water table below 20 in. during season of use	Moderately well and imperfectly drained soils; water table during season of use may be less than 20 in. for short periods	Poorly and very poorly drained soils; water table above 20 in. and often near the surface for a month or more during season of use
Flooding (Flood)	None during season of use	May flood 1 or 2 times a yr for short periods during season of use	Floods more than 2 times a yr during season of use
Slope (Slope)	0–9% (AD)	9–15% (E)	15–30% (F)
Useful moisture[3] (Moist)	Water storage capacity >5 in. and/or adequate rainfall and/or low evapotranspiration	Water storage capacity 2–5 in. and/or moderate rainfall and/or moderate evapotranspiration	Water storage capacity <2 in. and/or low rainfall and/or high evapotranspiration
Surface soil texture[4] (Text)	SL, FSL, VFSL, L, SiL	CL, SCL, SiCL, LS, and sand other than loose sand	SC, SiC, C, loose sand subject to severe blowing, organic soils
Coarse fragments on surface[5] (CF)	0–20%	20–50%[6]	>50%
Stoniness[5] (Stony)	Stones greater than 5 ft apart	Stones 2–5 ft apart	Stones less than 2 ft apart
Rockiness[5] (Rock)	Rock exposures roughly 100–300 or more ft apart and cover less than 10% of the surface	Rock exposures 30–100 ft apart and cover about 10–25% of the surface	Rock exposures less than 30 ft apart and cover greater than 25% of the surface

1For information specific to roads or parking lots see Tables 15 and 16.

2The abbreviations in brackets are used in Table 8 to indicate the nature of the limitation.

3This item attempts to evaluate the adequacy of moisture for vegetative growth. It incorporates the concept of supply through rainfall, loss through evapotranspiration, and storage within the rooting zone. In soils where the water table is within rooting depth for a significant portion of the year, water storage capacity may not significantly influence vegetation growth.

4Surface soil texture influences soil ratings as it affects foot trafficability, dust, and soil permeability.

5See also definitions for gravels, rockiness, and stoniness in *The System of Soil Classification for Canada* (Canada Soil Survey Committee 1970), pp. 213–214. Coarse fragments include both gravels and cobbles.

6Some gravelly soils may be rated as slight if the content of gravel exceeds 20% by only a small margin providing (a) the gravel is imbedded in the soil matrix or (b) the fragments are less than ¾ inch in size.

7A fourth degree of limitation is also defined for the purposes of Table 8—Unsuitable: Slopes greater than 30%; permanently wet soils; floods more than 3 times a year during season of use; rock outcrop too frequent to permit location of picnic areas.

Table 8. Interpretation of soil characteristics for picnic areas
(Based on Table 7, Guide for assessing soil limitations for picnic areas)

Map unit	Slight	Moderate	Severe	Unsuitable
1/AC, 1/AD		CF Stony	Moist	
1/DE		Slope Stony CF	Moist	
1/EF, 1/F		Stony CF	Slope Moist	
1/FG, 1/G, 1/GH		Stony CF	Moist	*Slope*[2]
4/AC		CF	Stony Rock Moist	
4/DE		CF Slope	Stony Rock Moist	
8/AC		Moist		
11/AC, 11/DE		Flood Wet		
12/AC	Text			
12/DE		Slope		
14/AB			Flood	*Wet*
15/AB		Flood		
16/AC	Flood			
17/AC, 17/AD		CF	Moist	
18/AC		CF Moist		
19/AC	Nil			
19/AD, 19/DE		Slope		
20/AC, 20/AD			Rock CF	*Flood*
20/FG			Rock CF	*Slope* Flood
21[6]/AC		CF	Moist	
21[6]/F		CF	Moist Slope	
22[6]/AC		CF	Moist	
22[6]/DE, 22[6]/E		Slope CF	Moist	
22[6]/EF		CF	Slope Moist	
25/AC	Moist			
25/DE		Moist Slope		
25/EF		Moist	Slope	
25/G		Moist		*Slope*
26/AC	Nil			
27/AC, 27/AD		CF Moist		
27/DE, 27/E		CF Moist Slope		
27/EF, 27/F		Moist CF	Slope	
28[6]/AC, 28[6]/D		Moist CF		
28[6]/E		Moist CF Slope		
28[6]/EF		Moist CF	Slope	
28[6]/GH		Moist CF		*Slope*
29/AB, 29/AC, 29/CD		Wet		
29/DE, 29/E		Wet Slope		
29/EF		Wet CF	Slope	
29/G		Wet CF		*Slope*
31/AB			Flood	*Wet*
32/AB, 32/AC, 32/AD, 32/CD			Flood	*Wet*
36[6]/AC	Text			
36[6]/DE		Slope		
36[6]/EF			Slope	
36[6]/G				*Slope*
37/AC		Wet		
37/DE		Wet Slope		
37/EF, 37/F		Wet	Slope	
37/G, 37/GH, 37/H				*Slope*
38[6]/AC, 38[6]/AD, 38[6]/CD, 38[6]/D		Moist Wet[1]		
38[6]/DE, 38[6]/E		Moist Slope CF		
38[6]/EF, 38[6]/F		Moist CF	Slope	
38[6]/FG, 38[6]/G, 38[6]/GH		Moist CF		*Slope*
39[6]/AC		Moist CF		
39[6]/EF		Moist CF	Slope	
39[6]/FG, 39[6]/G, 39[6]/GH		Moist CF		*Slope*
41/AC	Wet[1]			
41/DE		Slope		
41/EF			Slope	
41/FG				*Slope*
42/AC	Nil			
44/AC			Flood	*Wet*
46/AC		CF		
46/DE		CF Slope		
46/EF		CF	Slope	
47[6]/AC		CF		
47[6]/DE		CF Slope		
47[6]/EF		CF	Slope	
48[6]/AC		CF		
48[6]/AD, 48[6]/DE		CF Slope		
48[6]/EF		CF	Slope	
48[6]/FG		CF		*Slope*
49[6]/AC		CF		
49[6]/DE		CF Slope		
49[6]/EF		CF	Slope	
50/AD, 50/CD		CF Moist		
50/DE		CF Moist Slope		
50/EF		CF Moist	Slope	
50/FG, 50/G		CF Moist		*Slope*
52/AD		CF Stony Moist		
52/DE		CF Stony Moist Slope		
52/EF		CF Stony Moist	Slope	
52/EG, 52/FG, 52/G, 52/GH, 52/H		CF Stony Moist		*Slope*
53/AC				*Wet*
53/DE		CF Slope		*Wet*
53/EF, 53/FG		CF	Slope	*Wet*
54/AD		Stony	CF	
54/DE		Slope Stony	CF	
54/EF		Stony	CF Slope	
54/FG, 54/GH, 54/H		Stony	CF	*Slope*

Table 8. Interpretation of soil characteristics for picnic areas (cont'd)

Map unit	Slight	Moderate	Severe	Unsuitable
55/AD		CF		
55/DE		CF Slope		
55/EF		CF	Slope	
55/FG, 55/G, 55/GH, 55/H		CF		*Slope*
57/AC, 57/AD, 57/CD, 57/D		CF		
57/DE, 57/E		CF Slope		
57/EF, 57/F		CF	Slope	
57/FG, 57/G, 57/GH		CF		*Slope*
58/AC, 58/AD		Text		
58/DE		Slope		
58/EF			Slope	
58/G				*Slope*
61/EF			Slope CF Rock Stony	
61/FG, 61/G, 61/GH			CF Rock Stony	*Slope*
64/AC	Text			
64/AD, 64/CD, 64/D		Text		
64/DE		Slope		
64/EF, 64/F			Slope	
64/FG, 64/G, 64/GH, 64/H				*Slope*
66/EF		CF Stony	Slope	
67/AD		Moist[1]		
67/DE		Moist[1] Slope		
67/EF		Moist[1]	Slope	
67/FG		Moist[1]		*Slope*
100[3]/AC			Text	
100[3]/DE		Slope	Text	
100[3]/EF			Text Slope	
100[3]/FG, 100[3]/G, 100[3]/H			Text	*Slope*
101[3]/AD		Text		
101[3]/DE		Text Slope		
101[3]/EF, 101[3]/F		Text	Slope	
101[3]/FG, 101[3]/G, 101[3]/GH		Text		*Slope*
102/AC		Text		
102/DE		Text Slope		
102/EF		Text	Slope	
102/FG, 102/G		Text		*Slope*
103/GH		Rock-D		*Slope*
105/AD				*Wet*
105/DE		Slope		*Wet*
105/EF			Slope	*Wet*
106/AC		Text		
106/DE		Text Slope		
106/F		Text	Slope	
106/FG, 106/G		Text		*Slope*
107[3]/E		Text Slope		
107[3]/EF		Text	Slope	
107[3]/FG, 107[3]/G		Text		*Slope*
141[6]/DE		Slope CF		
141[6]/EF, 141[6]/F		CF	Slope	
141[6]/FG, 141[6]/G, 141[6]/GH, 141[6]/H		CF		*Slope*
142[6]/DE		CF Slope		
142[6]/EF, 142[6]/F		CF	Slope	
142[6]/FG, 142[6]/G, 142[6]/GH, 142[6]/H		CF		*Slope*
150[6]/DE		Slope CF		
150[6]/EF		CF	Slope	
150[6]/FG, 150[6]/G, 150[6]/GH, 150[6]/H		CF		*Slope*
156[6]/DE		Slope CF		
156[6]/EF, 156[6]/F		CF	Slope	
156[6]/FG, 156[6]/G, 156[6]/GH, 156[6]/H		CF		*Slope*
160[6]/DE		Slope CF		
160[6]/EF		CF	Slope	
160[6]/G		CF		*Slope*
170/EF			Slope Moist Text	
171/AD		Text Moist		
190/AB			Flood Text	*Wet*
90R[6]/EF			Slope CF Rock	
90R[6]/FG, 90R[6]/G, 90R[6]/GH, 90R[6]/H			CF Rock	*Slope*
91R[6]/FG, 91R[6]/G, 91R[6]/GH, 91R[6]/H		CF	Rock	*Slope*
Talus/G, *Talus*/GH, *Talus*/H				*Slope*
Rock				*Rock*
BP				*Wet* Flood
RD[4]				[4]
Pit[4]				[4]
Chute[5]			Wet[1]	*Slope*

Footnotes

[1]This limitation occurs occasionally within the map unit but should not be expected throughout the area. Field checks on selected sites are necessary to ascertain whether this limitation applies to the given map unit.

[2]The limitations listed in italics under "Unsuitable" are considered to be the most significant ones for evaluating the appropriate map units for use as camp areas.

[3]These map units are located on materials subject to large rotational slumping or excessive creep.

[4]These are miscellaneous land units representing cultural features. Unless the present use is abandoned these areas are unsuitable for any other use.

[5]Chute areas are subject to periodic snowslides or avalanches which result in a severe limitation for most uses.

[6]These soils are very susceptible to water erosion whenever runoff occurs, particularly if the vegetative cover is damaged. Fortunately, however, permeability is very high and seldom is water added fast enough to have surface flow. When a stream is diverted or some similar phenomenon occurs which provides surface flow, the results can be catastrophic.

Table 9. Guide for assessing soil limitations for paths and trails

This guide applies to soils to be used for local and cross-country footpaths and trails and for bridle paths. It is assumed that these areas will be used as they occur in nature and that little or no soil will be moved (excavated or filled). The steeper the slope upon which a trail is to be built the more soil that will have to be moved to obtain a level tread and the more miles of trail needed to cover a given horizontal distance. Severe limitation does not indicate a trail can not or should not be built. It does suggest higher design requirements and higher cost of construction and maintenance. Soil features that affect trafficability, dust, design, and maintenance of trafficways are given special emphasis.

Item affecting use	Degree of soil limitation[8]		
	None to slight	Moderate	Severe
Wetness (Wet)[1]	Rapidly, well, and moderately well drained soils; water table below 20 in. during season of use	Imperfectly drained soils; water table during season of use may be above 20 in. for short periods	Poorly and very poorly drained soils; water table above 20 in. and often near surface for month or more during season of use
Flooding (Flood)	May flood once a yr during season of use	May flood 2 or 3 times during season of use	Floods more than 3 times during season of use
Slope[2] (Slope)	0–15% (AE)	15–30% (F)	30–60%[3] (G)
Surface soil texture[4] (Text)	SL, FSL, VFSL, L, SiL	CL, SCL, SiCL, LS	SC, SiC, C, sand, organic soils
Coarse fragments on surface[5] (CF)	0–20%	20–50%[6]	>50%
Rockiness or stoniness[7] (Rock)	Stones greater than 25 ft apart; rock exposures roughly 100 ft apart and cover less than 10% of the surface	Stones 5–25 ft apart; rock exposures 30–100 ft apart and cover 10-25% of the surface	Stones less than 5 ft apart; rock exposures less than 30 ft apart and cover more than 25% of the surface

1The abbreviations in brackets are used in Table 10 to indicate the nature of the limitation.

2Slope in this context refers to the slope of the ground surface, not the slope of the tread of the trail.

3A distinction between severe limitation (30–60%) and very severe limitation (greater than 60%) will be made in the interpretation table (Table 10).

4Surface texture influences soil ratings as it affects foot trafficability, dust, design, or maintenance of paths and trails.

5Soils on steep colluvial slopes and alluvial fans often do not provide a significant limitation to trails other than coarse fragments and slope. However, this is in part a result of their low bulk density and extreme permeability which does not normally allow any surface runoff of water. If some act of nature or man should result in a significant flow of water down the trail, these soils will erode very quickly, forming deep gullies. Soils on steep till slopes may have the same limitations as the above soils according to Table 10 but will not erode as badly if water is diverted down the trail.

6Some gravelly soils may be rated slight if the content of the gravel exceeds 20% by only a small margin providing (a) the gravel is imbedded in the soil matrix or (b) the fragments are less than ¾ inch in size.

7See also definitions for gravels, rockiness, and stoniness in *The System of Soil Classification for Canada* (Canada Soil Survey Committee 1970), pp. 213–214. Coarse fragments include both gravels and cobbles.

8A fourth degree of soil limitation is also defined for the purposes of Table 10—Unsuitable: Permanently wet soils; floods more than 4 times during season of use; rock outcrop too frequent to permit location of paths and trails.

Table 10. Interpretation of soil characteristics for paths and trails
(Based on Table 9, Guide for assessing soil limitations for paths and trails)

Map unit	Degree and nature of limitation: Slight	Moderate	Severe	Unsuitable
1/AC, 1/AD, 1/DE		CF Stony		
1/EF, 1/F		Slope Stony CF		
1/FG, 1/G, 1/GH		Stony CF	Slope	
4/AC		CF	Rock	
4/DE		CF Slope	Rock	
8/AC	Text			
11/AC, 11/DE		Flood Wet		
12/AC	Text			
12/DE	Text			
14/AB			Flood	*Wet*[7]
15/AB		Flood		
16/AC	Nil			
17/AC, 17/AD	Nil			
18/AC	Nil			
19/AC	Nil			
19/AD, 19/DE		Slope		
20/AC, 20/AD			Rock CF	*Flood*
20/FG			Rock CF Slope	*Flood*
21[6]/AC		CF		
21[6]/F		Slope CF		
22[6]/AC, 22[6]/DE, 22[6]/E		CF		
22[6]/EF		CF Slope		
25/AC, 25/DE	Text			
25/EF		Slope		
25/G			Slope	
26/AC	Nil			
27/AC, 27/AD, 27/DE, 27/E		CF		
27/EF, 27/F		CF Slope		
28[6]/AC, 28[6]/D		CF		
28[6]/E, 28[6]/EF		CF Slope		
28[6]/GH		CF	Slope	
29/AB, 29/AC, 29/CD, 29/DE, 29/E		Wet		
29/EF		Wet CF Slope		
29/G		Wet CF	Slope	
31/AB			Flood	*Wet*
32/AB, 32/AC, 32/AD, 32/CD		Flood		*Wet*
36[6]/AC, 36[6]/DE	Text			
36[6]/EF		Slope		
36[6]/G			Slope	
37/AC, 37/DE		Wet		
37/EF, 37/F		Wet Slope		
37/G, 37/GH			Slope	
37/H				*Slope*
38[6]/AC, 38[6]/AD, 38[6]/CD, 38[6]/D	Wet[1]			
38[6]/DE, 38[6]/E		CF		
38[6]/EF, 38[6]/F		CF Slope		
38[6]/FG, 38[6]/G		CF Rock[1]	Slope	
38[6]/GH		CF Rock	Slope[2]	
39[6]/AC	CF			
39[6]/EF		CF Slope		
39[6]/FG, 39[6]/G		CF Rock	Slope	
39[6]/GH		CF Rock	Slope[2]	
41/AC, 41/DE	Wet[1]			
41/EF		Slope		
41/FG			Slope	
42/AC	Nil			
44/AC			Wet Flood	
46/AC, 46/DE	Text			
46/EF		Slope		
47[6]/AC, 47[6]/DE		CF		
47[6]/EF		Slope CF		
48[6]/AC, 48[6]/AD, 48[6]/DE		CF		
48[6]/EF		CF Slope		
48[6]/FG		CF	Slope	
49[6]/AC, 49[6]/DE		CF		
49[6]/EF		CF Slope		
50/AD, 50/CD, 50/DE		CF		
50/EF		CF Slope		
50/FG, 50/G		CF	Slope	
52/AD, 52/DE		CF Rock		
52/EF		CF Rock Slope		
52/EG, 52/FG, 52/G		CF Rock	Slope	
52/GH, 52/H		CF Rock	Slope[2]	
53/AC		CF	Wet	
53/DE		CF	Wet	
53/EF, 53/FG		Slope CF	Wet	
54/AD, 54/DE		Slope	CF Rock	
54/EF		Slope	CF Rock	
54/FG		Slope	CF Rock Slope	
54/GH, 54/H		Slope	CF Rock Slope[2]	

Table 10. Interpretation of soil characteristics for paths and trails (cont'd)

Map unit	Degree and nature of limitation: Slight	Moderate	Severe	Unsuitable
55/AD, 55/DE		Rock CF		
55/EF		Rock CF Slope		
55/FG, 55/G		Rock CF	Slope	
55/GH, 55/H		Rock CF Slope[2]		
57/AC, 57/AD, 57/CD, 57/D, 57/DE, 57/E		CF		
57/EF, 57/F		CF Slope		
57/FG, 57/G		CF	Slope	
57/GH		CF	Slope[2]	
58/AC	Wet[1] Text			
58/AD, 58/DE	Text			
58/EF		Slope		
58/G			Slope	
61/EF		Slope	Rock CF	
61/FG, 61/G		Slope	Slope Rock CF	
61/GH		Slope	Rock CF Slope[2]	
64/AC, 64/AD, 64/CD, 64/D, 64/DE	Text			
64/EF, 64/F		Slope		
64/FG, 64/G			Slope	
64/GH, 64/H			Slope[2]	
66/EF		Slope CF Rock-D		
67/AD, 67/DE	Text			
67/EF		Slope		
67/FG			Slope	
100[3]/AC, 100[3]/DE		Slope	Text	
100[3]/EF		Slope	Text	
100[3]/FG, 100[3]/G		Slope	Text Slope	
100[3]/H		Slope	Text Slope[2]	
101[3]/AD, 101[3]/DE		Text		
101[3]/EF, 101[3]/F		Text Slope		
101[3]/FG, 101[3]/G		Text	Slope	
101[3]/GH		Text	Slope[2]	
102/AC, 102/DE		Text		
102/EF		Text Slope		
102/FG, 102/G		Text	Slope	
103/GH		Rock-D	Slope[2]	
105/AD, 105/DE			Wet	
105/EF		Slope	Wet	
106/AC, 106/DE		Text		
106/F		Text Slope		
106/FG, 106/G		Text	Slope	
107[3]/E		Text		
107[3]/EF		Text Slope		
107[3]/FG, 107[3]/G		Text	Slope	
141[6]/DE		CF		
141[6]/EF, 141[6]/F		CF Slope		
141[6]/FG, 141[6]/G		CF	Slope	
141[6]/GH, 141[6]/H		CF	Slope[2]	
142[6]/DE		CF		
142[6]/EF, 142[6]/F		CF Slope		
142[6]/FG, 142[6]/G		CF	Slope	
142[6]/GH, 142[6]/H		CF	Slope[2]	
150[6]/DE		CF		
150[6]/EF		CF Slope		
150[6]/FG, 150[6]/G		CF	Slope	
150[6]/GH, 150[6]/H		CF	Slope[2]	
156[6]/DE		CF		
156[6]/EF, 156[6]/F		CF Slope		
156[6]/FG, 156[6]/G		CF	Slope	
156[6]/GH, 156[6]/H		CF	Slope[2]	
160[6]/DE		CF		
160[6]/EF		CF Slope		
160[6]/G		CF	Slope	
170/EF		Slope	Text	
171/AD		Text		
190/AB				*Wet* Flood Text
90R[6]/EF		Slope	CF Rock	
90R[6]90R[6]/FG, G			CF Rock Slope	
90R[6]90R[6]/GH, H			CF Rock Slope[2]	
91R[6]91R[6]/FG, G		CF	Slope Rock	
91R[6]91R[6]/GH, H		CF	Rock Slope[2]	
Talus/G			Slope	
Talus/GH, *Talus*/H			Slope[2]	
Rock				*Rock*[2]
BP				*Wet* Flood
RD[4]				[4]
Pit[4]				[4]
Chute[5]			Wet[1] Slope[2]	

Footnotes

[1]This limitation occurs occasionally within the map unit but should not be expected throughout the area. Field checks on selected sites are necessary to ascertain whether this limitation applies to the given map unit.

