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ISSUED MARCH 1962

# SOIL SURVEY
# Fraser Alpine Area Colorado

UNITED STATES DEPARTMENT OF AGRICULTURE
Forest Service and Soil Conservation Service
in cooperation with
COLORADO AGRICULTURAL EXPERIMENT STATION

THE FRASER ALPINE AREA is a rough, mountainous area that lies approximately 50 miles west of Denver, Colo., and covers approximately 134 square miles. About seven-eighths of it is above timberline, and all is within the boundaries of Arapaho National Forest, U.S. Forest Service. The land in the Area is not suitable for cultivation and has never been farmed.

The survey of the Fraser Alpine Area was made where the soils had never before been studied, classified, or mapped. The purpose was to obtain basic information that would aid in planning multiple-use management for the Area, and, in a general way, in such planning for extensive tracts in the high Rockies of Colorado and adjoining States. Among the objectives of such management are to stop soil deterioration, to increase sustained yields of water, to improve yields of timber and herbage, to increase wildlife and recreational values, and to aid in locating and building roads and trails.

Part I of this report gives general information about geology, landforms, drainage, climate, vegetation, wildlife, and past and current use of the land. Part II consists of descriptions of the various kinds of soils in the Area and a discussion of how they were formed. Part III first describes the general soil management areas, which are shown on a colored map at the back of the report, and then discusses general management of soils for production of herbage, timber, and water; for control of erosion; and for other major uses. The colored map is adequate for planning broad uses of large areas but is not suitable for intensive planning within small areas.

The soil map at the back of the report shows the location and distribution of the soils. Each soil is identified on the map by a symbol. An index to map sheets shows what part of the Area is represented on each of the numbered map sheets.

Fieldwork for this survey was completed in 1956. Unless otherwise specified, all statements in the report refer to conditions at that time.

**Cover picture.—Alpine land is useful mainly for the winter snows that furnish water for summer irrigation and summer grazing.**

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# SOIL SURVEY OF FRASER ALPINE AREA, COLORADO

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UNITED STATES DEPARTMENT OF AGRICULTURE IN COOPERATION WITH COLORADO AGRICULTURAL EXPERIMENT STATION

## *Part I: The Landscape*

The Fraser Alpine Area is located on top of the Rocky Mountains, some 50 miles west of Denver, Colo., and contains parts of Grand, Summit, and Clear Creek Counties (fig. 1). It is at 39° 55′ north latitude and 105° 55′ west longitude. It is bounded on the east by U.S. Highway No. 6 at Loveland Pass and by U.S. Highway No. 40 at Berthoud Pass. Timberline marks the boundary for the alpine and subalpine parts of the survey, and the watershed of St. Louis Creek is the boundary of the survey for the part below timberline. The Area lies entirely within the Arapaho National Forest. The total surveyed area is about 85,700 acres, of which 69,800 acres is above timberline.

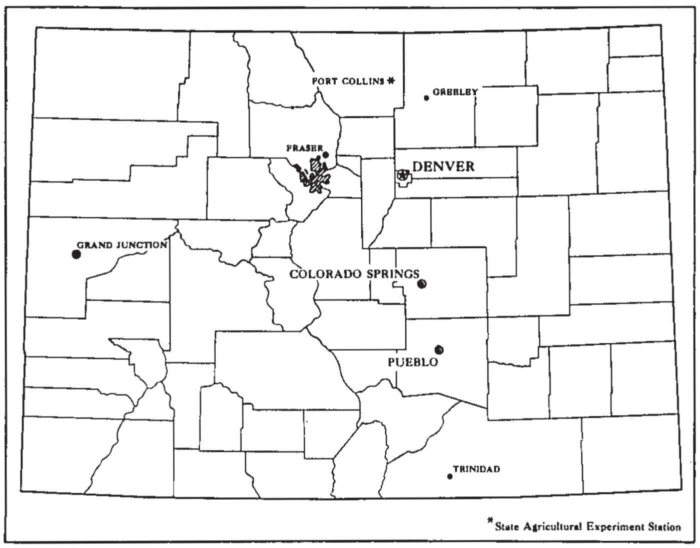



***Figure 1.*—Location of Fraser Alpine Area in Colorado.**

The Area is representative of a much larger territory in the high Rockies of Colorado and Wyoming. It contrasts sharply with all other landscapes in the United States that are at lower elevations. This is a high-altitude land of short, cool summers and long, cold winters. The boundary between the alpine and subalpine parts is timberline. Wherever slopes are long and uniform, timberline is relatively even at an elevation of about 11,500 feet. More commonly, however, the timberline is irregular, with local differences of several hundred feet in elevation (fig. 2).