[2]In mountain parks it is often necessary to build trails on areas with greater than 60% slopes. These areas are expensive and difficult to build trails on. Especially on these areas Talus or Rock (not cliffs) will provide a comparative advantage for trails because of its stability with respect to erosion. Root and Knapik (1972) have many useful comments on trail location.

[3]These map units are located on materials subject to large rotational slumping or excessive creep.

[4]These are miscellaneous land units representing cultural features. Unless the present use is abandoned these areas are unsuitable for any other use.

[5]Chute areas are subject to periodic snowslides or avalanches which result in a severe limitation for most uses.

[6]These soils are very susceptible to water erosion whenever runoff occurs, particularly if the vegetative cover is damaged. Fortunately, however, permeability is very high and seldom is water added fast enough to have surface flow. When a stream is diverted or some similar phenomenon occurs which provides surface flow, the results can be catastrophic.

[7]The limitations listed in italics under "Unsuitable" are considered to be the most significant ones for evaluating the appropriate map units for use as paths and trails.

Table 11. Guide for assessing soil limitations for septic tank absorption fields

This guide applies to soils to be used as an absorption and filtering medium for effluent from septic tank systems. A subsurface tile system laid in such a way that effluent from the septic tank is distributed reasonably uniformly into the natural soil is assumed when applying this guide. A rating of severe need not mean that a septic system should not be installed in the given soil, but rather may suggest the difficulty, in terms of installation[4] and maintenance, which can be expected during and upon installation.

Item affecting use	Degree of soil limitation[8]		
	None to slight	Moderate	Severe
Permeability class[1] (Perm)[2]	Moderately rapid[3] (approx. 1–5 in./h)	Moderate (approx. 1–0.5 in./h)	Slow (less than approx. 0.5 in./h)
Percolation rate (auger hole method)[4] (Perm)	About 20–45 min/in.[3]	45–60 min/in.	Slower than 60 min/in.
Depth to seasonal water table[5] (W.T.)	More than 72 in.[6]	48–72 in.	Less than 48 in.
Flooding hazard (Flood)	Not subject to flooding	Not subject to flooding	Subject to flooding
Slope (Slope)	0–9% (AD)	9–15% (E)	15–30% (F)
Depth to hard rock, bedrock, or other impervious materials (Rock-D)	Over 72 in.[6]	48–72 in.[7]	Less than 48 in.

[1]The limitation ratings should be related to the permeability of soil layers at and below depth of the tile line.

[2]The abbreviations in brackets are used in Table 12 to indicate the nature of the limitation.

[3]Soils having a permeability rate greater than about 5 in./h or percolation rate less than about 20 min/in. are likely to present a pollution hazard to adjacent waters. This hazard should be noted but the degree of hazard must, in each case, be assessed by examining the proximity of the proposed installation to water bodies, water table, and related features.

[4]Refer to Alberta Dept. of Manpower and Labour (1972) or U.S. Dept. of Health, Education and Welfare (1969) for details.

[5]Seasonal means for more than 1 month. It may, with caution, be possible to make some adjustment for the severity of a water table limitation in those cases where seasonal use of the facility does not coincide with the period of high water table.

[6]A seasonal water table should be at least 4 ft below the bottom of the trench at all times for soils having a slight limitation (U.S. Dept. of Health, Education and Welfare 1969). The depths used to water table or bedrock are based on an assumed tile depth of 2 ft. Where relief permits, the effective depth above a water table or rock can be increased by adding appropriate amounts of fill.

[7]Where slope is greater than 9% a depth to bedrock of 48 to 72 in. is a severe limitation.

[8]A fourth degree of soil limitation is also defined for the purposes of Table 12—Unsuitable: Slopes greater than 30%; permeability very slow; floods every year, or oftener; depth to hard rock, bedrock, or other impervious materials less than 24 in.

Table 12. Interpretation of soil characteristics for septic tank absorption fields

(Based on Table 11, Guide for assessing soil limitations for septic tank absorption fields)

Map unit	Degree and nature of limitation				
	Slight	Moderate	Severe	Unsuitable	Pollution hazard
1/AC, 1/AD	Nil				Po
1/DE		Slope			Po
1/EF, 1/F			Slope		Po
1/FG, 1/G,		Stony		*Slope*[2]	Po
1/GH					
4/AC				*Rock-D*	
4/DE		Slope		*Rock-D*	
8/AC	Nil				
11/AC			W.T.	*Flood*	Po
11/DE		Slope	W.T.	*Flood*	Po
12/AC			Perm		
12/DE		Slope	Perm		
14/AB		Perm	Flood	*W.T.*	Po
15/AB			W.T. Flood		
16/AC		W.T.	Flood		Po
17/AC, 17/AD	Nil				Po
18/AC	Nil				Po
19/AC	Nil				Po
19/AD, 19/DE		Slope			Po
20/AC, 20/AD				*Flood*	Po
20/FG				*Slope* Flood	Po
21[6]/AC	Nil				Po
21[6]/F			Slope		Po
22[6]/AC	Nil				Po
22[6]/DE, 22[6]/E		Slope			Po
22[6]/EF			Slope		Po
25/AC	Nil				Po
25/DE		Slope			Po
25/EF			Slope		Po
25/G				*Slope*	Po
26/AC	W.T.[1]				
27/AC, 27/AD	Nil				Po
27/DE, 27/E		Slope			Po
27/EF, 27/F			Slope		Po
28[6]/AC, 28[6]/D	Nil				Po
28[6]/E		Slope			Po
28[6]/EF			Slope		Po
28[6]/GH				*Slope*	Po
29/AB, 29/AC, 29/CD				*W.T.*	
29/DE, 29/E		Slope		*W.T.*	
29/EF			Slope	*W.T.*	
29/G				*W.T.* Slope	
31/AB		Perm		*W.T.*	Po
32/AB, 32/AC, 32/AD, 32/CD		Perm	Flood	*W.T.*	Po
36[6]/AC	Rock				
36[6]/DE		Slope			
36[6]/EF			Slope		
36[6]/G				*Slope*	
37/AC			W.T. Flood		Po
37/DE		Slope	W.T.		Po
37/EF, 37/F			Slope		Po
37/G, 37/GH, 37/H				*Slope*	Po
38[6]/AC, 38[6]/AD, 38[6]/CD, 38[6]/D	W.T.[1]				Po
38[6]/DE, 38[6]/E		Slope			Po
38[6]/EF, 38[6]/F			Slope		Po
38[6]/FG, 38[6]/G, 38[6]/GH				*Slope*	Po
39[6]/AC	Nil				Po
39[6]/EF			Slope		Po
39[6]/FG, 39[6]/G, 39[6]/GH				*Slope*	Po
41/AC		Perm W.T.			
41/DE		Perm Slope			
41/EF		Perm	Slope		
41/FG		Perm		*Slope*	
42/AC	Nil				
44/AC			Flood	*W.T.*	Po
46/AC	Nil				
46/DE		Slope			
46/EF			Slope		
47[6]/AC	Nil				Po
47[6]/DE		Slope			Po
47[6]/EF			Slope		Po
48[6]/AC		W.T.			Po
48[6]/AD, 48[6]/DE		W.T. Slope			Po
48[6]/EF			Slope		Po
48[6]/FG				*Slope*	Po
49[6]/AC	Nil				Po
49[6]/DE		Slope			Po
49[6]/EF			Slope		Po
50/AD, 50/CD		Perm			
50/DE		Perm Slope			
50/EF		Perm	Slope		
50/FG, 50/G		Perm		*Slope*	
52/AD		Stony	Rock-D[1]		
52/DE		Slope	Rock-D[1]		
52/EF			Slope Rock-D[1]		
52/EG, 52/FG, 52/G, 52/GH, 52/H			Rock-D[1]	*Slope*	
53/AC			Flood	*W.T.*	Po
53/DE		Slope	Flood	*W.T.*	Po
53/EF, 53/FG			Flood	*W.T.* Slope	Po
54/AD	Nil				
54/DE		Slope			
54/EF			Slope		
54/FG, 54/GH, 54/H				*Slope*	
55/AD	Nil				
55/DE		Slope			
55/EF			Slope		
55/FG, 55/G, 55/GH, 55/H				*Slope*	

Table 12. Interpretation of soil characteristics for septic tank absorption fields (cont'd)

Map unit	Degree and nature of limitation				
	Slight	Moderate	Severe	Unsuitable	Pollution hazard
57/AC, 57/AD, 57/CD, 57/D		Perm			
57/DE, 57/E		Perm Slope			
57/EF, 57/F		Perm	Slope		
57/FG, 57/G, 57/GH		Perm		*Slope*	
58/AC, 58/AD		Perm			
58/DE		Perm Slope			
58/EF		Perm	Slope		
58/G		Perm		*Slope*	
61/EF			Slope		
61/FG, 61/G, 61/GH				*Slope*	
64/AC, 64/AD, 64/CD, 64/D	Perm[1]				
64/DE		Slope			
64/EF, 64/F			Slope		
64/FG, 64/G, 64/GH, 64/H				*Slope*	
66/EF			Slope		
67/AD	Perm				
67/DE		Slope W.T.[1]			
67/EF		W.T.[1]	Slope		
67/FG		W.T.[1]		*Slope*	
100[3]/AC			Perm		
100[3]/DE		Slope	Perm		
100[3]/EF			Perm Slope		
100[3]/FG, 100[3]/G, 100[3]/H			Perm	*Slope*	
101[3]/AD		Perm W.T.[1]			
101[3]/DE		Perm Slope W.T.[1]			
101[3]/EF, 101[3]/F		Perm W.T.[1]	Slope		
101[3]/FG, 101[3]/G, 101[3]/GH		Perm W.T.[1]		*Slope*	
102/AC			Perm		
102/DE		Slope	Perm		
102/EF			Perm Slope		
102/FG, 102/G			Perm	*Slope*	
103/GH			Rock-D	*Slope*	
105/AD				*W.T.*	Po
105/DE		Slope		*W.T.*	Po
105/EF			Slope	*W.T.*	Po
106/AC			Perm		
106/DE		Slope	Perm		
106/F			Perm Slope		
106/FG, 106/G			Perm	*Slope*	
107[3]/E		Slope	Perm		
107[3]/EF			Perm Slope		
107[3]/FG, 107[3]/G			Perm	*Slope*	
141[6]/DE		Slope			Po
141[6]/EF, 141[6]/F			Slope		Po
141[6]/FG, 141[6]/G, 141[6]/GH, 141[6]/H				*Slope*	Po
142[6]/DE		Slope			Po
142[6]/EF, 142[6]/F			Slope		Po
142[6]/FG, 142[6]/G, 142[6]/GH, 142[6]/H				*Slope*	Po
150[6]/DE		Slope			Po
150[6]/EF			Slope		Po
150[6]/FG, 150[6]/G, 150[6]/GH, 150[6]/H				*Slope*	Po
156[6]/DE		Slope			Po
156[6]/EF, 156[6]/F			Slope		Po
156[6]/FG, 156[6]/G, 156[6]/GH, 156[6]/H				*Slope*	Po
160[6]/DE		Slope			
160[6]/EF			Slope		
160[6]/G				*Slope*	
170/EF			Slope		Po
171/AD	Nil				Po
190/AB			Flood	*W.T.*	Po
90R[6]/EF			Rock-D Slope		
90R[6]/FG, 90R[6]/G, 90R[6]/GH, 90R[6]/H			Rock-D	*Slope*	
91R[6]/FG, 91R[6]/G, 91R[6]/GH, 91R[6]/H				*Rock-D* Slope	
Talus/G, Talus/GH, Talus/H				*Slope*	Po
Rock				*Rock*	Po
BP				*Wet* Flood	Po
RD[4]					
Pit[4]					
Chute[5]			Wet[1]	*Slope*[1]	

Footnotes

[1]*This limitation occurs occasionally within the map* unit but should not be expected throughout the area. Field checks on selected sites are necessary to ascertain whether this limitation applies to the given map unit.

[2]The limitations listed in italics under "Unsuitable" are considered to be the most significant ones for evaluating the appropriate map units for use as septic tank absorption fields.

[3]These map units are located on materials subject to large rotational slumping or excessive creep.

[4]These are miscellaneous land units representing cultural features. Unless the present use is abandoned these areas are unsuitable for any other use.

[5]Chute areas are subject to periodic snowslides or avalanches which result in a severe limitation for most uses.

[6]*These soils are very susceptible to water erosion* whenever runoff occurs, particularly if the vegetative cover is damaged. Fortunately, however, permeability is very high and seldom is water added fast enough to have surface flow. When a stream is diverted or some similar phenomenon occurs which provides surface flow, the results can be catastrophic.

Table 13. Guide for assessing soil limitations for permanent buildings[1]

This guide provides ratings for undisturbed soils evaluated for single-family dwellings and other structures with similar foundation requirements. The emphasis for rating soils for buildings is on foundations; but soil slope, and susceptibility to flooding and other hydrologic conditions, such as seasonal wetness, that have effects beyond those related exclusively to foundations are considered too. Also considered are soil properties, particularly depth to bedrock, which influence excavation and construction costs both for the building itself and for the installation of utility lines. Excluded are limitations for soil corrosivity (which is of little consequence in Waterton Lakes Park), landscaping, and septic tank absorption fields. On-site investigations are needed for specific placement of buildings and utility lines, and for detailed design of foundations. All ratings are for undisturbed soils on information gained from observations to a depth of 4 to 5 ft.

Item affecting use	Degree of soil limitation[2,13]		
	None to slight	Moderate	Severe
Soil drainage class[3] (Wet)[4]	*With basements:* Rapidly drained and well drained *Without basements:* Rapidly, well, and moderately well drained	*With basements:* Moderately well drained *Without basements:* Imperfectly drained	*With basements:* Imperfectly, poorly, and very poorly drained *Without basements:* Poorly and very poorly drained
Depth to seasonal water table (seasonal means 1 month or more) (W.T.)	*With basements:* Below 60 in. *Without basements:* Below 30 in.	*With basements:* Below 30 in. *Without basements:* Below 20 in.	*With basements:* Above 30 in. *Without basements:* Above 20 in.
Flooding (Flood)	None	None	Occasional to frequent
Slope[5] (Slope)	0–9% (AD)	9–15% (E)	15–30% (F)
Shrink-swell potential[6] (Sh-Sw)	Low (PI[7] less than 15)[6]	Moderate (PI[7] 10–35)	High (PI[7] greater than 20)
Unified soil group[8] (Str)	GW, GP, SW, SP, GM, GC, SM, SC	ML, CL	CH, MH[9], OL, OH, Pt
Potential frost action[10] (Frost)	Low (F1, F2)[10]	Moderate (F3)[10]	High (F4)[10]
Stoniness[11] (Stony)	Stones greater than 25 ft apart	Stones 5–25 ft apart	Stones less than 5 ft apart
Rockiness[11,12] (Rock)	Rock exposures greater than 300 ft apart and cover less than 2% of the surface	Rock exposures 300–100 ft apart and cover 2–10% of the surface	Rock exposures less than 100 ft apart and cover greater than 10% of the surface
Depth to bedrock[12] (Rock-D)	*With basements:* More than 60 in. *Without basements:* More than 40 in.	*With basements:* 40 to 60 in. *Without basements:* 20 to 40 in.	*With basements:* Less than 40 in. *Without basements:* Less than 20 in.

1 By reducing the slope limits 50%, this table can be used for evaluating soil limitations for buildings with large floor areas but with foundation requirements not exceeding those of ordinary three-storey dwellings.

2 Some soils rated as having moderate or severe limitations may be good sites from an aesthetic or use standpoint but require more preparation or maintenance.

3 For an explanation of soil drainage classes see *The System of Soil Classification for Canada* (Canada Soil Survey Committee 1970), pp. 215–216.

4 The abbreviations in brackets are used in Table 14 to indicate the nature of the limitation.

5 Reduce slope limits 50% for those soils subject to hillside slippage.

6 Inherent swelling capacity is estimated as low when the plasticity index is less than 15, medium when the plasticity index is 10–35, and high when the plasticity index is greater than 20 (Terzaghi and Peck 1967). Gravelly and stony soils may not exhibit shrink-swell as estimated by the plasticity index because of dilution of the fines with coarse fragments. In these situations decrease a severe limitation to moderate and a moderate limitation to slight.

7 PI means plasticity index.

8 This item estimates the strength of the soil, that is, its ability to withstand applied loads.

9 Upgrade to moderate if MH is largely kaolinitic, friable, and free from mica.

10 Frost heave only applies where frost penetrates to the assumed depth of the footings and the soil is moist. The potential frost action classes are taken from the United States Army Corps of Engineers (1962), pp. 5–8. Table 17 is reproduced from this article.

11 See also definitions for rockiness and stoniness in *The System of Soil Classification for Canada* (Canada Soil Survey Committee 1970), pp. 213–214.

12 If the bedrock is soft enough so that it can be dug with light power equipment such as a backhoe, reduce moderate and severe limitation ratings by one class.

13 A fourth degree of soil limitation is also defined for the purposes of Table 14—Unsuitable: Slopes greater than 30%; permanently wet soils; floods every year, or oftener; rock outcrop too frequent to permit location of permanent buildings.

Table 14a. Interpretation of soil characteristics for buildings with basements
(Based on Table 13, Guide for assessing soil limitations for permanent buildings)

Map unit	Degree and nature of limitation: Slight	Moderate	Severe	Unsuitable
1/AC, 1/AD		Stony		
1/DE		Stony Slope		
1/EF, 1/F		Stony	Slope	
1/FG, 1/G, 1/GH		Stony		*Slope*[2]
4/AC			Rock-D	
4/DE		Slope	Rock-D	
8/AC		Str		
11/AC				*Wet* Flood W.T.
11/DE		Slope		*Wet* Flood W.T.
12/AC		Wet Frost	Sh-Sw Str	
12/DE		Wet Frost Slope	Sh-Sw Str	
14/AB			Flood	*Wet* W.T.
15/AB		Wet Str	W.T. Flood	
16/AC		Wet Str	W.T. Flood	
17/AC, 17/AD	Nil			
18/AC	Nil			
19/AC	Wet			
19/AD, 19/DE		Slope		
20/AC, 20/AD				*Flood*
20/FG				*Slope* Flood
21[6]/AC	Stony			
21[6]/F			Slope	
22[6]/AC		Stony		
22[6]/DE, 22[6]/E		Stony Slope		
22[6]/EF		Stony	Slope	
25/AC	Frost			
25/DE		Slope		
25/EF			Slope	
25/G				*Slope*
26/AC	Nil			
27/AC, 27/AD	Nil			
27/DE, 27/E		Slope		
27/EF, 27/F			Slope	
28[6]/AC, 28[6]/D		Stony		
28[6]/E		Stony Slope		
28[6]/EF		Stony	Slope	
28[6]/GH		Stony		*Slope*
29/AB, 29/AC, 29/CD				*Wet* W.T.
29/DE, 29/E		Slope		*Wet* W.T.
29/EF			Slope	*Wet* W.T.
29/G				*Wet* W.T. Slope
31/AB		Sh-Sw Str Frost	Flood	*Wet* W.T.
32/AB, 32/AC, 32/AD, 32/CD		Str	Flood	*Wet* W.T.
36[6]/AC	Rock			
36[6]/DE		Slope		
36[6]/EF			Slope	
36[6]/G				*Slope*
37/AC		Wet	W.T.	
37/DE		Wet Slope	W.T.	
37/EF, 37/F		Wet W.T.	Slope	
37/G, 37/GH, 37/H				*Slope*
38[6]/AC, 38[6]/AD, 38[6]/CD, 38[6]/D	W.T.[1]			
38[6]/DE, 38[6]/E		Slope		
38[6]/EF, 38[6]/F		Stony	Slope	
38[6]/FG, 38[6]/G, 38[6]/GH				*Slope*
39[6]/AC	Nil			
39[6]/EF			Slope	
39[6]/FG, 39[6]/G, 39[6]/GH		Stony		*Slope*
41/AC		Str W.T. Stony		
41/DE		Str W.T. Stony Slope		
41/EF		Str W.T. Stony	Slope	
41/FG		Str W.T. Stony		*Slope*
42/AC	Sh-Sw			
44/AC		Stony	Flood	*Wet* W.T.
46/AC	Stony[1]			
46/DE		Slope		
46/EF			Slope	
47[6]/AC		Stony		
47[6]/DE		Stony Slope		
47[6]/EF		Stony	Slope	
48[6]/AC		Wet Stony		
48[6]/AD, 48[6]/DE		Wet Stony Slope		
48[6]/EF		Wet Stony	Slope	
48[6]/FG		Wet Stony		*Slope*
49[6]/AC	Stony			
49[6]/DE		Slope		
49[6]/EF			Slope	
50/AD, 50/CD		Stony		
50/DE		Stony Slope		
50/EF		Stony	Slope	
50/FG, 50/G		Stony		*Slope*
52/AD		Stony	Rock-D[1]	
52/DE		Stony Slope	Rock-D[1]	
52/EF		Stony	Slope Rock-D[1]	
52/EG, 52/FG, 52/G, 52/GH, 52/H		Stony	Rock-D[1]	*Slope*
53/AC		Str	Flood	*Wet* W.T.
53/DE		Slope Str	Flood	*Wet* W.T.
53/EF, 53/FG		Str	Flood Slope	*Wet* W.T.
54/AD			Stony	
54/DE		Slope	Stony	
54/EF			Slope Stony	
54/FG, 54/GH, 54/H			Stony	*Slope*
55/AD		Stony		
55/DE		Stony Slope		
55/EF		Stony	Slope	
55/FG, 55/G, 55/GH, 55/H		Stony		*Slope*

Table 14a. Interpretation of soil characteristics for buildings with basements (cont'd)

Map unit	Degree and nature of limitation: Slight	Moderate	Severe	Unsuitable
57/AC, 57/AD, 57/CD, 57/D		Sh-Sw		
57/DE, 57/E		Sh-Sw Slope		
57/EF, 57/F		Sh-Sw	Slope	
57/FG, 57/G, 57/GH		Sh-Sw		*Slope*
58/AC, 58/AD		Sh-Sw Str		
58/DE		Sh-Sw Str Slope		
58/EF		Sh-Sw Str	Slope	
58/G		Sh-Sw Str		*Slope*
61/EF			Slope Stony	
61/FG, 61/G, 61/GH			Stony	*Slope*
64/AC, 64/AD, 64/CD, 64/D		Stony		
64/DE		Stony Slope		
64/EF, 64/F		Stony	Slope	
64/FG, 64/G, 64/GH, 64/H		Stony		*Slope*
66/EF		Sh-Sw	Slope Stony	
67/AD		Str Sh-Sw[1] Wet W.T.		
67/DE		Str Sh-Sw[1] Slope Wet W.T.		
67/EF		Str Sh-Sw[1] Wet[1] W.T.	Slope	
67/FG		Str Sh-Sw[1] Wet[1] W.T.		*Slope*
100[3]/AC		Sh-Sw	Str	
100[3]/DE		Sh-Sw Slope	Str	
100[3]/EF		Sh-Sw	Str Slope	
100[3]/FG, 100[3]/G, 100[3]/H		Sh-Sw	Str	*Slope*
101[3]/AD		Sh-Sw Str Wet[1] W.T.[1]		
101[3]/DE		Sh-Sw Str Slope Wet[1] W.T.[1]		
101[3]/EF, 101[3]/F		Sh-Sw Str Wet[1] W.T.[1]	Slope	
101[3]/FG, 101[3]/G, 101[3]/GH		Sh-Sw Str Wet[1] W.T.[1]		*Slope*
102/AC		Sh-Sw Str		
102/DE		Sh-Sw Str Slope		
102/EF		Sh-Sw Str	Slope	
102/FG, 102/G		Sh-Sw Str		*Slope*
103/GH		Str		*Slope*
105/AD		Wet Str	W.T.	
105/DE		Wet Str Slope	W.T.	
105/EF		Wet Str	W.T. Slope	
106/AC		Sh-Sw Str		
106/DE		Sh-Sw Str Slope		
106/F		Sh-Sw Str	Slope	
106/FG, 106/G		Sh-Sw Str		*Slope*
107[3]/E		Sh-Sw Str Slope		
107[3]/EF		Sh-Sw Str	Slope	
107[3]/FG, 107[3]/G		Sh-Sw Str		*Slope*
141[6]/DE		Slope Stony		
141[6]/EF, 141[6]/F		Stony	Slope	
141[6]/FG, 141[6]/G, 141[6]/GH, 141[6]/H		Stony		*Slope*
142[6]/DE		Slope Stony		
142[6]/EF, 142[6]/F		Stony	Slope	
142[6]/FG, 142[6]/G, 142[6]/GH, 142[6]/H		Stony		*Slope*
150[6]/DE		Slope		
150[6]/EF			Slope	
150[6]/FG, 150[6]/G, 150[6]/GH, 150[6]/H				*Slope*
156[6]/DE		Slope		
156[6]/EF, 156[6]/F			Slope	
156[6]/FG, 156[6]/G, 156[6]/GH, 156[6]/H				*Slope*
160[6]/DE		Slope		
160[6]/EF			Slope	
160[6]/G				*Slope*
170/EF		Str	Slope	
171/AD	W.T.			
190/AB			Flood Str	*Wet* W.T.
90R[6]/EF			Slope	*Rock-D*
90R[6]/FG, 90R[6]/G, 90R[6]/GH, 90R[6]/H				*Slope* Rock-D
91R[6]/FG, 91R[6]/G, 91R[6]/GH, 91R[6]/H				*Slope* Rock-D
Talus/G, *Talus*/GH, *Talus*/H				*Slope*
Rock				*Rock*
BP				*Wet* Flood
RD[4]				[4]
Pit[4]				[4]
Chute[5]			Wet[1]	Slope[1]

Footnotes

[1]This limitation occurs occasionally within the map unit but should not be expected throughout the area. Field checks on selected sites are necessary to ascertain whether this limitation applies to the given map unit.

[2]The limitations listed in italics under "Unsuitable" are considered to be the most significant ones for evaluating the appropriate map units for use to support buildings with basements.

[3]These map units are located on materials subject to large rotational slumping or excessive creep.

[4]These are miscellaneous land units representing cultural features. Unless the present use is abandoned these areas are unsuitable for any other use.

[5]Chute areas are subject to periodic snowslides or avalanches which result in a severe limitation for most uses.

[6]These soils are very susceptible to water erosion whenever runoff occurs, particularly if the vegetative cover is damaged. Fortunately, however, permeability is very high and seldom is water added fast enough to have surface flow. When a stream is diverted or some similar phenomenon occurs which provides surface flow, the results can be catastrophic.

Table 13. Guide for assessing soil limitations for permanent buildings[1]

This guide provides ratings for undisturbed soils evaluated for single-family dwellings and other structures with similar foundation requirements. The emphasis for rating soils for buildings is on foundations; but soil slope, and susceptibility to flooding and other hydrologic conditions, such as seasonal wetness, that have effects beyond those related exclusively to foundations are considered too. Also considered are soil properties, particularly depth to bedrock, which influence excavation and construction costs both for the building itself and for the installation of utility lines. Excluded are limitations for soil corrosivity (which is of little consequence in Waterton Lakes Park), landscaping, and septic tank absorption fields. On-site investigations are needed for specific placement of buildings and utility lines, and for detailed design of foundations. All ratings are for undisturbed soils on information gained from observations to a depth of 4 to 5 ft.

Item affecting use	Degree of soil limitation[2, 13]		
	None to slight	Moderate	Severe
Soil drainage class[3] (Wet)[4]	*With basements:* Rapidly drained and well drained *Without basements:* Rapidly, well, and moderately well drained	*With basements:* Moderately well drained *Without basements:* Imperfectly drained	*With basements:* Imperfectly, poorly, and very poorly drained *Without basements:* Poorly and very poorly drained
Depth to seasonal water table (seasonal means 1 month or more) (W.T.)	*With basements:* Below 60 in. *Without basements:* Below 30 in.	*With basements:* Below 30 in. *Without basements:* Below 20 in.	*With basements:* Above 30 in. *Without basements:* Above 20 in.
Flooding (Flood)	None	None	Occasional to frequent
Slope[5] (Slope)	0–9% (AD)	9–15% (E)	15–30% (F)
Shrink-swell potential[6] (Sh-Sw)	Low (PI[7] less than 15)[6]	Moderate (PI[7] 10–35)	High (PI[7] greater than 20)
Unified soil group[8] (Str)	GW, GP, SW, SP, GM, GC, SM, SC	ML, CL	CH, MH[9], OL, OH, Pt
Potential frost action[10] (Frost)	Low (F1, F2)[10]	Moderate (F3)[10]	High (F4)[10]
Stoniness[11] (Stony)	Stones greater than 25 ft apart	Stones 5–25 ft apart	Stones less than 5 ft apart
Rockiness[11,12] (Rock)	Rock exposures greater than 300 ft apart and cover less than 2% of the surface	Rock exposures 300–100 ft apart and cover 2–10% of the surface	Rock exposures less than 100 ft apart and cover greater than 10% of the surface
Depth to bedrock[12] (Rock-D)	*With basements:* More than 60 in. *Without basements:* More than 40 in.	*With basements:* 40 to 60 in. *Without basements:* 20 to 40 in.	*With basements:* Less than 40 in. *Without basements:* Less than 20 in.

1By reducing the slope limits 50%, this table can be used for evaluating soil limitations for buildings with large floor areas but with foundation requirements not exceeding those of ordinary three-storey dwellings.

2Some soils rated as having moderate or severe limitations may be good sites from an aesthetic or use standpoint but require more preparation or maintenance.

3For an explanation of soil drainage classes see *The System of Soil Classification for Canada* (Canada Soil Survey Committee 1970), pp. 215–216.

4The abbreviations in brackets are used in Table 14 to indicate the nature of the limitation.

5Reduce slope limits 50% for those soils subject to hillside slippage.

6Inherent swelling capacity is estimated as low when the plasticity index is less than 15, medium when the plasticity index is 10–35, and high when the plasticity index is greater than 20 (Terzaghi and Peck 1967). Gravelly and stony soils may not exhibit shrink-swell as estimated by the plasticity index because of dilution of the fines with coarse fragments. In these situations decrease a severe limitation to moderate and a moderate limitation to slight.

7PI means plasticity index.

8This item estimates the strength of the soil, that is, its ability to withstand applied loads.

9Upgrade to moderate if MH is largely kaolinitic, friable, and free from mica.

10Frost heave only applies where frost penetrates to the assumed depth of the footings and the soil is moist. The potential frost action classes are taken from the United States Army Corps of Engineers (1962), pp. 5–8. Table 17 is reproduced from this article.

11See also definitions for rockiness and stoniness in *The System of Soil Classification for Canada* (Canada Soil Survey Committee 1970), pp. 213–214.

12If the bedrock is soft enough so that it can be dug with light power equipment such as a backhoe, reduce moderate to slight and severe to moderate.

13A fourth degree of soil limitation is also defined for the purposes of Table 14—Unsuitable: Slopes greater than 30%; permanently wet soils; floods every year, or oftener; rock outcrop too frequent to permit location of permanent buildings.

Table 14b. Interpretation of soil characteristics for buildings without basements
(Based on Table 13, Guide for assessing soil limitations for permanent buildings)

Map unit	Degree and nature of limitation: Slight	Moderate	Severe	Unsuitable
1 1 / AC,AD		Stony		
1 / DE		Stony Slope		
1 1 / EF,F		Stony	Slope	
1 1 / FG,G, 1 / GH		Stony		*Slope*
4 / AC			Rock-D	
4 / DE		Slope	Rock-D	
8 / AC		Str Frost		
11 / AC				*Wet* Flood W.T.
11 / DE		Slope		*Wet* Flood W.T.
12 / AC		Frost	Sh-Sw Str	
12 / DE		Frost Slope	Sh-Sw Str	
14 / AB		Sh-Sw Str	Flood Frost	*Wet* W.T.
15 / AB		Str W.T.	Flood Frost	
16 / AC		Str Frost	Flood	
17 17 / AC,AD	Nil			
18 / AC	Nil			
19 / AC	Nil			
19 19 / AD,DE		Slope		
20 20 / AC,AD				*Flood*
20 / FG				*Slope* Flood
21[6] / AC	Stony			
21[6] / F			Slope	
22[6] / AC		Stony		
22[6] 22[6] / DE,E		Stony Slope		
22[6] / EF		Stony	Slope	
25 / AC	Frost			
25 / DE		Slope		
25 / EF			Slope	
25 / G				*Slope*
26 / AC		Frost		
27 27 / AC,AD	Nil			
27 27 / DE,E		Slope		
27 / EF, 27 / F			Slope	
28[6] 28[6] / AC,D		Stony		
28[6] / E		Stony Slope		
28[6] / EF		Stony	Slope	
28[6] / GH		Stony		*Slope*
29 29 / AB,AC, 29 / CD		Wet	W.T.	
29 29 / DE,E		Wet Slope	W.T.	
29 / EF		Wet	W.T. Slope	
29 / G		Wet	W.T.	*Slope*
31 / AB		Sh-Sw Str Frost	Flood	*Wet* W.T.
32 32 / AB,AC, 32 32 / AD,CD		Str	Flood Frost	*Wet* W.T.
36[6] / AC		Frost Str		
36[6] / DE		Frost Str Slope		
36[6] / EF		Frost Str	Slope	
36[6] / G		Frost Str		*Slope*
37 / AC		Frost W.T.		
37 / DE		Frost W.T. Slope		
37 37 / EF,F		Frost	Slope	
37 37 / G, GH, 37 / H		Frost		*Slope*
38[6] 38[6] / AC,AD, 38[6] 38[6] / CD,D	W.T.[1]			
38[6] 38[6] / DE,E		Slope		
38[6] 38[6] / EF,F		Stony	Slope	
38[6] 38[6] / FG,G, 38[6] / GH		Stony		*Slope*
39[6] / AC	Nil			
39[6] / EF			Slope	
39[6] 39[6] / FG,G, 39[6] / GH		Stony		*Slope*
41 / AC		Str Frost		
41 / DE		Str Frost Slope		
41 / EF		Str Frost	Slope	
41 / FG		Str Frost		*Slope*
42 / AC		Sh-Sw Str Frost		
44 / AC		Stony	Flood	*Wet* W.T.
46 / AC	Stony[1]			
46 / DE		Slope		
46 / EF			Slope	
47[6] / AC		Stony		
47[6] / DE		Stony Slope		
47[6] / EF		Stony	Slope	
48[6] / AC		Stony		
48[6] 48[6] / AD,DE		Stony Slope		
48[6] / EF		Stony	Slope	
48[6] / FG		Stony		*Slope*
49[6] / AC	Stony			
49[6] / DE		Slope		
49[6] / EF			Slope	
50 50 / AD,CD		Frost Stony		
50 / DE		Stony Slope Frost		
50 / EF		Frost Stony	Slope	
50 50 / FG,G		Frost Stony		*Slope*
52 / AD		Frost Stony Rock-D[1]		
52 / DE		Frost Stony Slope Rock-D[1]		
52 / EF		Frost Stony Rock-D[1]	Slope	
52 52 52 / EG,FG,G, 52 52 / GH,H		Frost Stony Rock-D[1]		*Slope*
53 / AC		Str	W.T. Flood Frost	*Wet*
53 / DE		Slope Str	W.T. Flood Frost	*Wet*
53 53 / EF,FG		Str	W.T. Flood Frost	*Wet* Slope
54 / AD			Stony	
54 / DE		Slope	Stony	
54 / EF			Slope Stony	
54 / FG, 54 54 / GH,H			Stony	*Slope*
55 / AD		Stony		
55 / DE		Stony Slope		
55 / EF		Stony	Slope	
55 55 / FG,G, 55 55 / GH,H		Stony		*Slope*

Table 14b. Interpretation of soil characteristics for buildings without basements (cont'd)

Map unit	Degree and nature of limitation: Slight	Moderate	Severe	Unsuitable
57 57 / AC,AD, 57 57 / CD,D		Sh-Sw Frost		
57 57 / DE,E		Sh-Sw Frost Slope		
57 57 / EF,F		Sh-Sw Frost	Slope	
57 57 / FG,G, 57 / GH		Sh-Sw Frost		*Slope*
58 / AC, 58 / AD		Sh-Sw Str Frost		
58 / DE		Sh-Sw Str Frost Slope		
58 / EF		Sh-Sw Str Frost	Slope	
58 / G		Sh-Sw Str Frost		*Slope*
61 / EF			Slope Stony	
61 61 / FG,G, 61 / GH			Stony	*Slope*
64 64 / AC,AD, 64 64 / CD,D	Frost			
64 / DE		Slope		
64 64 / EF,F			Slope	
64 64 / FG,G, 64 64 / GH,H				*Slope*
66 / EF		Sh-Sw Frost	Slope Stony	
67 / AD		Str Sh-Sw[1] Frost W.T.		
67 / DE		Str Sh-Sw[1] Frost Slope W.T.		
67 / EF		Str Sh-Sw[1] Frost W.T.	Slope	
67 / FG		Str Sh-Sw[1] Frost W.T.		*Slope*
100[3] / AC		Sh-Sw Frost	Str	
100[3] / DE		Sh-Sw Frost Slope	Str	
100[3] / EF		Sh-Sw Frost	Str Slope	
100[3] 100[3] / FG,G, 100[3] / H		Sh-Sw Frost	Str	*Slope*
101[3] / AD		Sh-Sw Str Frost Wet[1] W.T.[1]		
101[3] / DE		Sh-Sw Str Frost Slope Wet[1] W.T.[1]		
101[3] 101[3] / EF, F		Sh-Sw Str Frost Wet[1] W.T.[1]	Slope	
101[3] 101[3] / FG,G, 101[3] / GH		Sh-Sw Str Frost Wet[1] W.T.[1]		*Slope*
102 / AC		Sh-Sw Str Frost		
102 / DE		Sh-Sw Str Frost Slope		
102 / EF		Sh-Sw Str Frost	Slope	
102 102 / FG,G		Sh-Sw Str Frost		*Slope*
103 / GH		Str		*Slope*
105 / AD		Wet W.T. Str		
105 / DE		Wet W.T. Str Slope		
105 / EF		Wet W.T. Str	Slope	
106 / AC		Sh-Sw Str Frost		
106 / DE		Sh-Sw Str Frost Slope		
106 / F		Sh-Sw Str Frost	Slope	
106 106 / FG,G		Sh-Sw Str Frost		*Slope*
107[3] / E		Slope Sh-Sw Str Frost		
107[3] / EF		Sh-Sw Str Frost	Slope	
107[3] 107[3] / FG,G		Sh-Sw Str Frost		*Slope*
141[6] / DE		Slope Stony		
141[6] 141[6] / EF, G		Stony	Slope	
141[6] 141[6] / FG,G, 141[6] 141[6] / GH,H		Stony		*Slope*
142[6] / DE		Slope Stony		
142[6] 142[6] / EF, F		Stony	Slope	
142[6] 142[6] / FG,G, 142[6] 142[6] / GH,H		Stony		*Slope*
150[6] / DE		Slope		
150[6] / EF			Slope	
150[6] 150[6] / FG,G, 150[6] 150[6] / GH,H				*Slope*
156[6] / DE		Slope		
156[6] 156[6] / EF, F			Slope	
156[6] 156[6] / FG,G, 156[6] 156[6] / GH,H				*Slope*
160[6] / DE		Slope Frost		
160[6] / EF		Frost	Slope	
160[6] / G		Frost		*Slope*
170 / EF		Str	Slope	
171 / AD	Nil			
190 / AB			Flood Str	*Wet* W.T.
90R[6] / EF			Slope Rock-D	
90R[6] 90R[6] / FG, G, 90R[6] 90R[6] / GH, H			Rock-D	*Slope*
91R[6] 91R[6] / FG, G, 91R[6] 91R[6] / GH, H			Frost Rock-D	*Slope*
Talus / G, Talus Talus / GH, H				*Slope*
Rock				*Rock*
BP				*Wet* Flood
RD[4]				4
Pit[4]				4
Chute[5]			Wet[1]	*Slope*[1]

Footnotes

[1] This limitation occurs occasionally within the map unit but should not be expected throughout the area. Field checks on selected sites are necessary to ascertain whether this limitation applies to the given map unit.

[2] The limitations listed in italics under "Unsuitable" are considered to be the most significant ones for evaluating the appropriate map units for use to support buildings without basements.

[3] These map units are located on materials subject to large rotational slumping or excessive creep.

[4] These are miscellaneous land units representing cultural features. Unless the present use is abandoned these areas are unsuitable for any other use.

[5] Chute areas are subject to periodic snowslides or avalanches which result in a severe limitation for most uses.

[6] These soils are very susceptible to water erosion whenever runoff occurs, particularly if the vegetative cover is damaged. Fortunately, however, permeability is very high and seldom is water added fast enough to have surface flow. When a stream is diverted or some similar phenomenon occurs which provides surface flow, the results can be catastrophic.

Table 15. Guide for assessing soil limitations for local roads and streets

This guide applies to soils evaluated for construction and maintenance of local roads and streets. These are improved roads and streets having some kind of all-weather surfacing, commonly asphalt or concrete, and are expected to carry automobile traffic all year. They consist of: (1) underlying local soil material (either cut or fill) called the subgrade; (2) the base material of gravel, crushed rock, or lime – or soil cement – stabilized soil called the subbase; and (3) the actual road surface or pavement, either flexible or rigid. They also are graded to shed water and have ordinary provisions for drainage. With the probable exception of the hardened surface layer, the roads and streets are built mainly from the soil at hand, and cuts and fills are limited, usually less than 6 ft. Excluded from consideration in this guide are highways designed for fast-moving, heavy trucks.

Properties that affect design and construction of roads and streets are: (1) those that affect the load supporting capacity and stability of the subgrade, and (2) those that affect the workability and amount of cut and fill. The AASHO and Unified Classification, and the shrink-swell potential give an indication of the traffic supporting capacity. Wetness and flooding affect stability. Slope, depth of hardrock, stoniness, rockiness, and wetness affect the ease of excavation and the amount of cut and fill to reach an even grade.

Soil limitation ratings do not substitute for basic soil data or for on-site investigations.