The lower boundary of the alpine area has the following:

| | *Miles* | *Percent* |
|---|---|---|
| Solid rock | 15 | 6 |
| Rock slides | 53 | 24 |
| Burned timber | 25 | 11 |
| Live timber | 128 | 59 |

Within the survey area, only the lower part of the St. Louis Creek drainage supports trees.

## Geology

Many of the distinctive features of the landscapes and the soils can be attributed to composition of the rock formations. Metamorphic rocks—schist and gneiss derived from granite—are most common. Unaltered granite is not extensive. Pegmatites are common. Sedimentary rocks are not extensive, though they may be remnants of a once extensive mantle. The sedimentary rocks are Dakota sandstone and the Morrison shale. A few thin beds of limestone are on Bottle Mountain and southward on the divide between Iron and Lunch Creeks. This limestone may be a lens in the Morrison formation, or it may be of considerably older geologic age.

Volcanic tuff outcrops in a small area east of the Fraser Experimental Forest headquarters. It is part of a once extensive deposit of tuff in the Fraser basin. Along St. Louis Creek the tuff has been covered with glacial till in some places and in others has been incorporated with the till. Old lake-bed deposits occur in the northernmost part of the forest according to Tweto (*9*).[1]

The geologic map of Colorado (*11*) shows a relatively simple pattern of rocks, but Tweto's study (*9*) does not bear this out. Tweto worked on a portion of the northwestern part of the USGS Fraser Quadrangle, Colo. He found the rock patterns complex and very faulted.

Glaciation has been extensive and, beyond doubt, has played a major role in shaping the landscape as it is today. Generally, glaciers carved cirques only on north- and east-facing ridges. No distinct cirque basins are below the present timberline. Till deposits are extensive and are composed of a mixture of rocks. The occurrence of glacial deposits in the St. Louis Creek basin is shown in figure 3.

Except for the sandstone, shale, and tuff, which occupy only small areas, all the rocks are hard and strongly resist weathering and erosion. Their resistance is one of the important reasons for the high, rugged terrain and the shallow, stony soils. Although a wide assortment of minerals is present, the dominant ones are quartz and feldspars, with assorted metamorphic minerals. Soils de-

[1] Italic numbers in parentheses refer to Literature Cited, page 47.