Item affecting use	Degree of soil limitation[12]		
	None to slight	Moderate	Severe
Soil drainage class[1] (Wet)[2]	Rapidly,[1] well, and moderately well drained	Imperfectly drained	Poorly and very poorly drained
Flooding (Flood)	None	Once in 5 yr	More than once in 5 yr
Slope (Slope)	0–9% (AD)	9–15% (E)	15–30% (F)
Depth to bedrock[3] (Rock-D)	More than 40 in.	20–40 in.	Less than 20 in.
Subgrade[4] (Str)			
a. AASHO Group Index[5]	0–4	5–8	More than 8
b. Unified soil classes	GW, GP, SW, SP, GM, SM, and GC[6] and SC[6]	CL (with PI[7] less than 15), ML	CL (with PI[7] 15 or more), CH, MH[8], OH, OL, Pt
Shrink-swell potential[9] (Sh-Sw)	Low (PI[7] less than 15)	Moderate (PI[7] 10–35)	High (PI[7] greater than 20)
Susceptibility to frost heave[10] (Frost)	Low (F1, F2)[10]	Moderate (F3)[10]	High (F4)[10]
Stoniness[11] (Stony)	Stones greater than 5 ft apart	Stones 2–5 ft apart	Stones less than 2 ft apart
Rockiness[11] (Rock)	Rock exposures greater than 300 ft apart and cover less than 2% of the surface	Rock exposures 300 to 100 ft apart and cover 2 to 10% of the surface	Rock exposures less than 100 ft apart and cover greater than 10% of the surface

1For an explanation of soil drainage classes see *The System of Soil Classification for Canada* (Canada Soil Survey Committee 1970), pp. 215–216.

2The abbreviations in brackets are used in Table 16 to indicate the nature of the limitation.

3If bedrock is soft enough so that it can be dug with light power equipment and is rippable by machinery, reduce moderate to slight and severe to moderate.

4This item estimates the strength of a soil as it applies to roadbeds. When available, AASHO Group Index values from laboratory tests were used; otherwise the estimated Unified classes were used. The limitations were estimated assuming that the roads would be surfaced. On unsurfaced roads, rapidly drained, very sandy, poorly graded soils may cause washboard or rough roads.

5Group Index values were estimated from information published by the Portland Cement Association (PCA 1962), pp. 23–25.

6Downgrade to moderate if content of fines (less than 200 mesh) is greater than about 30%.

7PI means plasticity index.

8Upgrade to moderate if MH is largely kaolinitic, friable, and free from mica.

9Inherent swelling capacity is estimated as low when the plasticity index is less than 15, medium when the plasticity index is 10 to 35, and high when the plasticity index is greater than 20 (Terzaghi and Peck 1967). Gravelly and stony soils may not exhibit shrink-swell as estimated by the plasticity index because of dilution of the fines with coarse fragments. In these situations decrease a severe limitation to moderate and a moderate limitation to slight.

10Frost heave is important where frost penetrates below the paved or hardened surface layer and moisture transportable by capillary movement is sufficient to form ice lenses at the freezing front. The susceptibility classes are taken from the United States Army Corps of Engineers (1962), pp. 5–8. Table 17 is reproduced from the above article.

11See also definitions for rockiness and stoniness in *The System of Soil Classification for Canada* (Canada Soil Survey Committee 1970), pp 213–214.

12A fourth degree of soil limitation is also defined for the purposes of Table 16—Unsuitable: Slopes greater than 30%; permanently wet soils; floods every year, or oftener; rock outcrop too frequent to permit location of local roads and streets.

Table 16. Interpretation of soil characteristics for local roads and streets
(Based on Table 15, Guide for assessing soil limitations for local roads and streets)

Map unit	Slight	Moderate	Severe	Unsuitable
1 1 / AC,AD	Stony			
1 / DE		Slope		
1 1 / EF,F			Slope	
1 1 / FG,G,				*Slope*[2]
1 / GH				
4 / AC			Rock	
4 / DE		Slope	Rock-D	
8 / AC		Str Frost		
11 / AC				*Flood*
11 / DE		Slope		*Flood*
12 / AC		Frost	Str Sh-Sw	
12 / DE		Frost Slope	Str Sh-Sw	
14 / AB		Sh-Sw	Flood Str Frost	*Wet*
15 / AB		Flood Str	Frost	
16 / AC		Frost	Flood Str	
17 17 / AC,AD	Nil			
18 / AC	Nil			
19 / AC	Nil			
19 19 / AD,DE		Slope		
20 20 / AC,AD				*Flood*
20 / FG				*Slope Flood*
21[6] / AC	Stony			
21[6] / F			Slope	
22[6] / AC	Stony			
22[6] 22[6] / DE,E		Slope		
22[6] / EF			Slope	
25 / AC	Frost			
25 / DE		Slope		
25 / EF			Slope	
25 / G				*Slope*
26 / AC		Str Frost		
27 27 / AC,AD	Nil			
27 27 / DE,E		Slope		
27 27 / EF, F			Slope	

Map unit	Slight	Moderate	Severe	Unsuitable
28[6] 28[6] / AC,D	Nil			
28[6] / E		Slope		
28[6] / EF			Slope	
28[6] / GH				*Slope*
29 29 / AB,AC,		Wet		
29 / CD				
29 29 / DE,E		Wet Slope		
29 / EF		Wet	Slope	
29 / G		Wet		*Slope*
31 / AB		Sh-Sw Frost	Flood Str	*Wet*
32 32 / AB,AC,		Str	Flood Frost	*Wet*
32 32 / AD,CD				
36[6] / AC		Str Frost		
36[6] / DE		Str Frost Slope		
36[6] / EF		Str Frost	Slope	
36[6] / G		Str Frost		*Slope*
37 / AC		Frost		
37 / DE		Frost Slope		
37 37 / EF,F		Frost	Slope	
37 37 / G, GH,		Frost		*Slope*
37 / H				
38[6] 38[6] / AC,AD,	Wet[1]			
38[6] 38[6] / CD,D				
38[6] 38[6] / DE,E		Slope		
38[6] 38[6] / EF, F			Slope	
38[6] 38[6] / FG,G,				*Slope*
38[6] / GH				
39[6] / AC	Nil			
39[6] / EF			Slope	
39[6] 39[6] / FG,G,				*Slope*
39[6] / GH				
41 / AC		Str Frost		
41 / DE		Str Frost Slope		
41 / EF		Str Frost	Slope	
41 / FG		Str Frost		*Slope*
42 / AC		Frost Sh-Sw	Str	
44 / AC		Str	Flood	*Wet*

Map unit	Slight	Moderate	Severe	Unsuitable
46 / AC	Nil			
46 / DE		Slope		
46 / EF			Slope	
47[6] / AC	Stony			
47[6] / DE		Slope		
47[6] / EF			Slope	
48[6] / AC	Wet			
48[6] 48[6] / AD,DE		Slope		
48[6] / EF			Slope	
48[6] / FG				*Slope*
49[6] / AC	Nil			
49[6] / DE		Slope		
49[6] / EF			Slope	
50 50 / AD,CD		Frost Str		
50 / DE		Frost Str Slope		
50 / EF		Frost Str	Slope	
50 50 / FG,G		Frost Str		*Slope*
52 / AD		Frost Rock[1]		
52 / DE		Frost Slope Rock[1]		
52 / EF		Frost Rock[1]	Slope	
52 52 52 / EG,FG,G,		Frost Rock[1]		*Slope*
52 52 / GH,H				
53 / AC		Str	Flood Frost	*Wet*
53 / DE		Slope Str	Flood Frost	*Wet*
53 53 / EF,FG		Str	Flood Frost Slope	*Wet*
54 / AD		Str Stony		
54 / DE		Str Stony Slope		
54 / EF		Str Stony	Slope	
54 / FG,		Str Stony		*Slope*
54 54 / GH,H				
55 / AD	Stony			
55 / DE		Slope		
55 / EF			Slope	
55 55 / FG,G,				*Slope*
55 55 / GH,H				

Table 16. Interpretation of soil characteristics for local roads and streets (cont'd)

Map unit	Slight	Moderate	Severe	Unsuitable
57 57 / AC,AD,		Sh-Sw Frost	Str	
57 57 / CD,D				
57 57 / DE,E		Sh-Sw Frost Slope	Str	
57 57 / EF,F		Sh-Sw Frost	Str Slope	
57 57 / FG,G		Sh-Sw Frost	Str	*Slope*
57 / GH				
58 58 / AC,AD		Sh-Sw Frost	Str	
58 / DE		Sh-Sw Frost Slope	Str	
58 / EF		Sh-Sw Frost	Str Slope	
58 / G		Sh-Sw Frost	Str	*Slope*
61 / EF			Slope Stony	
61 61 / FG,G,			Stony	*Slope*
61 / GH				
64 64 / AC,AD,	Frost			
64 64 / CD,D				
64 / DE		Slope		
64 64 / EF,F			Slope	
64 64 / FG,G,				*Slope*
64 64 / GH,H				
66 / EF		Sh-Sw Frost Stony	Slope	
67 / AD		Sh-Sw Frost	Str	
67 / DE		Sh-Sw Frost Slope	Str	
67 / EF		Sh-Sw Frost	Str Slope	
67 / FG		Sh-Sw Frost	Str	*Slope*
100[3] / AC		Sh-Sw Frost	Str	
100[3] / DE		Sh-Sw Frost Slope	Str	
100[3] / EF		Sh-Sw Frost	Str Slope	
100[3] 100[3] / FG,G,		Sh-Sw Frost	Str	*Slope*
100[3] / H				

Map unit	Slight	Moderate	Severe	Unsuitable
101[3] / AD		Sh-Sw Frost Wet[1]	Str	
101[3] / DE		Sh-Sw Frost Slope Wet[1]	Str	
101[3] 101[3] / EF, F		Sh-Sw Frost Wet[1]	Str Slope	
101[3] 101[3] / FG,G,		Sh-Sw Frost Wet[1]	Str	*Slope*
101[3] / GH				
102 / AC		Sh-Sw Frost	Str	
102 / DE		Sh-Sw Frost Slope	Str	
102 / EF		Sh-Sw Frost	Str Slope	
102 102 / FG,G		Sh-Sw Frost	Str	*Slope*
103 / GH			Str	*Slope*
105 / AD		Wet	Str	
105 / DE		Wet Slope	Str	
105 / EF		Wet	Str Slope	
106 / AC		Sh-Sw Frost	Str	
106 / DE		Sh-Sw Frost Slope	Str	
106 / F		Sh-Sw Frost	Str Slope	
106 106 / FG,G		Sh-Sw Frost	Str	*Slope*
107[3] / E		Sh-Sw Frost Slope	Str	
107[3] / EF		Sh-Sw Frost	Slope Str	
107[3] 107[3] / FG,G		Sh-Sw Frost	Str	*Slope*
141[6] / DE		Slope		
141[6] 141[6] / EF, F			Slope	
141[6] 141[6] / FG,G,				*Slope*
141[6] 141[6] / GH,H				
142[6] / DE		Slope		
142[6] 142[6] / EF, F			Slope	
142[6] 142[6] / FG,G,				*Slope*
142[6] 142[6] / GH,H				
150[6] / DE		Slope		
150[6] / EF			Slope	
150[6] 150[6] / FG,G,				*Slope*
150[6] 150[6] / GH,H				

Map unit	Slight	Moderate	Severe	Unsuitable
156[6] / DE		Slope		
156[6] 156[6] / EF, F			Slope	
156[6] 156[6] / FG,G,				*Slope*
156[6] 156[6] / GH,H				
160[6] / DE		Slope Frost		
160[6] / EF		Frost	Slope	
160[6] / G		Frost		*Slope*
170 / EF	Str		Slope	
171 / AD	Nil			
190 / AB			Str Flood	*Wet*
90R[6] / EF			Slope Rock-D	
90R[6] 90R[6] / FG, G,			Rock-D	*Slope*
90R[6] 90R[6] / GH, H				
91R[6] 91R[6] / FG, G,			Frost Rock-D	*Slope*
91R[6] 91R[6] / GH, H				
Talus / G, Talus Talus / GH, H				*Slope*
Rock				*Rock*
BP				*Wet Flood*
RD[4]				[4]
Pit[4]				[4]
Chute[5]			Wet[1]	*Slope*[1]

Footnotes

[1]This limitation occurs occasionally within the map unit but should not be expected throughout the area. Field checks on selected sites are necessary to ascertain whether this limitation applies to the given map unit.

[2]The limitations listed in italics under "Unsuitable" are considered to be the most significant ones for evaluating the appropriate map units for use as local roads and streets.

[3]These map units are located on materials subject to large rotational slumping or excessive creep.

[4]These are miscellaneous land units representing cultural features. Unless the present use is abandoned these areas are unsuitable for any other use.

[5]Chute areas are subject to periodic snowslides or avalanches which result in a severe limitation for most uses.

[6]These soils are very susceptible to water erosion whenever runoff occurs, particularly if the vegetative cover is damaged. Fortunately, however, permeability is very high and seldom is water added fast enough to have surface flow. When a stream is diverted or some similar phenomenon occurs which provides surface flow, the results can be catastrophic.

Table 17. Frost Design Soil Classification

Frost group	Kind of soil	Percentage, by weight, finer than 0.02 mm	Typical soil types under Unified Soil Classification System
F1	Gravelly soils	3 to 10	GW, GP, GW-GM, GP-GM
F2	(a) Gravelly soils	10 to 20	GM, GW-GM, GP-GM
	(b) Sands	3 to 15	SW, SP, SM, SW-SM, SP-SM
F3	(a) Gravelly soils	Over 20	GM, GC
	(b) Sands, except very fine silty sands	Over 15	SM, SC
	(c) Clays, PI>12		CL, CH
F4	(a) All silts		ML, MH
	(b) Very fine silty sands	Over 15	SM
	(c) Clays, PI<12		CL, CL-ML
	(d) Varved clays and other fine-grained, banded sediments		CL, and ML; CL, ML, and SM; CL, CH, and ML; CL, CH, ML, and SM

Note: Taken from the United States Army Corps of Engineers 1962

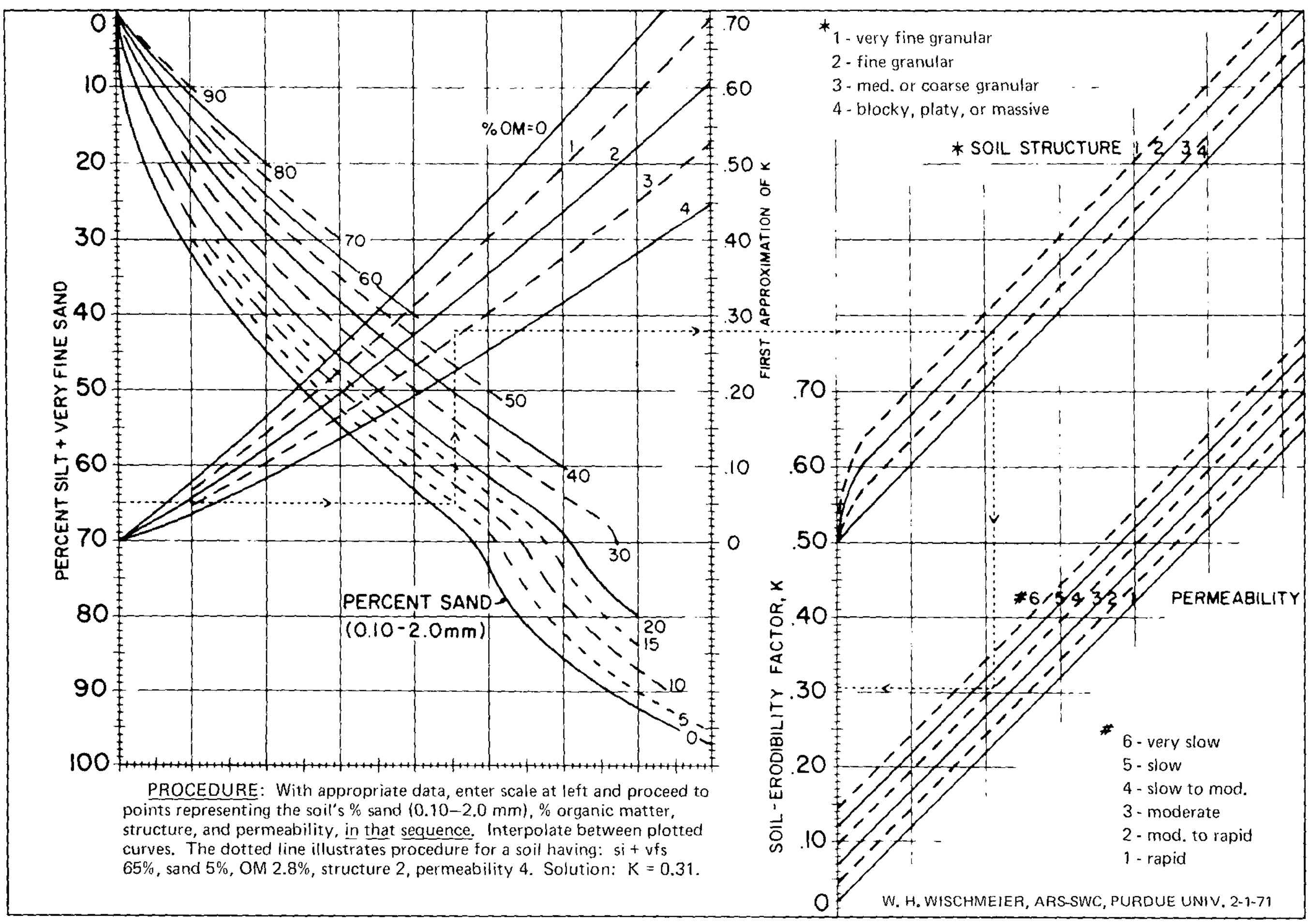


Figure 79. Soil-erodibility nomograph (taken from Wischmeier, Johnson, and Cross 1971).

GUIDE FOR ASSESSING SOIL SUSCEPTIBILITY TO WATER EROSION

The interpretations in Table 18 and Figure 80 are based on the assumption that natural geologic water erosion is expected and accepted. Thus, an erosion hazard occurs only when man's activities (including fires) cause a change in the vegetation on the surface soil. Also, it is assumed that for many activities within the Park the disruption generally will not be deep enough to penetrate the C horizon below the solum. In Table 18 the erosion hazard of the surface 15 to 25 inches is reported. Not infrequently the materials below the solum have a different erosion hazard from the surface material. Where the erosion hazard of the parent materials or lime-cemented tills is of interest, this can be estimated by Rutter's (1968) method using information presented in this report.

To estimate the susceptibility to erosion of the map units the soil-erodibility factor was determined first using the nomograph in Figure 79 (Wischmeier, Johnson, and Cross 1971). The soil-erodibility factor and associated slope were then used to determine the susceptibility to erosion from Figure 80.

Field observations indicate that in Waterton Lakes Park there are two main exceptions to the foregoing procedure for estimating susceptibility to water erosion. The soil-erodibility factor, K (Figure 79), is a poor estimate in lime-rich horizons (Ck, Cca) or dense till materials. These materials are generally found below the solum and were not considered in constructing Figure 69. The second exception occurs when soils contain appreciable quantities of coarse fragments (>2 mm). Coarse fragments are not evaluated by the soil-erodibility factor, but the problem is partially evaluated by Figure 80. Several map units (indicated in Table 18 by footnote 6) have soils with significantly greater susceptibility to erosion than estimated by the foregoing procedure. This is primarily because of the number, size, and shape of the coarse fragments, none of which are taken into account by Figure 79. Several alluvial and colluvial soils have large percentages of fine gravel-sized plate-shaped coarse fragments (mostly argillites), as well as inherent low bulk density and compaction. These factors alter the physical characteristics of the soils to the extent that the routine procedures could not be used, and the soil erodibility was rated primarily on field observations.

Soils with greater than 20% coarse fragments (CF = 2 mm to 25 cm) are less susceptible to erosion and the band between the dashed lines indicates moderate erosion risk in such cases.

K values are poor estimates of erodibility in Ck or Cca horizons especially in tills which are also dense, and estimates made from this figure exclude lime-cemented horizons.

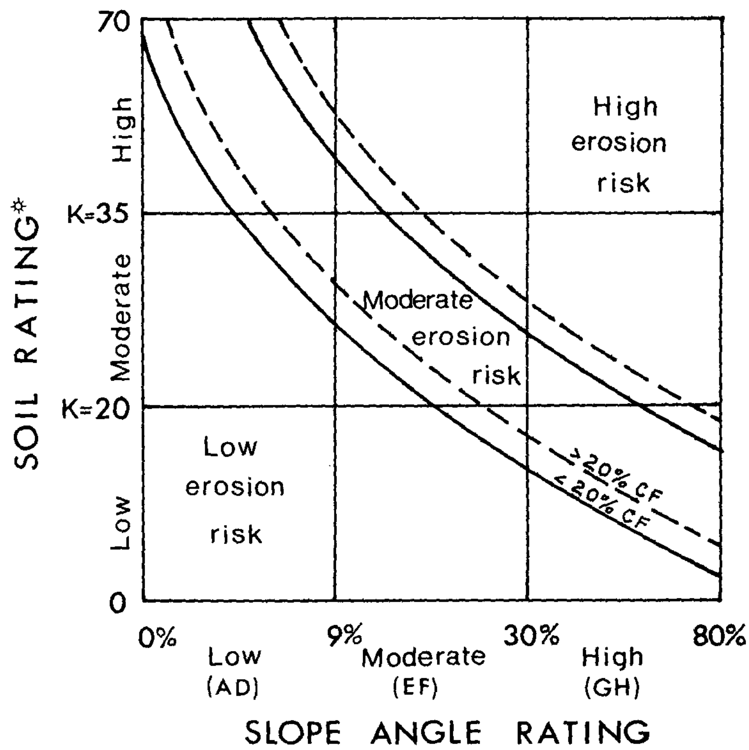


Figure 80. Erosion hazard of soils.

Table 18. Interpretation of soil characteristics for susceptibility to water erosion
(Based on Guide for assessing soil susceptibility to water erosion)

Map unit	Degree and nature of limitation: Low	Moderate	High	Not applic.[1]
1/AC, 1/AD, 1/DE, 1/EF, 1/F	√[2]			
1/FG, 1/G, 1/GH		√		
4/AC, 4/DE	√			
8/AC		√		
11/AC, 11/DE	√			
12/AC		√		
12/DE			√	
14/AB	√			
15/AB	√			
16/AC	√			
17/AC, 17/AD	√			
18/AC	√			
19/AC, 19/AD, 19/DE	√			
20/AC, 20/AD, 20/FG				
21[6]/AC		√[6]		
21[6]/F			√[6]	
22[6]/AC		√[6]		
22[6]/DE, 22[6]/E, 22[6]/EF			√[6]	
25/AC, 25/DE	√			
25/EF		√		
25/G			√	
26/AC		√		
27/AC, 27/AD, 27/DE, 27/E	√			
27/EF		√		
27/F		√		
28[6]/AC, 28[6]/D		√[6]		
28[6]/E, 28[6]/EF, 28[6]/GH			√[6]	
29/AB, 29/AC, 29/CD, 29/DE, 29/E	√			
29/EF		√		
29/G			√	
31/AB	√			
32/AB, 32/AC, 32/AD, 32/CD	√			
36[6]/AC	√[6]			
36[6]/DE, 36[6]/EF		√[6]		
36[6]/G			√[6]	
37/AC, 37/DE	√			
37/EF, 37/F, 37/G, 37/GH		√		
37/H			√	
38[6]/AC, 38[6]/AD, 38[6]/CD, 38[6]/D		√[6]		
38[6]/DE, 38[6]/E, 38[6]/EF, 38[6]/F, 38[6]/FG, 38[6]/G, 38[6]/GH			√[6]	
39[6]/AC		√[6]		
39[6]/EF, 39[6]/FG, 39[6]/G, 39[6]/GH			√[6]	
41/AC, 41/DE, 41/EF		√		
41/FG			√	
42/AC		√		
44/AC	√			
46/AC, 46/DE	√			
46/EF		√		
47[6]/AC	√[6]			
47[6]/DE		√[6]		
47[6]/EF			√[6]	
48[6]/AC	√[6]			
48[6]/AD, 48[6]/DE, 48[6]/EF		√[6]		
48[6]/FG			√[6]	
49[6]/AC		√[6]		
49[6]/DE, 49[6]/EF			√[6]	
50/AD, 50/CD, 50/DE, 50/EF	√			
50/FG, 50/G		√		
52/AD, 52/DE	√			
52/EF		√		
52/EG, 52/FG, 52/G, 52/GH, 52/H			√	
53/AC, 53/DE	√			
53/EF, 53/FG		√		
54/AD, 54/DE, 54/EF, 54/FG	√			
54/GH, 54/H		√		
55/AD, 55/DE	√			
55/EF		√		
55/FG, 55/G, 55/GH, 55/H			√	

Table 18. Interpretation of soil characteristics for susceptibility to water erosion (cont'd)

Map unit	Degree and nature of limitation: Low	Moderate	High	Variable
57/AC, 57/AD, 57/CD, 57/D	√			
57/DE, 57/E, 57/EF, 57/F		√		
57/FG, 57/G, 57/GH			√	
58/AC, 58/AD		√		
58/DE, 58/EF, 58/G			√	
61/EF	√			
61/FG, 61/G, 61/GH		√		
64/AC, 64/AD, 64/CD, 64/D		√		
64/DE, 64/EF, 64/F			√	
64/FG, 64/G, 64/GH, 64/H			√	
66/EF		√		
67/AD, 67/DE, 67/EF	√			
67/FG		√		
100[3]/AC, 100[3]/DE	√			
100[3]/EF, 100[3]/FG, 100[3]/G		√		
100[3]/H			√	
101[3]/AD		√		
101[3]/DE, 101[3]/EF, 101[3]/F, 101[3]/FG, 101[3]/G, 101[3]/GH			√	
102/AC		√		
102/DE, 102/EF, 102/FG, 102/G			√	
103/GH			√	
105/AD	√			
105/DE, 105/EF		√		
106/AC		√		
106/DE			√	
106/F			√	
106/FG, 106/G			√	
107[3]/E		√		
107[3]/EF, 107[3]/EG, 107[3]/G			√	
141[6]/DE		√[6]		
141[6]/EF, 141[6]/F, 141[6]/FG, 141[6]/G, 141[6]/GH, 141[6]/H			√[6]	
142[6]/DE		√[6]		
142[6]/EF, 142[6]/F, 142[6]/FG, 142[6]/G, 142[6]/GH, 142[6]/H			√[6]	
150[6]/DE		√[6]		
150[6]/EF, 150[6]/FG, 150[6]/G, 150[6]/GH, 150[6]/H			√[6]	
156[6]/DE		√[6]		
156[6]/EF, 156[6]/F, 156[6]/FG, 156[6]/G			√[6]	
156[6]/GH, 156[6]/H			√[6]	
160[6]/DE, 160[6]/EF		√[6]		
160[6]/G			√[6]	
170/EF	√			
171/AD	√			
190/AB	√			
90R[6]/EF		√[6]		
90R[6]/FG, 90R[6]/G, 90R[6]/GH, 90R[6]/H			√[6]	
91R[6]/FG, 91R[6]/G, 91R[6]/GH, 91R[6]/H			√[6]	
Talus/G	√			
Talus/GH, Talus/H	√			
Rock	√			
BP				√
RD[4]				√
Pit[4]				√
Chute[5]				√

Footnotes

[1]Not applicable. The erosion is the natural geologic erosion, or occurs below the profile as discussed in the erosion guidelines.

[2]Susceptibility to water erosion is rated low, moderate, high, and not applicable without reference to the soil property influencing the susceptibility (e.g., slope, aggregation, bulk density).

[3]These map units are located on materials subject to large rotational slumping or excessive creep.

[4]These are miscellaneous land units representing cultural features. Unless the present use is abandoned these areas are unsuitable for any other use.

[5]Chute areas are subject to periodic snowslides or avalanches which result in a severe limitation for most uses.

[6]These soils are very susceptible to water erosion whenever runoff occurs, particularly if the vegetative cover is damaged. Fortunately, however, permeability is very high and seldom is water added fast enough to have surface flow. When a stream is diverted or some similar phenomenon occurs which provides surface flow, the results can be catastrophic.

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Appendix A Physical and chemical analyses of soils typifying the major map units in Waterton Lakes National Park

Map unit	Lab. No.[1]	Horizon	Depth (in.)	Chemical analysis (based on fraction <2 mm): pH, $CaCl_2$	Exchangeable cations meq/100 g: H	Na	K	Ca	Mg	E.C.[2] (det.) meq/100 g	Organic carbon %	% $CaCO_3$ equiv.	Oxalate extractable: Fe %	Al %	Fe+Al %	Pounds per acre available[3]: N	P	K	Mechanical analysis: Gravel %	% from faction <2 mm: Sand	Silt	Clay	Fine clay	Textural classes: Lab. det.	Field est.	Moisture: 1/10 Bar %	1/3 Bar %	15 Bar %	Est. avail. water (in./in.)[9]	Bulk density	Infiltration (in./h)[7]	Percolation (min/in.)[8]	Est. permeability[10]
1	71,498	Ah	0–8	5.2	5.8	0.1	0.4	7.7	1.2	20.3	5.0		0.32	0.24	0.56	1	8	291	34	64	27	9	4	GCoSL	GCoSL		24.3	14.5	0.04[9]				Rapid
	71,499	Bm1	8–15	5.1	3.7	0.1	0.2	3.4	0.4	12.7	3.1		0.28	0.25	0.53				74	54	35	11	4	GSL	GCoSL		16.3	9.1					
	71,500	Bm2	15–30	6.5	0.7	0.1	0.1	5.6	0.5	9.7	1.3	0.9	0.16	0.16	0.32	0	2	87	94	68	27	5	2	GCoSL	GCoSL								
	71,501	Ck	30–40+	7.3[4]								8.3	0.09	0.07	0.16				76	77	18	5	2	GLCoS	GCoSL		9.1	3.5					
4		Ah	0–3½										Pedon not sampled												GL								Rapid
		Bm	3½–12																						GL								
		C	12–15																						GSL								
		R																															
8	71,601	Ah	0–4	6.0	2.1	tr[6]	0.3	11.9	1.3	15.6	4.5					4	3	229	8	63	30	7	2	VFSL	SiL								Mod. rapid
	71,602	AB	4–6	6.0	1.2	tr	0.1	4.7	0.6	8.2	1.3								7	49	45	6	2	SL	VFSL								
	71,603	Bm	6–13	5.9	1.1	tr	0.1	3.4	0.5	6.7	0.9		0.15	0.14	0.29	0	0	93	5	46	50	4	2	SiL-SL	VFS								
	71,604	BC	13–18	7.3								5.3	0.13	0.12	0.25				tr	61	36	3	1	VESL	VFS								
	71,605	Ck1	18–28	7.7								10.3							tr	30	68	2	1	SiL	SiL								
	71,606	Ck2	28–41+	7.7								19.5							Nil	28	70	2	1	SiL	Si								
11		L-H	½–0																														Rapid
	71,592	C1	0–7	7.2							3.8	6.0				6	1	221	Nil	24	54	22	8	SiL	SiL								
	71,593	C2	7–20	7.2							0.5	6.0							58	70	18	12	3	GSL	GCoSL								
	71,594	C3	20–30	7.2							0.2	5.7							2	68	22	10	4	SL	CoS								
	71,595	C4	30–40+	7.4							Nil	9.3							75	71	21	8	1	GCoSL	GCoS								
12	71,567	L-F	1–0																Nil														
	71,568	Ah	0–5	4.8	11.7	0.1	0.6	9.8	1.6	29.6	7.0					0	62	304	4	31	50	19	6	SiL-L	L		38.7	15.9					Mod.
	71,569	C	5–11	4.9	3.8	tr	0.2	2.8	0.6	11.1	0.9								7	35	49	16	4	SiL-L	L-SiL		21.7	7.5					
	71,570	Cg	11–17	4.9	2.1	tr	0.1	1.1	0.6	6.5	0.4								13	31	52	17	3	SiL	SiL		19.1	6.1					
	71,571	IIABgb1	17–20	4.8	2.8	0.1	0.1	2.0	1.5	9.8	0.5								5	26	50	25	10	SiL	CL		21.7	8.7					
	71,572	IIBtgb1	20–30	5.1	2.4	0.1	0.2	5.6	5.4	15.9	1.0								4	21	45	34	15	CL	C		19.8	12.4					slow
	71,573	IIBtgb2	30–43	5.1	2.4	0.2	0.2	5.2	6.0	15.4	1.2								2	22	46	32	15	CL	C		21.8	14.6					
	71,574	IIBCgb	43–46+	5.8	1.3	0.2	0.1	5.6	6.7	13.8									19	25	47	28	11	CL	C		21.4	10.4					
14	72,191	L-H	8–0	6.9																													Mod.
	72,192	ACg	0–2	6.8	1.1	0.1	0.1	33.0	8.2	38.4	6.0								Nil	2	66	32	13	SiCL	L								
	72,193	Cg	2–20	6.9	0.5	0.1	0.2	18.1	6.6	23.4	1.9								Nil	1	64	35	14	SiCL	SiCL								
15	72,269	Ah1	0–5	7.0	0.8	0.1	0.5	18.3	8.4	23.8	4.5	0.3							Nil	9	69	22	9	SiL	SiL		36.6	16.1		0.9			Mod. rapid
	72,270	Ah2	5–10	6.8	1.0	0.1	0.3	16.1	7.1	20.7	3.3								Nil	10	68	22	8	SiL	SiL								
	72,271	C1	10–26	6.4	1.0	tr	0.2	11.6	4.7	15.5									Nil	8	69	23	9	SiL	SiL								
	72,272	C2	26–38+	7.0	0.3	0.1	0.1	10.8	5.7	14.3		0.3							Nil	7	71	22	8	SiL	SiL		25.5	10.0		1.2			
16	72,259	Ah	0–4	6.8	0.5	tr	1.1	26.7	6.3	27.4	5.9								Nil	19	56	25	14	SiL	SiL								Mod. rapid
	72,260	Ck1	4–16	7.1								8.5							Nil	20	56	24	13	SiL	SiL								
	72,261	Ck2	16–40+	7.5								13.3							Nil	15	58	27	14	SiL	SiL								
17	72,030	Ah1	0–1	6.0	5.6	tr	1.4	22.5	5.5	32.4	12.8									55	36	9	4	SL	L					0.8	1.9		Rapid
	72,031	Ah2	1–10	5.5	3.0	tr	0.2	7.5	2.0	16.2	2.4									32	44	24	13	G[5]L	GSL					0.9			
	73,032	Bm	10–26	6.9	0.4	tr	0.2	13.4	3.2	11.2	2.0									32	43	25	11	G[5]L	GSL					0.8			
	72,033	Cca	26–31	6.9	0.2	0.1	0.1	12.0	1.4	4.0										81	17	2	20	VG[5]SiC	VGS								
	72,034	Ck	31–40+	7.2								11.5							77	30	46	25	7	GL	GLCoS								
18	72,250	L-F	½–0	4.8																													Rapid
	72,251	Ah	0–2	4.6	4.8	0.1	0.3	3.0	1.5	12.1	2.0		0.27	0.07	0.34				70	61	30	9	4	GSL	GSL								
	72,252	Bm	2–14	5.2	1.7	0.1	0.1	2.5	1.6	6.6	0.8		0.14	0.06	0.20				70	67	25	8	4	GSL	GSL								
	72,253	C	14–26+	7.0	0.1	tr[6]	0.1	7.8	1.5	5.1		1.6	0.11	0.04	0.15				84	74	21	5	3	VGSL	VGSL								
19	72,026	Ah1	0–15	5.7	3.4	0.1	0.1	12.5	2.7	19.3	3.6									56	30	14	6	GFSL	GSL	35.2		11.7	0.13	0.7	2.4	16	Rapid
	72,027	Ah2	15–37	5.8	2.5	tr	0.1	8.8	3.5	14.9	1.9									61	28	11	6	GFSL	GSL	25.4		8.5					
	72,028	AC	37–43	6.2	1.7	tr	0.1	6.2	3.7	13.2	1.7									66	21	13	4	GFSL	GSL	24.2		8.8		1.2			
	72,029	Ck	43–50+	6.8	0.2	tr	0.1	7.5	4.6	9.4									89	34	43	23	9	GL	GCoSL								
20											Not sampled														Cobbly								Rapid
21	71,508	Ah	0–5	7.1						15.7	3.0	1.3				1	12	252	49	59	32	9	2	GSL	GSL		18.9	9.3	0.01		5.4	6	Rapid
	71,509	Ck1	5–30	7.7						3.9		10.6							61	74	22	4	1	VGLCoS	VGCoSL								
	71,510	Ck2	30–35+	7.1								10.5							43	79	17	4	1	VGLCoS	VGCoSL		5.4	2.6					
22	71,533	Ah	0–12	6.3	1.9	tr	0.5	11.9	3.0	20.3	4.0	Nil	0.31	0.23	0.54	0	6	322	43	47	39	14	5	GL	GL		18.3	13.9	0.01				Rapid
	71,534	Bm	12–28	7.3							1.7	0.8	0.17	0.14	0.31	1	5	142	70	65	26	9	3	VGCoSL	VGCoSL		8.4	6.7					
	71,535	Ck	28–36+	7.6								5.2	0.14	0.10	0.24				55	74	19	7	2	VGCoSL	VGCoSL								

Appendix A Physical and chemical analyses of soils typifying the major map units in Waterton Lakes National Park

Map unit	Lab. No.[1]	Horizon	Depth (in.)	Chemical analysis (based on fraction <2 mm)															Mechanical analysis					Textural classes		Moisture							
					Exchangeable cations meq/100 g								Oxalate extractable			Pounds per acre available[3]				% from faction <2 mm													
				pH, $CaCl_2$	H	Na	K	Ca	Mg	E.C.[2] (det.) meq/100 g	Organic carbon %	% $CaCO_3$ equiv.	Fe %	Al %	Fe+Al %	N	P	K	Gravel %	Sand	Silt	Clay	Fine clay	Lab. det.	Field est.	1/10 Bar %	1/3 Bar %	15 Bar %	Est. avail. water (in./in.)[9]	Bulk density	Infiltration (in./h)[7]	Percolation (min/in.)[8]	Est. permeability[10]
25	71,512	Ah	0–1½	6.7	1.7	0.1	0.5	16.1	2.7	21.5	4.7	0.8				0	24	360	16	61	31	8	2	CoSL	SL		23.6	13.2					Rapid
	71,513	C1	1½–6	7.2							3.3	2.4							12	51	37	12	2	L	SL								
	71,514	C2	6–11	7.4							1.1	6.7				2	3	230	78	68	24	8	1	GCoSL	GSL		7.0	5.1					
	71,515	C3	11–45+	7.3								5.4							1	26	55	19	5	SiL	SiL								
26	72,301	Ah	0–12	6.4	1.4	0.1	0.5	17.3	4.6	20.4	5.4								Nil	51	37	12	4	L	SL								Mod.
	72,302	C	12–29	7.0	0.2	tr	0.1	8.1	2.2	9.3		0.1							Nil	47	39	14	4	L	SL								rapid
	72,303	Ck1	29–42	7.1								6.9							6	57	35	8	2	FSL	SL								
	72,304	Ck2	42–46+	7.2								11.6							82	57	31	12	3	GSL	GSL								
27	72,015	L-H	2–0	4.4																													Rapid
		C1	0–1												Not sampled										L								
	72,016	C2	1–7	5.8	1.4	0.3	0.2	11.5	2.1	12.4	2.0									60	31	9	3	G[5]CoSL	GSL	20.7		8.2					
	72,017	C3	7–15	6.0	0.5	Nil	0.1	5.0	1.2	5.7	0.4								68	79	15	6	2	GLCoS	GCoS				0.09		14		
	72,018	C4	15–17½	6.0	1.0	Nil	0.1	7.5	1.9	8.7	0.8									47	38	15	4	L	SiL		19.7	6.5					
	72,019	C5	17½–35	6.1	0.5	Nil	0.1	4.2	0.9	4.7	0.3									85	12	3	1	G[5]LS	GCoS								
	72,020	C6	35–44+	6.0	0.4	Nil	0.2	3.1	0.7	4.2	0.2								79	68	22	10	3	GCoSL	GCoSL								
28	72,275	L-H	½–0	4.3																													Rapid
	72,276	Ah	0–4½	4.9	6.1	Nil	0.3	3.1	1.2	14.1	2.4		0.53	0.21	0.74				57	53	35	12	5	GSL	GSL								
	72,277	Bf	4½–15	5.2	3.2	0.1	0.2	0.8	0.4	7.6	1.0		0.77	0.67	1.06				59	59	32	9	3	GSL	GSL								
	72,278	C	15–30+	5.1	1.1	tr	0.1	1.3	1.1	2.4			0.11	0.04	0.15				78	68	24	8	2	GCoSL	GLCoS								
29	71,516	Ck1	0–2	7.3								8.0				1	3	235	Nil	30	60	9	2	SiL	VFSL		13.4	8.7					Mod.
	71,517	Ahb	2–4	7.1							8.7	3.1				2	5	211	Nil	7	60	33	8	SiCL	SL		41.4	36.2					rapid
	71,518	Ck2	4–10	7.5								9.6							Nil	36	52	12	3	SiL	SL-FSL		12.8	7.4					
	71,519	Ckg1	10–18	7.5							0.2	11.7							Nil	81	15	4	1	LS	SL								
	71,520	Ckg2	18–29	7.6							0.3	12.4							Nil	53	41	6	2	FSL	SiL								
	71,521	Ckg3	29–35+	7.0							0.2	10.7							59	62	32	6	2	CFSL	GSL								
31	71,529	Ahgk	0–6	7.7							11.5	8.8				2	1	179	Nil	7	52	41	22	SiC	L								Mod.
	71,530	Bgk	6–16	7.8							1.2	1.8				2	1	172	Nil	32	44	24	12	L	SiL-SiCL								
	71,531	BCgk	16–30	7.9								37.4							10	17	53	30	16	SiCL	SiL								
	71,532	Cgk	30–35+	7.8								17.9							4	30	52	18	8	SiL	SiL								
32	71,522	Ahg	0–5	7.2							6.1	4.3				17	8	269	Nil	32	54	14	5	SiL	L		24.7	16.3					Mod.
	71,523	Bg1	5–7	7.3							2.0	4.2							2	37	53	10	3	SiL	VFSL				0.06				
	71,524	Bg2	7–21	7.1							1.3	0.4				3	0	125	2	51	39	10	3	L	SiL		12.2	7.4					
	71,525	Cg	21–30+	7.6								3.8							7	47	41	12	3	L	VFSL								
36	72,308	L-H	1½–0	6.8																													Mod.
	72,309	Ahe	0–3	6.8	1.6	0.3	0.6	39.7	8.5	46.4	9.5								6	59	31	10	5	FSL	SL		48.1	36.4					rapid
	72,310	Ae	3–6	6.8	0.6	0.1	0.2	15.5	4.3	18.8	2.2								Nil	58	30	12	6	FSL	SL				0.16				
	72,311	Bt	6–18	6.9	0.5	0.1	0.3	14.5	5.3	17.6	0.8								2	53	25	22	15	SCL	L								
	72,312	C1	18–38	7.0	0.3	0.1	0.1	9.5	3.4	11.8		5.4							1	68	24	8	4	FSL	SL	17.5		5.2					
	72,313	C2	38–43+	6.9	0.2	0.1	0.3	12.8	3.2	12.9									Nil	78	19	3	1	LFS	SL								
37	72,254	L-H	6–0	6.0																													Rapid
	72,255	Ah	0–5	6.2	3.8	0.1	0.3	19.0	8.6	23.8	5.2								Nil	57	30	13	6	SL	SL-L								
	72,256	C	5–18	6.0	1.1	0.1	0.2	6.1	3.1	10.5									Nil	48	39	13	6	L	SL								
	72,257	Ahb	18–21	6.1	1.4	0.1	0.2	10.3	5.2	15.3	1.5								4	61	27	12	6	SL	SL								
	72,258	Cg	21–24	6.2	1.1	0.1	0.1	6.1	3.7	10.7									Nil	64	25	11	6	SL	SL								
38	71,540	Ah1	0–8	6.2	1.7	tr	0.7	9.8	2.8	17.5	3.3					0	31	500	15	72	19	9	1	CoSL	SL		15.0	10.8					Rapid
	71,541	Ah2	8–12	6.9		0.1	0.4	13.8	4.0	19.4	0.7	3.0							86	52	36	12	3	GL	GSL				0.02				
	71,542	C1	12–28	7.0		tr	0.3	6.1	2.2	10.5		3.9							65	57	32	11	5	GCoSL	GL								
	71,543	C2	28–32+	7.3								5.4							42	69	23	8	3	GCoSL	GSL		8.3	4.2					
39	72,316	F-H	2–0	6.1																													Rapid
	72,317	Ah	0–1	6.1	6.7	tr	0.8	49.9	9.8	72.6	17.9								Nil	39	46	15	6	L	SL								
	72,318	C1	1–11	6.6	0.4	tr	0.2	7.2	2.8	9.2									68	66	26	8	3	GCoSL	GCoSL								
		Ahb	11–12												Not sampled										SL								
	72,319	C2	12–26+	6.9	0.3	Nil	0.2	6.3	3.2	8.3									79	58	32	10	4	GSL	GSL								
41	71,575	L-H	2–0																5														Mod.
	71,576	C1	0–5	6.9		0.1	0.2	20.3	6.9	21.4		0.3				0	3	142	8	30	49	21	8	L-SiL	L		31.5	14.1					rapid
	71,577	C2	5–17	6.9		0.1	0.2	14.8	5.7	23.3		0.2							9	27	51	22	8	SiL	SiL				0.15				
	71,578	IIC1	17–33	7.1								0.3							16	35	47	18	9	GL	GCL		22.0	4.6					Mod.
	71,579	IIC2	33–40+	7.3								6.4							38	42	43	15	8	GL	GCL								

Appendix A Physical and chemical analyses of soils typifying the major map units in Waterton Lakes National Park

Map unit	Lab. No.[1]	Horizon	Depth (in.)	pH, $CaCl_2$	Exchangeable cations meq/100 g: H	Na	K	Ca	Mg	E.C.[2] (det.) meq/100 g	Organic carbon %	% $CaCO_3$ equiv.	Oxalate extractable: Fe %	Al %	Fe+Al %	Pounds per acre available[3]: N	P	K	Gravel %	% from faction <2 mm: Sand	Silt	Clay	Fine clay	Textural classes: Lab. det.	Field est.	Moisture: 1/10 Bar %	1/3 Bar %	15 Bar %	Est. avail. water (in./in.)[9]	Bulk density	Infiltration (in./h)[7]	Percolation (min/in.)[8]	Est. permeability[10]
42	71,563	Ah	0–8	6.2	2.1	tr	0.4	18.4	5.3	29.0	4.3					0	15	328	1	22	52	26	11	SiL	L		33.9	15.6		0.96			Mod.
	71,564	C1	8–24	5.9	1.9	0.1	0.3	13.0	3.8	21.3									1	23	54	23	11	SiL	SiL				0.19	1.11	20.3	33	rapid
	71,565	C2	24–47	6.1	1.7	0.1	0.2	10.2	3.6	17.8									1	22	53	25	11	SiL	SiL					1.25			
	71,566	C3	47–51+	6.5	1.0	0.1	0.3	9.8	4.3	17.0									54	31	43	26	12	GL	GCL		26.4	11.2					
44		Ah	0–4												Pedon not sampled										L								Rapid
		Cg	4–20+																						GSL								
46	72,216	L-F	½–0	4.5																													Mod.
	72,217	Ae	0–3	5.7	2.1	tr	0.2	4.8	2.8	8.4	1.5								12	45	42	13	3	L	SL								rapid
	72,218	Bt	3–15	6.5	0.6	tr	0.3	14.4	11.4	18.0	3.2								52	29	37	34	20	GCL	GCL								
	72,219	Ck	15–25+	7.1								52.5							78	39	50	11	3	GSiL-L	GL								
47	72,230	L-H	2–0	4.4																													Rapid
	72,231	Ae	0–1	4.2	7.9	0.1	0.2	3.0	1.8	13.7	2.6		0.22	0.10	0.32				55	25	52	24	4	GSiL	GSL				0.07				
	72,232	Bm	1–12	5.3	2.6	0.1	0.1	2.7	1.2	6.8	0.7		0.34	0.19	0.53				56	59	31	10	4	GCoSL	GSL	17.8		6.7					
	72,233	C	12–25+	5.5	0.9	tr	0.1	2.5	1.2	5.4			0.14	0.06	0.20				42	75	18	7	3	GCoSL	GSL	13.0		4.9					
48	72,286	L-F	2–0	4.6																													Rapid
	72,287	C1	0–18	4.7	8.7	0.1	0.4	4.4	1.3	19.9									61	29	42	30	14	GCL	GSiL								
	72,288	C2	18–30+	5.1	3.0	tr	0.1	3.0	1.0	7.8									81	58	30	12	6	GCoSL	GSL								
49	72,280	L-H	½–0	3.8															Nil														Rapid
	72,281	Ae	0–4	4.1	11.6	tr	0.2	0.2	0.3	14.5	2.9		0.28	0.17	0.45				67	18	71	11	4	GSiL	GSL								
	72,282	Bf	4–12	5.3	5.6	0.1	0.3	0.1	0.2	23.4	3.4		1.69	2.64	4.33				51	24	66	10	2	GSiL	GL		39.2	20.2	0.10				
	72,283	Aeb	12–16	4.7	3.7	tr	0.1	0.8	0.6	7.9	0.8		0.27	0.20	0.47				71	36	53	11	4	GSiL	GSL								
	72,284	Bfb	16–20	5.2	2.7	tr	0.1	0.1	0.1	8.3	0.9		0.48	1.95	2.43				78	44	49	7	1	GFSL	GVFSL								
	72,285	C	20–35+	4.6	1.9	Nil	0.1	0.2	0.2	3.5	Nil		0.08	0.13	0.21				72	60	35	5	2	GFSL	GSL	19.5		3.5					
50	71,494	Ah1	0–3½	6.3	3.8	0.1	1.2	27.9	3.5	38.7	9.2					4	12	694	15	48	40	12	5	GL	GL		40.2	25.1		1.0			Mod.
	71,495	Ah2	3½–6	5.6	2.0	0.1	0.3	4.3	0.7	10.6	2.2		0.25	0.21	0.46	0	5	301	42	43	43	14	6	GL	GL				0.09		1.3		rapid
	71,496	Bm	6–17	6.3	0.9	0.1	0.3	4.5	2.0	10.6	0.9		0.19	0.18	0.37				48	44	40	16	9	GL	GSL-L		16.6	7.1		1.2			
	71,497	Ck	17–24+	7.7								27.9							43	41	47	12	6	GL	GL		13.9	5.2		1.7			Mod.
52	72,207	L-F	1–0	4.3																													Mod.
	72,208	Ah	0–1	5.0	10.9	0.1	0.6	10.3	1.6	27.7	8.1		0.52	0.65	1.17				28	28	59	13	4	GSiL	GL		36.4	17.3	0.14				and
	72,209	Bf	1–10	5.4	4.0	0.1	0.2	3.2	0.4	13.0	2.2		0.58	0.88	1.46				50	35	53	12	2	GSiL	GL		24.6	10.2					mod.
	72,210	C	10–30+	4.8	1.3	0.1	0.1	0.8	0.3	3.2			0.12	0.07	0.19				56	48	43	9	2	GL	GSL								rapid
53	72,211	L	½–0	5.1																													Mod.
	72,212	Ahg	0–3½	5.0	15.2	0.1	0.3	5.1	2.9	52.8	12.8								Nil	8	66	26	12	SiL	L								
	72,213	Bg	3½–7	5.1	11.4	0.1	0.2	4.4	2.6	31.4	4.5	0.1							4	19	58	23	12	SiL	L								
	72,214	BCg	7–10	5.2	7.6	0.1	0.2	4.2	3.1	23.1	2.1								67	21	53	26	10	GSiL	GSiL								
	72,215	Cg	10–20+	5.1	1.0	tr	0.1	1.7	1.8	5.0									5	41	49	10	4	L	FSL								
54	72,035	Ah	0–1½	4.8	12.6	tr	0.8	10.0	2.0	40.1	11.6									30	46	24	9	L	L								Mod.
	72,036	C	1½–15+	4.5	7.9	0.1	0.1	1.6	2.7	18.8	2.1								77	25	42	33	15	GCL	GL								rapid
55	72,225	L-F	1–0	6.5																													Mod.
	72,226	Ck1	0–6	7.1							1.6	4.4							17	63	28	9	3	SL	SL	17.5		6.41					rapid
	72,227	Ck2	6–24	7.2							0.7	2.2							57	79	17	4	2	GLCoS	GSL				0.09				
	72,228	Ck3	24–30	7.4							0.1	9.2							78	68	24	8	3	GSL	GSL								
	72,229	Ck4	30–40+	7.3							0.3	11.3							61	70	23	7	2	GSL	GSL	16.8		2.3					
57	71,502	L-F	1–0																Nil														Mod.
	71,503	Ae1	0–3	4.3	3.9	tr	0.3	0.5	0.3	7.8	1.4					0	23	220	34	54	38	8	3	GCoSL	GVFSL		15.1	5.3					rapid
	71,504	Ae2	3–5½	4.3	3.6	0.1	0.2	1.2	0.3	7.4	1.2								35	39	50	11	4	GSiL-L	GSiL								
	71,505	Bt1	5½–17½	4.9	2.8	0.1	0.2	3.3	2.5	13.8	0.7					0	4	184	41	36	38	26	13	GL	GSiCL				0.08		5.3	50	
	71,506	Bt2	17½–26	6.8		0.1	0.1	5.6	4.7	11.4	0.7	2.9							35	38	41	21	10	GL	GSiCL								
	71,507	Ck	26–32+	7.3		0.1	0.1	6.4	4.5	11.0		7.4							35	41	43	16	8	GL	GSiL		18.9	9.3					Mod.
58	72,001	L-H	2–0	6.2																													Mod.
	72,002	Ahe	0–6	5.1	2.9	Nil	0.7	7.5	2.4	13.5	1.3									25	60	15	5	SiL	SiL		23.5	8.4		1.3			
	72,003	Bt1	6–12	5.5	1.7	tr[6]	0.2	2.2	0.5	21.2	0.9									16	54	30	16	SiCL	SiCL		26.3	14.6	0.22	1.4			
	72,004	Bt2	12–20	5.7	1.2	Nil	0.3	2.9	0.6	20.3	0.7									11	66	23	14	SiL	SiCL					1.4			
	72,005	Ck1	20–25	7.1								24.1							7	9	72	19	4	SiL	SiL		28.3	9.8		1.5			
	72,006	Ck2	25–50+	7.3								22.9							5	5	79	16	2	SiL	SiL					1.6			

Appendix A Physical and chemical analyses of soils typifying the major map units in Waterton Lakes National Park

Map unit	Lab. No.[1]	Horizon	Depth (in.)	Chemical analysis (based on fraction <2 mm): pH, $CaCl_2$	Exchangeable cations meq/100 g: H	Na	K	Ca	Mg	E.C.[2] (det.) meq/100 g	Organic carbon %	% $CaCO_3$ equiv.	Oxalate extractable: Fe %	Al %	Fe+Al %	Pounds per acre available[3]: N	P	K	Mechanical analysis: Gravel %	% from faction <2 mm: Sand	Silt	Clay	Fine clay	Textural classes: Lab. det.	Field est.	Moisture: 1/10 Bar %	1/3 Bar %	15 Bar %	Est. avail. water (in./in.)[9]	Bulk density	Infiltration (in./h)[7]	Percolation (min/in.)[8]	Est. permeability[10]
61		L	½–0																														Mod. rapid
		Ae	0–2										Pedon not sampled												GSiL								
		Bt	2–9																						VGSiCL								
		C	9–20+																						VGSiL-SL								
64	71,623	L-H	1–0																Nil														Mod. rapid
	71,624	Ae	0–1	3.4	12.0	0.1	0.2	1.0	0.4	14.4	2.3					0	6	115	19	25	68	7	2	SiL	SiL								
	71,625	Bf1	1–5	4.4	14.6	0.1	0.2	0.1	0.2	39.9	6.1		1.70	2.80	4.50	0	14	138	30	29	59	12	2	GSiL	GL					0.7			
	71,626	Bf2	5–11	4.9	6.2	0.1	0.2	0.3	0.1	16.8	2.6		0.88	2.44	3.32				22	37	58	5	1	GSiL	GL				0.08		8.6		
	71,627	C1	11–28	4.3	3.6	tr	0.1	0.5	0.4	6.4			0.17	0.18	0.35				51	48	44	8	2	GL	GL-SL					1.2			
	71,628	C2	28–38+	4.6	2.6	tr	0.1	0.4	0.3	4.7			0.20	0.17	0.37				62	67	25	8	3	GSL	GSL								
66	72,188	Ah	0–1	6.6	1.6	tr	0.7	15.8	2.8	19.9	2.9		0.18	0.10	0.28				16	40	40	20	10	L	L-CL		17.4	12.4					Mod. rapid
	72,189	Bm	1–11	6.6	1.3	0.1	0.8	22.8	2.2	23.9	1.8		0.16	0.13	0.29					29	36	35	23	CL	CL		24.8	16.3	0.08				
	72,190	Ck	11–26+	7.3									0.09	0.07	0.16				50	19	44	37	20	GSiCL	GCL								
67	72,042	Ah	0–9	5.8	4.5	tr	0.8	23.2	7.7	33.2	8.7									21	44	35	15	CL	L		35.0	32.3					Mod. rapid
	72,043	Bm	9–17	5.2	3.1	tr	0.3	7.3	7.8	15.9	1.8									36	40	24	14	L	CL		21.3	11.6					
	72,044	BC	17–38	5.2	1.6	0.1	0.2	17.0	4.3	25.0										32	44	26	14	L	C				0.12				
	72,045	C	38–46+	6.0	1.7	0.1	0.3	18.1	8.4	25.2									4	4	54	42	19	SiC	C		26.3	15.3					
100	71,596	C1	0–7	5.4	3.5	0.1	0.4	15.3	5.7	28.6	3.4					0	2	291	Nil	7	49	44	20	SiC	C								Slow
	71,597	C2	7–11	5.6	3.6	0.1	0.4	18.8	7.0	31.9	3.8								tr	6	45	49	23	SiC	C								
	71,598	Btb1	11–23	5.9	2.4	0.1	0.3	16.3	6.8	26.0	2.2								Nil	7	48	45	19	SiC	C		30	15	0.15				
	71,599	Btb2	23–40	6.1	1.8	0.2	0.2	14.4	7.0	22.4	1.4								Nil	7	47	46	21	SiC	C								
	71,600	BCb	40–48+	6.3	1.4	0.1	0.3	16.3	7.9	25.7									Nil	6	45	49	23	SiC	C								
101	72,175	L-H	1–0	5.4															Nil														Mod.
	72,176	C	0–4	5.2	5.8	tr	0.6	10.8	7.3	24.2	3.2								3	33	44	23	1	SiL	SiL	29.1		13.8					
	72,177	Ahb	4–10	5.8	3.9	tr	0.3	13.0	8.5	23.4	3.0								2	26	58	16	6	SiL	SiL					1.1			
	72,178	C2	10–16	5.9	1.8	tr	0.4	15.2	12.2	24.9	1.0								4	51	35	14	5	L	CL	30.1		14.8					
	72,179	C3	16–23	5.9	1.6	tr	0.4	17.0	15.3	28.4	0.7								Nil	23	51	26	15	SiL	C				0.18	1.3			
	72,180	C4	23–29	6.3	1.2	tr	0.4	18.9	17.3	31.5									Nil	27	51	22	11	SiL	CL								
	72,181	C5	29–40+	6.7	0.6	0.1	0.3	18.9	15.5	29.2									Nil	19	48	33	17	SiCL	CL								
102	71,547	L-H	2–0																Nil														Slow
	71,548	Ae1	0–5	5.4	3.0	0.1	0.8	8.0	1.5	16.4	1.8					0	57	475	Nil	35	49	16	7	SiL-L	SiL		20.4	8.5		1.1			
	71,549	Ae2	5–9	5.3	2.3	0.1	0.5	7.0	1.4	14.5	1.0								Nil	34	38	18	7	L	SiL		18.2	8.2		1.1			
		AB	9–13												Not sampled										SiL								
	71,550	Bt1	13–22	5.3	2.1	0.1	0.5	11.1	3.1	20.0	1.2					0	47	525	Nil	26	45	29	15	CL	SiL				0.15	1.4	6.5	120	
	71,551	Bt2	22–37	5.6	1.7	2.9	0.5	12.3	4.2	21.8	0.4								Nil	27	44	29	18	CL	CL		25.0	13.9		1.4			
	71,522	BC	37–46	6.3	1.2	0.1	0.5	13.3	5.0	22.2									Nil	27	43	30	16	CL	CL								
	71,553	C	46–59+	7.6								14.0							Nil	24	48	28	13	SiL-L	SiL		24.3	11.5		1.4			
103		L-F	½–0																														Mod. rapid
	71,554	AC	0–1	7.5							4.3	4.0				0	27	629	tr	30	44	26	13	L	SiL								
	71,555	Ck	1–10	7.7								12.8				0	3	430	3	26	54	20	9	SiL	SiL								
		R	10–23+												Not sampled																		
105		L	½–0																Nil														Mod. rapid
	72,262	Ah	0–3	6.9	0.8	0.1	0.6	44.8	9.6	44.2	12.3								Nil	33	46	21	6	L	L								
	72,263	C	3–6	7.4								16.2							Nil	52	35	13	4	L-SL	SiL								
	72,264	Ahb	6–11	7.3							4.5	1.7							Nil	22	54	24	9	SiL	L-CL								
	72,265	Cg1	11–26	7.2								1.9							Nil	38	45	17	6	L	SiL								
	72,266	Ahbg	26–29	6.8	0.6	0.2	0.5	35.2	13.0	41.9	4.1								Nil	10	50	40	20	SiCL	CL								
	72,267	Cgk	29–32	6.9	0.3	0.1	0.4	21.4	11.7	24.5		10.2							Nil	5	59	36	14	SiCL	CL								
	72,268	Cg2	32–37+	7.0	0.3	0.1	0.2	13.6	5.9	14.9		2.2							Nil	21	53	26	9	SiL	SL								
106	71,556	L-H	1–0																Nil														Slow
	71,557	Ae1	0–4	4.8	3.1	0.2	0.5	2.7	0.6	10.3	1.2					0	64	344	Nil	18	67	15	3	SiL	SiL		27.9	6.2					
	71,558	Ae2	4–7	5.1	1.9	0.1	0.3	3.9	0.9	10.3	1.6								Nil	14	68	18	5	SiL	SiL								
	71,559	Bt1	7–14	5.1	2.4	1.3	0.5	8.1	2.8	17.9	0.8								Nil	10	55	35	16	SiCL	CL				0.43				
	71,560	Bt2	14–25	4.8	3.6	0.1	0.7	11.1	4.9	25.3	0.8								Nil	3	53	44	24	SiC	C								
	71,561	BC	25–60	4.8	4.0	0.1	0.5	9.8	5.0	24.3									Nil	2	58	40	17	SiCL	C		51.9	16.9					
	71,562	C	60–74+	5.3	2.1	0.1	0.3	12.5	6.7	24.0									Nil	2	62	36	13	CL	CL								

Appendix A Physical and chemical analyses of soils typifying the major map units in Waterton Lakes National Park

Map unit	Lab. No.[1]	Horizon	Depth (in.)	pH, $CaCl_2$	Exch. cations meq/100 g: H	Na	K	Ca	Mg	E.C.[2] (det.) meq/100 g	Organic carbon %	% $CaCO_3$ equiv.	Oxalate extractable: Fe %	Al %	Fe+Al %	Pounds per acre available[3]: N	P	K	Gravel %	% from faction <2 mm: Sand	Silt	Clay	Fine clay	Textural classes: Lab. det.	Field est.	Moisture: 1/10 Bar %	1/3 Bar %	15 Bar %	Est. avail. water (in./in.)[9]	Bulk density	Infiltration (in./h)[7]	Percolation (min/in.)[8]	Est. permeability[10]
107	72,194	L-H	1–0	4.4							32.3																						Slow
	72,195	C1	0–8	4.6	4.2	0.1	0.3	2.7	1.5	9.3	1.0								Nil	9	63	27	4	SiL-SiCL	SiCL								
	72,196	C2	8–13	4.8	4.3	0.1	0.3	4.5	3.3	13.2	0.9								Nil	4	53	43	15	SiC	SiCL								
	72,197	C3	13–20	4.6	4.8	0.1	0.3	5.6	4.4	15.5									Nil	3	49	48	22	SiC	C								
	72,198	C4	20–40+	4.6	4.6	0.2	0.4	8.1	6.6	19.7									Nil	2	43	55	27	SiC	C								
141	72,305	L-H	2–0	5.4																													Rapid
	72,306	C1	0–23	5.6	1.3	Nil	0.2	4.4	2.1	8.2									61	60	29	11	4	GSL	GLCoS								
	72,307	C2	23–32+	6.1	0.7	tr	0.1	2.2	2.0	5.6									72	74	20	6	3	GCoSL	GLCoS								
142	71,544	Ah	0–4	6.6	1.0	tr	0.6	7.3	2.1	13.4	3.7					0	7	427	37	78	17	5	3	GLCoS	GSL		11.4	7.7					Rapid
	71,545	C1	4–29	6.8	0.7	tr	0.3	10.3	3.1	16.0	2.4	0.5							63	60	33	7	4	GSL	GSL				0.03				
	71,546	C2	29–35+	6.7		0.1	0.2	7.5	2.4	13.2	2.2	0.7							60	50	39	11	6	GL	GSL		7.8	3.3					
150	72,202	L-F	1–0	5.1																													Rapid
	72,203	Ah	0–5	5.5	2.6	tr	1.5	4.8	1.9	10.3	2.0								59	63	29	8	3	GFSL	GSL								
	72,204	C	5–12	5.5	2.3	0.1	0.5	2.5	1.4	7.6	1.2		0.22	0.13	0.35				78	46	42	12	4	GL	GSL								
	72,205	Bfb	12–22	5.5	3.6	0.1	0.4	1.4	0.6	13.9	1.7		0.56	1.75	2.31				68	58	38	4	1	GFSL	GL								
	72,206	Cb	22–40+	5.7	1.2	tr	0.1	2.3	1.5	5.5	0.4		0.08	0.12	0.20				78	62	35	7	3	GCoSL	GCoSL								
156	72,289	L-F	1½–0	4.5																													Rapid
	72,290	Ae	0–4	4.3	9.4	0.1	0.2	1.3	0.7	13.8	2.2		0.29	0.14	0.43				84	24	63	13	3	GSiL	GSL				0.05				
	72,291	Bf	4–16	5.1	5.9	tr	0.2	0.9	0.5	15.4	2.2		0.78	1.17	1.95				12	41	51	8	1	GSiL-L	GSL		23.4	10.9					
	72,292	C	16–30+	4.9	1.8	0.1	0.1	0.3	0.6	3.8			0.07	0.06	0.13				75	44	47	9	2	GL	GSL		9.5	3.4					
160	72,220	L-H	2½–0	4.8																													Mod.
	72,221	Ae	0–3	5.2	3.2	tr	0.5	6.4	2.2	12.3	1.9								29	26	56	18	6	GSiL	GL								rapid
	72,222	Bt1	3–8	5.5	2.6	tr	0.3	7.3	2.9	14.5	1.7								34	30	47	23	12	GL	GCL		21.4	11.7	0.07				
	72,223	Bt2	8–15	6.0	1.4	tr	0.2	12.7	3.8	15.8	1.5								39	28	51	21	12	GCL	GCL								
	72,224	Ck	15–40+	7.0	0.1	tr	0.2	26.4	3.2	13.3		11.2							70	27	50	23	10	GSiL-L	GCL								
170	72,279	C	0–50+	6.4	0.1	tr	0.2	6.3	1.1	5.2									Nil	79	15	6	2	LS	LCoS								Rapid
171		C	0–16													Pedon not sampled									LS								Rapid
		IIAhb	16–26																						SL								
		IIBmb	26–36																						GSL								
		IICb	36–40+																						VGLS								
190	72,298	Of1	0–14	6.0																										0.2			
	72,299	Of2	14–35	6.0																										0.1			
	72,300	Of3	35–52+	6.1																										0.1			
90R	72,320	Ah	0–1	5.5	3.3	tr	0.5	5.0	1.5	7.7	3.9								9	79	16	5	2	CoSL	SL								
	72,321	C	1–12	5.6	2.0	tr	0.2	3.8	1.5	8.5									22	77	15	8	2	GLCoS	SL-LS								
		R	12+																														
91R	72,199	L-F	2–0	4.8																													
	72,200	Bm	0–5	5.7	2.4	tr	0.1	7.7	3.7	14.5	2.7		0.53	0.27	0.80				32	12	66	22	7	GSiL	GL								
	72,201	C	5–14	6.2	1.2	tr	0.1	8.9	4.6	13.1			0.34	0.16	0.50				Nil	5	70	25	10	SiL	SiL								
		R	14+																														

[1]Alberta Institute of Pedology laboratory number. See the section on methodology for details of procedures.
[2]Exchange capacity or cation exchange capacity.
[3]Analyses by the Alberta Soil and Feed Testing Laboratory. The following key provides an evaluation of the data:

	high	medium	low
N	> 51	21–50	0– 20
P	> 71	31–70	0– 30
K	> 300	151–300	0–150

[4]Blank—not determined or irrevelant.
[5]Value estimated.
[6]tr—trace.
[7]Infiltration rates apply to the surface horizons and are governed, more or less, by the horizons below.
[8]Percolation rates apply to the horizons at 20 to 30 inches from the surface and are governed, more or less, by the horizons below.
[9]The values for estimated available water (storage capacity) for plant growth based on the difference between field capacity and wilting point are a summation for the rooting zone.
[10]Permeability classes of slow, moderate, moderately rapid, and rapid are used as defined by Soil Survey Staff. 1951. Soil survey manual. U.S. Dept. Agric. Handbook 18, Govt. Printing Office, Washington, D.C. pp. 167-168.

Appendix B Engineering test data for soils of Waterton Lakes National Park

Parent materials	Map unit	Horizon	Depth (in.)	Mechanical analysis (from fraction < 3 in.[1]) % smaller than 0.05 mm	0.02 mm	0.005 mm	0.002 mm	% passing sieve 3 in.	¾ in.	No. 4	No. 10	No. 40	No. 200	Plasticity: Liquid limit %	Plasticity index	Activity[2]	Optimum moisture %[3]	Maximal dry density p.c.f.[3]	pH ($CaCl_2$)	Organic matter %	Classification: AASHO[7]	Unified[8]	Textural (USDA)
Gravelly glacial outwash	1	Ah	0–8	26	20	12	8	100	[4]	76	66	40	31						5.2	8.7			GCSL
		Bm1	8–15	14	11	7	5	100		34	26	20	14						5.1	5.3			GSL
		Bm2	15–30	2	2	2	1	100		12	6	5	2						6.5	2.3			GCoSL
		Ck	30–40+	6	3	3	2	100		37	24	12	6	NP[4]	NP				7.3		A-1-a	GP-GM	GLCoS
Gravelly and flaggy glacial outwash	4	Ah	0–3½																				GL[5]
		Bm	3½–12											Pedon not sampled									GL[5]
		C	12–15																				GSL[5]
		R	15+																				
Very sandy loam to silt loam, outwash, gravel-free	8	Ah	0–4	36	22	10	8	100		93	91	84	50						6.0	7.8			VFSL
		AB	4–6	48	30	13	6	100		94	93	85	56						6.0	2.2			SL
		Bm	6–13	51	32	13	4	100		98	95	81	56						5.9	1.5			SiL-SL
		BC	13–18	41	25	10	5				100	96	68						7.3				VFSL
		Ck1	18–28	70	45	15	2				100	96	75						7.7				SiL
		Ck2	28–41+	72	50	17	2				100	96	77	NP	NP				7.7		A-4	ML	SiL
Coarse alluvium with few boulders	11	L-H	½–0																				
		C1	0–7	76	60	33	22				100	95	80						7.2	6.6			SiL[6]
		C2	7–20	12	10	6	5	100	84	52	41	27	12						7.2	0.8			GSL[6]
		C3	20–30	32	19	19	11	100			98	67	34						7.2	0.4			SL[6]
		C4	30–40+	8	7	4	3	100	74	41	25	10	8	NP	NP				7.4		A-1-a[6]	GP-GM[6]	GCoSL[6]
15–20 in. silty surficial deposit over fine textured till	12	L-F	1–0																				
		Ah	0–5	69	54	31	21	100		99	96	91	79						4.8	12.1			SiL-L
		C	5–11	61	42	23	15	100		96	94	85	68						4.9	1.5			SiL-L
		Cg	11–17	66	56	32	21	100		87	86	82	70						4.9	0.7			SiL
		IIABgb	17–20	71	56	35	24	100		97	95	90	80						4.8	0.9			SiL
		IIBtgb1	20–30	77	56	40	34	100		97	96	95	87						5.1	1.7			CL
		IIBtgb2	30–43	77	64	41	32	100		99	98	97	90						5.1	2.1			CL
		IIBCgb	43–46+	70	56	39	32	100		83	82	81	75	50	28	0.8	23	100.0	5.8		A-7-6	CH	CL
Poorly drained fine textured river alluvium	14	L-H	8–0																6.9				
		A&Cg	0–2	98	88	47	21					100	98						6.8	10.2			SiCL
		Cg	2–20	97	83	42	30				100	98	98	53	23	0.8		91.0	6.9	3.2	A-7-5	MH	SiCL
Medium textured river alluvium with few stones	15	Ah1	0–5	91	65	35	22				100	99	95						7.0	7.8			SiL
		Ah2	5–10	90	64	33	22				100	99	95						6.8	5.8			SiL
		C1	10–26	92	65	36	23				100	99	95						6.4				SiL
		C2	26–38+	93	65	35	22				100	99	96	35	10	0.5			7.0		A-4	ML	SiL
Stone-free silt loam river alluvium	16	Ah	0–4	81	62	36	25				100	96	85						6.8	10.2			SiL
		Ck1	4–16	80	63	36	24				100	95	83						7.1				SiL
		Ck2	16–40+	85	72	40	27				100	96	87	42	15	0.6			7.5		A-7-6	ML-CL	SiL
Gravelly, coarse textured river alluvium	17	Ah1	0–1																6.0	22.1			SL[6]
		Ah2	1–10																5.5	4.1			G[5]L[6]
		Bm	10–26																6.9	3.4			G[5]L[6]
		Cca	26–31																6.9				VG[5]SiC[6]
		Ck	31–40+	17	13	10	8	100	62	43	24	21	18	22	8	1.0	12	120.0	7.2		A-2-4[6]	GC[6]	GL[6]
Coarse textured river alluvium	18	L-F	½–0																4.8				
		Ah	0–2	42	32	17	10	100			72	58	45						4.6	3.5			GSL
		Bm	2–14	7	4	2	1	100			30	21	8						5.2	1.3			GSL
		C	14–26+	4	2	2	1	100		29	16	10	4	NP	NP				7.0		A-1-a	GP	VGSL
Coarse textured alluvium	19	Ah1	0–15																5.7	6.2			GFSL
		Ah2	15–37																5.8	3.3			GFSL
		AC	37–43																6.2	2.9			GFSL
		Ck	43–50+	12		6	5	100	81	23	17	16	13	28	6	1.2	20	101.0	6.8		A-1-a	GM	GL
Alluvium	20									Not sampled											A-1-a[5,6]	GP[5,6]	Cobbly[5,6]

Appendix B Engineering test data for soils of Waterton Lakes National Park

Parent materials	Map unit	Horizon	Depth (in.)	Mechanical analysis (from fraction < 3 in.[1]) % smaller than 0.05 mm	0.02 mm	0.005 mm	0.002 mm	% passing sieve 3 in.	¾ in.	No. 4	No. 10	No. 40	No. 200	Plasticity: Liquid limit %	Plasticity index	Activity[2]	Optimum moisture %[3]	Maximal dry density p.c.f.[3]	pH (CaCl₂)	Organic matter %	Classification: AASHO[7]	Unified[8]	Textural (USDA)
Coarse textured fan alluvium	21	Ah	0–5	23	18	10	6	100			51	30	24						7.1	5.1			GSL[6]
		Ck1	5–30	11	9	3	2	100	67	40	38	18	11						7.7				VGLCoS[6]
		Ck2	30–35+	12	9	4	2	100	64	61	57	20	12	NP	NP				7.1		A-1-b[6]	SP-SM[6]	VGLCoS[6]
Coarse textured very stony fan alluvium	22	Ah	0–12	30	20	11	8	100			56	46	32						6.3	6.9			GL[6]
		Bm	12–28	11	10	5	3	100			30	20	11						7.3	2.9			VGCoSL[6]
		Ck	28–36+	12	10	6	4	100	88	64	45	22	13	27	5	1.3	22	100.0	7.6		A-1-a[6]	SC[6]	VGCoSL[6]
Fan alluvium	25	Ah	0–1½	37	30	16	11	100	96	90	84	61	39						6.7	8.1			CoSL
		C1	1½–6	47	38	21	14	100	96	92	86	74	50						7.2	5.6			L
		C2	6–11	8	6	4	2	100	56	31	22	13	8						7.4	1.9			GCoSL
		C3	11–45+	73	54	29	19		100	99	98	92	77	37	9	0.5			7.3	ND	A-4[6]	ML[6]	SiL
Nonstony fan alluvium	26	Ah	0–12	49	35	17	12				100	89	51						6.4	9.3			L
		C1	12–29	53	40	23	14				100	89	60						7.0				L
		Ck1	29–42	41	30	15	8		100	97	95	83	45						7.1		A-4[5]	SM[5]	FSL
		Ck2	42–46+	8	6	4	2	100	55	28	22	15	8	NP	NP				7.2		A-1-a	GP-GM	GSL
Gravelly and sandy fan alluvium	27	L-H	2–0																4.4				
		C1	0–1												Not sampled								
		C2	1–7																5.8	3.4			GCoSL[6]
		C3	7–15																6.0	0.6			GLCoS[6]
		C4	15–17½																6.0	5.4			L[6]
		C5	17½–35																6.1	0.3			GLS[6]
		C6	35–44+	7		4	2	100	72	45	21	12	7	NP	NP				6.0	0.3	A-1-a[6]	GP-GM[6]	GCoSL[6]
Coarse textured fan alluvium	28	L-H	½–0																4.3				
		Ah	0–4½	20	14	8	5	100			43	31	22						4.9	4.1			GSL
		Bf	4½–15	17	12	6	4	100			41	28	19						5.2	1.7			GSL
		C	15–30+	7	4	3	2	100	74	43	22	12	6	16	2	1.0	10	125.0	5.1		A-1-a	GP-GM	GCoSL
Imperfectly drained fan alluvium	29	L	¼–0																				
		Ck1	0–2	70	45	18	9				100	92	74						7.3				SiL
		Ahb	2–4	93	78	48	33				100	99	95						7.1	15.1			SiCL
		Ck2	4–10	64	41	20	11				100	92	70						7.5				SiL
		Ckg1	10–18	19	11	5	4				100	74	24						7.5	0.3			LS
		Ckg2	18–29	55	38	27	14				100	95	61						7.6	0.4			FSL
		Ckg3	29–35+	17	10	5	4	100	47	43	42	37	18	NP	NP				7.0	0.3	A-1-b	GM	GFSL
Medium textured alluvium (very poorly drained)	31	Ahgk	0–6	93	84	56	41				100	99	94						7.7	19.9			SiC
		Bgk	6–16	68	50	32	24				100	92	73						7.8	2.1			L
		BCgk	16–30	75	61	38	27	100	98	94	90	82	73						7.9				SiCL
		Cgk	30–35+	67	55	30	17		100	99	96	87	71	36	17	1.0	19	105.0	7.8		A-6	CL	SiL
Alluvium on fan margins (poorly drained)	32	Ahg	0–5	68	52	25	14				100	91	73						7.2	10.6			SiL
		Bg1	5–7	62	43	20	10		100	99	98	90	68						7.3	3.4			SiL
		Bg2	7–21	52	37	21	14		100	99	97	85	58						7.1	2.2			L
		Cg	21–30+	49	33	18	11		100	96	93	80	55	26	3	0.3	20	97.5	7.6		A-4	ML	L
Sandy material over sandstone at >5 ft	36	L-H	1½–0																6.8				
		Ahe	0–3	64		27	21	100			94	90	70						6.8	16.4			FSL
		Ae	3–6	45	30	17	12				100	96	50						6.8	3.8	A-4[5]	ML[5]	FSL
		Bt	6–18	45	34	25	22			100	98	94	52						6.9	1.4	A-6[5]	CL[5]	SCL
		C1	18–38	53	44	34	29			100	98	96	55						7.0		A-4[5]	ML[5]	FSL
		C2	38–43+	25	14	5	3				100	98	31	NP	NP				6.9		A-2-4	SM	LFS
Coarse and medium textured stratified alluvium	37	L-H	6–0																6.0				
		Ah	0–5	43	33	19	13				100	76	47						6.2	8.9			SL[6]
		C	5–18	52	39	22	13				100	85	56						6.0				L[6]
		Ahb	18–21	37	32	16	11				96	72	41						6.1	2.6			SL[6]
		Cg	21–24+	36	26	16	11				100	67	38	NP	NP				6.2		A-2[6]	SM[6]	SL[6]

Appendix B Engineering test data for soils of Waterton Lakes National Park

Parent materials	Map unit	Horizon	Depth (in.)	Mechanical analysis (from fraction < 3 in.[1]) % smaller than 0.05 mm	0.02 mm	0.005 mm	0.002 mm	% passing sieve 3 in.	¾ in.	No. 4	No. 10	No. 40	No. 200	Plasticity: Liquid limit %	Plasticity index	Activity[2]	Optimum moisture %[3]	Maximal dry density p.c.f.[3]	pH (CaCl2)	Organic matter %	Classification: AASHO[7]	Unified[8]	Textural (USDA)
Loose coarse local alluvium	38	Ah1	0–8	25	18	11	9	100		94	85	58	27						6.2	5.6			CoSL[6]
		Ah2	8–12	7	5	3	2	100			14	9	8						6.9	1.3			GL[6]
		C1	12–28	12	10	5	0	100	52	42	35	20	12						7.0				GCoSL[6]
		C2	28–32+	18	14	8	5	100	90	74	58	34	20	25	6	1.2	18	105.0	7.3		A-1-b[6]	SM-SC[6]	GCoSL[6]
Fairly coarse textured, loose alluvium–colluvium	39	F-H	2–0																6.1				
		Ah	0–1	51	41	22	5				100	93	65						6.1	31.0			L[6]
		C1	1–11	13	16	8	3	100	97	91	69	43	26						6.6				GCoSL[6]
		Ahb	11–12	Not sampled																			
		C2	12–26+	9	6	5	2	100	66	37	26	17	10	25	5	2.0	18	105.0	6.9		A-1-b[6]	GM-GC[6]	GSL[6]
Shallow alluvium over loam till	41	L-H	2–0																				
		C1	0–5	65	50	28	20	100	96	94	93	86	69						6.9				L-SiL
		C2	5–17	67	54	31	20	100	97	95	91	84	70						6.9				SiL
		IIC1	17–33	55	41	23	15	100	96	89	81	75	59						7.1				GL
		IIC2	33–40+	36	26	14	9	100	75	65	62	34	40	27	6	0.7	19	100.0	7.3		A-4	CL-ML	GL
Stone-free medium textured fan alluvium	42	Ah	0–8	77	64	39	26			100	99	92	80						6.2	7.4			SiL
		C1	8–24	76	60	33	23			100	98	95	81						5.9		A-6[5]	CL[5]	SiL
		C2	24–47	77	64	37	25			100	98	93	82						6.1		A-6[5]	CL[5]	SiL
		C3	47–51+	32	26	16	12	100	66	51	45	41	33	43	23	1.9	20	102.0	6.5		A-2-7	GC	GL
Cobbly, coarse textured fan alluvium (poorly drained)	44	Ah	0–4																				L[5,6]
		Cg	4–20+	Pedon not sampled																	A-4[5,6]	CL[5,6]	GSL[5,6]
Medium textured alluvium with many coarse fragments	46	L-F	½–0																4.5				
		Ae	0–3	49	37	20	12	100			89	79	58						5.7	2.6			L
		Bt	3–15	34	30	21	16	100			49	41	36						6.5	5.6			GCL
		Ck	15–25+	14	10	4	3	100	74	36	22	18	15	19	3	1.0	12	117.5	7.1		A-1-a	GM	GSiL-L
Gravelly, coarse textured fan alluvium	47	L-H	2–0																4.4				
		Ae	0–1	35	29	19	14	100			45	41	37						4.2	4.4			GSiL
		Bm	1–12	18	15	7	4	100			44	26	19						5.3	1.3			GCoSL
		C	12–25+	14	10	6	4	100	93	78	60	28	16	21	2	0.5	16	107.5	5.5		A-1-a	SM	GCoSL
Stratified, coarse textured cobbly alluvium	48	L-F	2–0																4.6				
		C1	0–18	29	23	16	12	100	95	65	39	34	31						4.7				GCL[6]
		C2	18–30+	9	6	4	3	100	72	37	20	12	9	25	15	5.0	12	125.0	5.1		A-2-6[6]	GP-GC[6]	GCoSL[6]
Coarse textured, fairly stable alluvium	49	L-H	½–0																3.8				
		Ae	0–4	28	22	10	4	100			34	33	30						4.1	5.0			GSiL[6]
		Bf	4–12	38	28	13	5	100			49	45	40						5.3	5.9			GSiL[6]
		Aeb	12–16	19	13	16	3	100			29	25	20						4.7	1.3			GSiL[6]
		Bfb	16–20	12	8	4	2	100			22	17	13						5.2	1.6			GFSL[6]
		C	20–35+	11	7	4	2	100	72	40	29	20	13	NP	NP				4.6		A-1-a[6]	GM[6]	GFSL[6]
Coarse to medium textured, compact, high lime till	50	Ah1	0–3½	44	33	16	10	100			85	70	48						6.3	15.9			GL
		Ah2	3½–6	33	25	13	8	100			57	49	36						5.6	4.0			GL
		Bm	6–17	29	23	12	8	100			51	45	33						6.3	1.5			GL
		Ck	17–24+	34	29	15	7	100	94	63	57	48	38	17	2	0.3	10	120.0	7.7		A-4	SM	GL
Light brown, medium to coarse textured till	52	L-F	1–0																4.3				
		Ah	0–1	52	43	20	10	100			73	65	56						5.0	14.0			GSiL[6]
		Bf	1–10	32	24	7	6	100			50	42	33						5.4	3.8			GSiL[6]
		C	10–30+	23	18	9	4	100	82	59	45	33	25	25	5	1.3	18	105.0	4.8		A-1-b[6]	SM-SC[6]	GL[6]
Stony, coarse textured, poorly drained till	53	L	½–0																5.1				
		Ahg	0–3½	92	65	33	26				100	98	95						5.0	1.5			SiL
		Bg	3½–7	78	63	33	22			100	96	92	84						5.1	7.9			SiL
		BCg	7–10	26	20	11	9	100			34	31	27						5.2	3.6			GSiL
		Cg	10–20+	56	40	20	10			100	97	95	61	19	4	0.4	12	111.0	5.1		A-4	ML	L

Appendix B Engineering test data for soils of Waterton Lakes National Park

Parent materials	Map unit	Horizon	Depth (in.)	Mechanical analysis (from fraction < 3 in.[1]): % smaller than 0.05 mm	0.02 mm	0.005 mm	0.002 mm	% passing sieve 3 in.	¾ in.	No. 4	No. 10	No. 40	No. 200	Plasticity: Liquid limit %	Plasticity index	Activity[2]	Optimum moisture %[3]	Maximal dry density p.c.f.[3]	pH (CaCl2)	Organic matter %	Classification: AASHO[7]	Unified[8]	Textural (USDA)
Bouldery and stony till	54	Ah	0–1½																4.8	18.1			L[6]
		C	1½–15+	17	14	11	8	100	69	42	23	19	17	47	10	1.3			4.5	3.7	A-4[6]	GM[6]	GCL[6]
Stony calcareous till	55	L-F	1–0																6.5				
		Ck1	0–6	31	22	12	7	100	98	93	86	66	35						7.1	2.9			SL[6]
		Ck2	6–24	12	12	12	12	100	86	62	44	24	14						7.2	1.2			GLCoS[6]
		Ck3	24–30	7	7	3	2	100	55	46	21	16	8						7.4	0.2			GSL[6]
		Ck4	30–40+	14	11	7	5	100	76	53	40	30	15	NP	NP				7.3	0.5	A-1-a[6]	SM[6]	GSL[6]
Compact calcareous pinkish gravelly loam till	57	L-F	1–0																				
		Ae1	0–3	32	26	13	7	100			66	46	33						4.3	2.5			GCoSL
		Ae2	3–5½	40	29	15	7	100			65	57	44						4.3	2.0			GSiL-L
		Bt1	5½–17½	38	30	20	15	100			59	51	40						4.9	1.2			GL
		Bt2	17½–26	40	30	20	14	100			65	56	42						6.8	1.3			GL
		Ck	26–32+	38	22	16	11	100	85	72	65	56	40	36	18	1.7	18	107.0	7.3		A-6	SC	GL
Silty clay loam till	58	L-H	2–0																6.2				
		Ahe	0–6																5.1	2.2			SiL
		Bt1	6–12																5.5	1.6			SiCL
		Bt2	12–20																5.7	1.2			SiL
		Ck1	20–25																7.1				SiL
		Ck2	25–50+	87	60	28	15		100	98	95	94	92	37	17	1.1	20	105.0	7.3		A-6	CL	SiL
Very stony, medium and coarse textured till	61	L	½–0																				GSiL[5,6]
		Ae	0–2									Pedon not sampled											VGSiCL[5,6]
		Bt	2–9																				
		C	9–20+																		A-1-a[5,6]	SM[5,6]	VGSiL[5,6]
Silt loam near surface, gravelly sandy loam till at 15 to 20 in.	64	L-H	1–0																				
		Ae	0–1	61	46	16	6	100			81	75	64						3.4	4.0			SiL[6]
		Bf1	1–5	50	40	18	9	100			70	63	53						4.4	10.6			GSiL[6]
		Bf2	5–11	49	34	13	4	100			78	68	52						4.9	4.5			GSiL[6]
		C1	11–28	26	18	8	4	100			49	42	29						4.3		A-1-a[5]	SM[5]	GL[6]
		C2	28–38+	13	8	4	3	100	74	52	38	26	14	18	2	0.7	12	117.0	4.6		A-1-a[6]	SM[6]	GSL[6]
Shallow deposit of fine textured till over rock	66	Ah	0–1	44	30	16	10	100			74	69	50						6.6	5.0			L
		Bm	1–11	60	45	31	24	100			100	91	65						6.6	3.2			CL
		Ck	11–26+	35	25	16	13	100	93	70	50	47	33	40	20	1.5	20	102.5	7.3		A-2-6	SC	GSiCL
Fine textured relatively stone-free Continental till	67	Ah	0–9	61	47	30	23	100			95	85	65						5.8	15.0			CL
		Bm	9–17	65	54	31	23	100			95	87	70						5.2	3.2			L
		BC	17–38	91	83	47	40	100			95	94	92						5.2				L
		C	39–46+	78	66	31	24	100			96	93	80	43	18	0.7	26	93.5	6.0		A-7-6	CL	SiC
Fine textured material, probably weathered shale	100	L-H	½–0																				
		C1	0–7	93	82	58	44					100	95						5.4	5.9			SiC
		C2	7–11	94	82	63	49					100	96						5.6	6.6			SiC
		Btb1	11–23	93	81	57	45					100	96						5.9	3.8			SiC
		Btb2	23–40	93	84	60	46					100	96						6.1	2.4			SiC
		BCb	40–48+	94	84	61	49					100	96	58	30	0.6	27	90.0	6.3		A-7-6	CH	SiC
Fine textured, water translocated, weathered shale materials	101	L-H	1–0																5.4				
		C1	0–4	30	25	15	11			97	94	64	20						5.2	5.5			SiL
		Ahb	4–10	73	54	28	16			100	98	87	76						5.8	5.2			SiL
		C2	10–16	47	38	19	13		100	98	96	59	46						5.9	1.8			L
		C3	16–23	77	57	35	26				100	99	85						5.9	1.1			SiL
		C4	23–29	94	47	28	23					100	85						6.3				SiL
		C5	29–40+	81	61	41	33				100	97	86	44	19	0.6	26	92.5	6.7		A-7-6	CL	SiCL

Appendix B Engineering test data for soils of Waterton Lakes National Park

Parent materials	Map unit	Horizon	Depth (in.)	Mechanical analysis (from fraction < 3 in.[1]): % smaller than 0.05 mm	0.02 mm	0.005 mm	0.002 mm	% passing sieve 3 in.	¾ in.	No. 4	No. 10	No. 40	No. 200	Plasticity: Liquid limit %	Plasticity index	Activity[2]	Optimum moisture %[3]	Maximal dry density p.c.f.[3]	pH (CaCl2)	Organic matter %	Classification: AASHO[7]	Unified[8]	Textural (USDA)
Fine textured material of either eroded local lucustrine or weathered shale origin	102	L-H	2–0																				
		Ae1	0–5	65	50	27	16				100	92	73						5.4	3.1			SiL-L
		Ae2	5–9	66	51	36	28				100	91	71						5.3	1.6			L
		AB	9–13	Not sampled																			
		Bt1	13–22	74	59	39	29				100	92	78						5.3	2.0			CL
		Bt2	22–37	73	58	39	29				100	93	77						5.6	0.7			CL
		BC	37–46	73	59	40	30				100	92	77						6.3				CL
		Ck	46–59+	76	60	40	28				100	94	80	44	22	0.8	22	97.5	7.6		A-7-6	CL	SiL-L
Fine textured calcareous deposit shallow to limestone	103	L-F	½–0																				
		AC	0–1	70	54	35	26				100	92	74						7.5	7.5			L
		Ck	1–10	72	58	34	20		100	99	96	89	75						7.7		A-7-6[5]	CL[5]	SiL
		R	10–25+																				
Fine and medium textured, imperfectly drained alluvium	105	L	½–0																				
		Ah	0–3	67	46	28	21				100	93	74						6.9	21.3			L
		C	3–6	48	30	19	12				100	90	60						7.4				L-SL
		Ahb	6–11	78	73	35	24				100	95	85						7.3	7.8			SiL
		Cgk	11–26	62	43	25	17				100	92	70						7.2				L
		Ahbg	26–29	90	75	50	40				100	99	93						6.8	7.1			SiCL
		Cg1	29–32	95	75	46	36				100	99	98	45	18				6.9		A-7-6	CL	SiCL
		Cg2	32–37+	79	60	47	26				100	95	83	35	14	0.5	22	100.0	7.0		A-6	CL	SiL
Fine textured materials of either eroded local lacustrine or weathered shale origin	106	L-H	1–0																				
		Ae1	0–4	82	61	28	15				100	97	85						4.8	2.0			SiL
		Ae2	4–7	86	74	35	18				100	96	88						5.1	2.8			SiL
		Bt1	7–14	90	81	52	35				100	98	92						5.1	1.3			SiCL
		Bt2	14–25	97	84	56	44					100	98						4.8	1.3			SiC
		BC	25–60	98	88	56	40						100						4.8				SiCL
		C	60–74+	98	88	53	36					100	99	48	23	0.6	26	92.5	5.3		A-7-6	CL	CL
Fine textured residual weathered shale	107	L-H	1–0																4.4	55.9			
		C1	0–8	91	72	38	28				100	98	93						4.6	1.7			SiL-SiCL
		C2	8–13	96	80	52	43					100	98						4.8	1.6			SiC
		C3	13–20	97	80	56	48					100	98						4.6				SiC
		C4	20–40+	98	81	62	55					100	99	44	20	0.4	24	95.0	4.6		A-7-6	CL	SiC
Fine gravelly, coarse textured loose colluvium	141	L-H	2–0																5.4				
		C1	0–23	16	13	7	4	100	96	76	40	28	18						6.0				GSL[6]
		C2	23–32+	7	6	3	2	100	95	69	28	17	8	21	1	0.5	16	102.5	6.1		A-1-a[6]	SP-SM[6]	GCoSL[6]
Fine gravelly, coarse textured loose colluvium	142	Ah	0–4	15	13	8	5	100			63	28	11						6.6	6.3			GLCoS[6]
		C1	4–29	15	20	9	3	100	67	57	36	33	25						6.8	4.2			GSL[6]
		C2	29–35+	20	16	9	5	100	79	65	46	32	22	NP	NP				6.7	3.9	A-1-b[6]	SM[6]	GL[6]
Fine gravelly, coarse textured loose colluvium	150	L-F	1–0																5.1				
		Ah	0–5	15	9	3	2				41	31	17						5.5	3.5			GFSL
		C	5–12	11	7	3	2	100	55	30	22	19	13						5.5	2.1			GL
		Bfb	12–22	14	8	3	2	100			33	24	15						5.5	2.9			GFSL
		Cb	22–40+	14	8	4	1	100	87	43	32	24	16	23	6	6.0	14	112.5	5.7	0.7	A-1-a	SM-GC	GCoSL
Fine gravelly, coarse textured loose colluvium	156	L-F	1½–0																4.5				
		Ae	0–4	12	8	4	2	100			16	15	13						4.3	3.8			GSiL[6]
		Bf	4–16	53	37	18	7	100			88	77	57						5.1	3.8			GSiL-L[6]
		C	16–30+	15	10	4	2	100	72	34	25	22	17	NP	NP				4.9		A-1-b[6]	GM[6]	GL[6]

Appendix B Engineering test data for soils of Waterton Lakes National Park

Parent materials	Map unit	Horizon	Depth (in.)	Mechanical analysis (from fraction < 3 in.[1]): % smaller than 0.05 mm	0.02 mm	0.005 mm	0.002 mm	% passing sieve: 3 in.	¾ in.	No. 4	No. 10	No. 40	No. 200	Plasticity: Liquid limit %	Plasticity index	Activity[2]	Optimum moisture %[3]	Maximal dry density p.c.f.[3]	pH ($CaCl_2$)	Organic matter %	Classification: AASHO[7]	Unified[8]	Textural (USDA)
Coarse and medium textured fairly loose colluvium	160	L-H	2½–0																4.8				
		Ae	0–3	53	40	22	13	100			71	64	55						5.2	3.4			GSiL
		Bt1	3–8	46	35	22	15	100			65	61	49						5.5	2.9			GL
		Bt2	8–15	44	34	20	13	100			61	57	46						6.0	2.7			GCL
		Ck	15–40+	22	21	13	7	100	92	51	30	24	22	31	10	1.4	20	102.5	7.0		A-2-4	SC	GSiL-L
Coarse textured windblown materials	170	C	0–50+	21	14	8	6	100			100	78	25	NP	NP				6.4		A-2-4	SM	LS
Wind-blown surficial material over river terrace alluvium	171	C	0–16	Pedon not sampled																			LS[5]
		IIAhb	16–26																				SL[5]
		IIBmb	26–36																				GSL[5]
		IICb	36–40+																		A-1-b[5]	GC[5]	VGLS[5]
Relatively undecomposed organic material	190	Of1	0–14	Organic soil															6.0	>95[5]			
		Of2	14–35																6.0	>95[5]			
		Of3	35–52+																6.1	>95[5]			
Variable shallow alluvium or colluvium, much rock outcrop	90R	Ah	0–1	19	14	7	4	100			91	26	20						5.5	6.9			CoSL[6]
		C	1–12	18	14	8	6	100			78	46	6						5.6		A-1-b[5,6]	GP-GM[5,6]	GLCoS[6]
		R	12+																				
Shallow silt loam over dolomite bedrock	91R	L-F	2–0																4.8				
		Bm	0–5	60	38	21	15	100			68	63	53						5.7	4.6			GSiL
		C	5–14	95	64	34	25				100	99	96	44	11	0.4			6.2		A-7-6	ML	SiL
		R	14+																				

[1]Mechanical analyses were determined by the pipet procedure (Toogood and Peters 1953), then cumulative curves drawn and percent passing 40 and 200 mesh sieves read from the curves. Gravels were sieved to arrive at the percent passing 4 mesh, and ¾ in. sieves.

[2]Activity was calculated from plastic index and percent passing 200 mesh sieve (Means and Parcher 1963).

[3]Standard Proctor tests for maximum density and optimum moistures percentage were based on the correlation method outlined by Ring and Sallberg (1962) using the nomograph charts developed by the Highways Laboratory, Alberta Department of Highways.

[4]Blank—not determined; NP—not plastic.

[5]Value estimated.

[6]Texture and percentage of coarse fragments variable within map unit.

[7]American Association of State Highway Officials. 1961. Standard specifications for highway materials and methods of sampling and testing, 8th ed. Washington, D.C. 2 vols.

[8]United States Army Corps of Engineers. 1957. The Unified soil classification system. Tech. Memorandum No. 3-357, Appendix B. Waterways Exp. Stn., Mississippi.

Appendix C Plants commonly found in Waterton Lakes National Park

Common name	Botanical name
Trees	
alpine fir	*Abies lasiocarpa*
alpine larch	*Larix lyallii*
aspen, trembling	*Populus tremuloides*
balsam poplar	*Populus balsamifera*
birch, water	*Betula occidentalis*
birch, white	*Betula papyrifera*
black cottonwood	*Populus tricocarpa*
Douglas-fir	*Pseudosuga menziesii*
maple, mountain	*Acer glabrum*
pine, limber	*Pinus flexis*
pine, lodgepole	*Pinus contorta*
pine, whitebark	*Pinus albicaulis*
spruce, Engelmann	*Picea engelmannii*
spruce, white	*Picea glauca*
Shrubs	
alder, green	*Alnus crispa*
alder, river	*Alnus tenuifolia*
buffaloberry, russet	*Shepherdia canadensis*
cherry, red choke	*Prunus virginiana*
creeping mahonia,	*Berberis repens*
currant, sticky	*Ribes viscosissimum*
currant, wild black	*Ribes hudsonianum*
currant, wild red	*Ribes triste*
dogwood, red osier	*Cornus stolonifera*
gooseberry, wild	*Ribes oxyacanthoides*
grouseberry	*Vaccinium scoparium*
honeysuckle, bracted	*Lonicera involuctra*
huckleberry, false	*Menziesia ferruginea*
juniper, creeping	*Juniperus horizontalis*
juniper, ground	*Juniperus communis*
kinnickinnick	*Arctostaphylos uva-ursi*
pine, prince's	*Chimaphila umbellata* var. *occidentalis*
rose, common wild	*Rosa woodsii*
rose, prickly	*Rosa acicularis*
saskatoon	*Amelanchier alnifolia*
shrubby cinquefoil	*Potentilla fruticosa*
silverberry	*Elaeagnus commutata*
snowberry, western	*Symphoricarpos occidentalis*
tall bilberry	*Vaccinium membranaceum*
thimbleberry	*Rubus parviflorus*
twinflower	*Linnaea borealis* var. *americana*
white meadowsweet	*Spirea lucida*
willow	*Salix* sp.
Herbs	
alum-root	*Heuchera cylindrica*
angelica, yellow	*Angelica dawsonii*
arnica, heart-leaved	*Arnica cordifolia*
arrow-leaved colt's-foot	*Petasites sagittatus*
aster	*Aster* sp.
bear grass	*Xerophyllum tenax*
bedstraw, northern	*Galium boreale*
bishop's cap	*Mitella breweri*
bluebell, common	*Campanula rotundifolia*
Herbs (cont)	
brome, awnless	*Bromus inermis*
brome, awnless northern	*Bromus pumpellianus*
clematis, purple	*Clematis verticellaris*
clintonia, one-flowered	*Clintonia uniflora*
cow parsnip	*Heracleum lenatum*
dandelion, common	*Taraxacum officinale*
daisy, ox-eye	*Chrysanthemum leucanthemum*
fairybells	*Disporum oreganum*
fairybells	*Disporum trachycarpum*
fescue, bluebunch	*Festuca idahoensis*
fescue, rough	*Festuca scabrella*
fireweed	*Epilobium angustifolium*
fleabane (wild daisy)	*Erigeron glabellus* var. *pubescens*
flax, wild blue	*Linum lewisii*
geranium, sticky purple	*Geraninaceae viscosissimum*
goldenrod, mountain	*Solidago decumbens*
grass family	*Gramineae*
hedysarum, yellow	*Hedysarum sulphurescens*
hellebore, false	*Veratrum eschscholtzii*
horse mint	*Monarda fistulosa* var. *menthaefolia*
horsetail, common	*Equisetum arvense*
kentucky bluegrass	*Poa pratensis*
larkspur, low	*Delphinium bicolor*
lily, glacier	*Erythonium grandiflorum*
locoweed, showy	*Oxytropis splendens*
lupine, perennial	*Lupinus argentus*
lupine, Pursh's silky	*Lupinus sericeus*
marigold, marsh	*Caltha palustris*
marsh reed grass	*Calamagrostis canadensis*
oat grass, parry	*Danthonia parryi*
oat grass, timber	*Danthonia intermedia*
onion, prairie	*Allium textile*
orchid, tall white	*Habenaria dilatata*
paintbrush, common red	*Castilleja miniata*
pine grass	*Calamagrostis rubescens*
plantain, rattlesnake	*Goodyera oblongifolia*
sage, pasture	*Artemisia frigida*
sarsaparilla, wild	*Aralia nudicaulis*
sedge, beaked	*Carex rostrata*
sedge, water	*Carex aquatilis*
Solomon's-seal, false	*Smilacina racemosa* var. *amplexliculis*
Solomon's-seal, star-flowered	*Smilacina stellata*
strawberry	*Fragaria* sp.
sweetpea, wild	*Lathyrus ochrolucus*
timothy	*Phleum pratense*
twisted stalk	*Streptopus amplexifolius*
meadow rue, veiny	*Thalictrum venulosum*
vetch, wild	*Vicia americana*
spring beauty, western	*Claytonia lanceolata*
heliotrope, wild	*Valerina sitchenis*
wintergreen	*Pyrola* sp.
wormwood	*Artemisia biennis*
wood rush	*Luzula glabrata*
yarrow, common	*Achillea millefolium*
yarrow, common wild	*Achillea lanulosa*

Note: Botanical names correspond to Moss (1959).