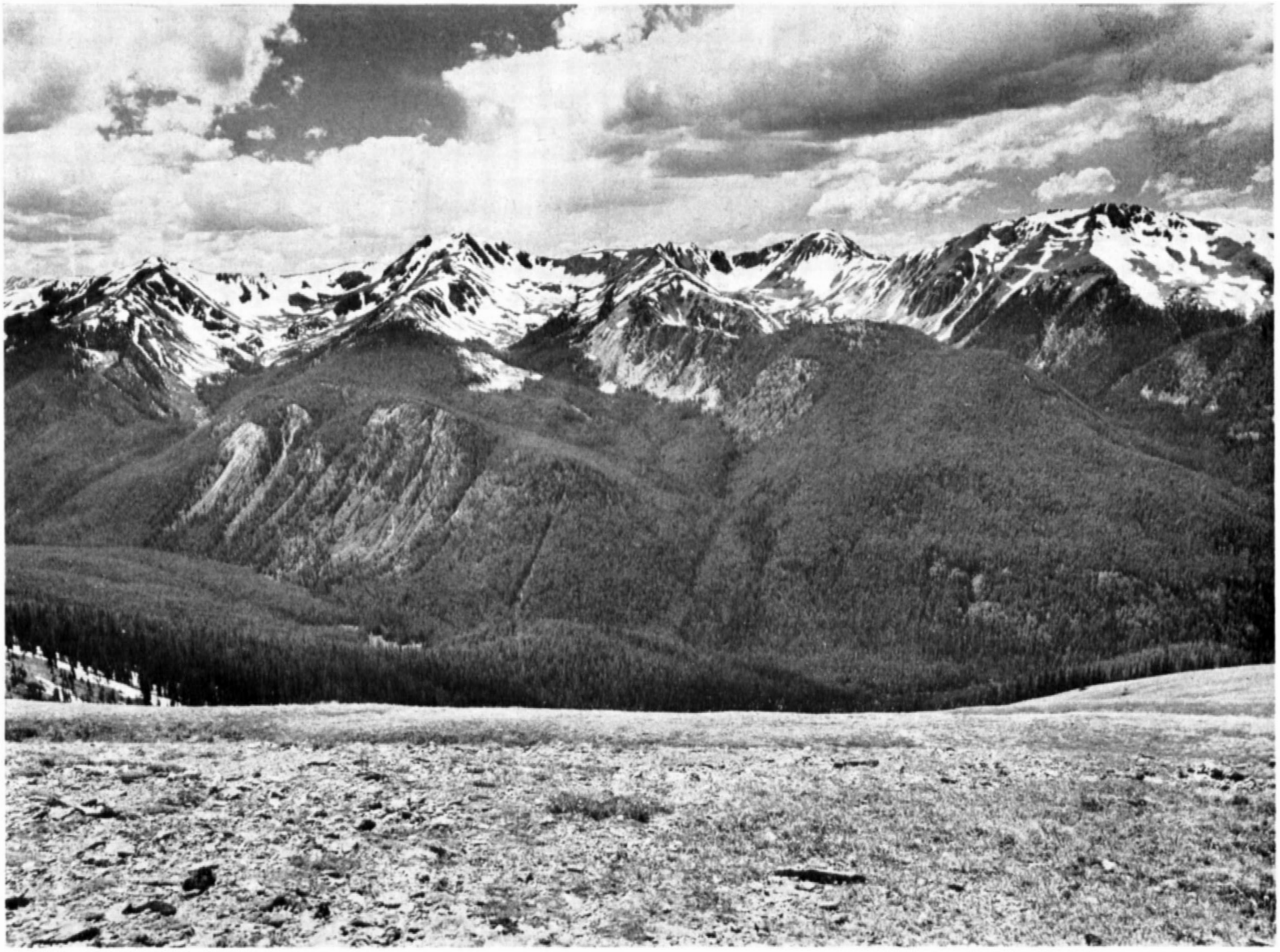


***Figure 2.*—Landscape of Fraser Alpine Area: Alpine grassland in foreground above spruce-covered slopes; the three high valleys in the background have been glaciated.**

veloped from rocks of these kinds can be expected to have low inherent fertility and coarse, gravelly texture.

Faulting and glaciation account for the major, and perhaps most of the minor, drainage channels in the St. Louis Creek watershed. The main branch of St. Louis Creek occupies a major fault that passes southward out of the basin through St. Louis Pass. To appreciate the complexity of the faulting, refer to Tweto's map (*9*). Behavior of ground water may be strongly influenced in places by the prevalence of these faults.

## Landforms

Steep, high mountain slopes are the most notable topographic feature of the Fraser Alpine Area. Except for narrow, small flood plains in the Fraser Experimental Forest, there is no level land. Ridgetops are narrow but rounding in most places. Valleys are V-shaped except where widened by glaciers at lower elevations. The topography is mature.

Vasquez Ridge, east of Vasquez Creek, has some of the features of a peneplain. It may be a remnant of the Rocky Mountain peneplain. If peneplanation at some earlier geologic period was once more extensive in this area, the evidence has largely been destroyed by glacial action.

Glaciation has had the greatest influence in modifying the topography in recent geologic times. Cirques on the east and north sides of high ridges and peaks (fig. 2) have caused appreciable retreat of the crest of the divide to both the west and south, but mostly to the west. In many areas the present crests of ridges are in positions that were once on west-facing slopes. Glaciation has also caused general lowering of the mountaintops.

The glaciation has produced two contrasting landscapes above timberline. The east sides of north-south ranging mountains have numerous, and in many places continuous, cirques. These cirques have vertical rock faces, lakes (fig. 4), valleys filled with rock glaciers, and glacier-scoured rock domes that may be bare or nearly bare of vegetation. Below the rock glaciers and below

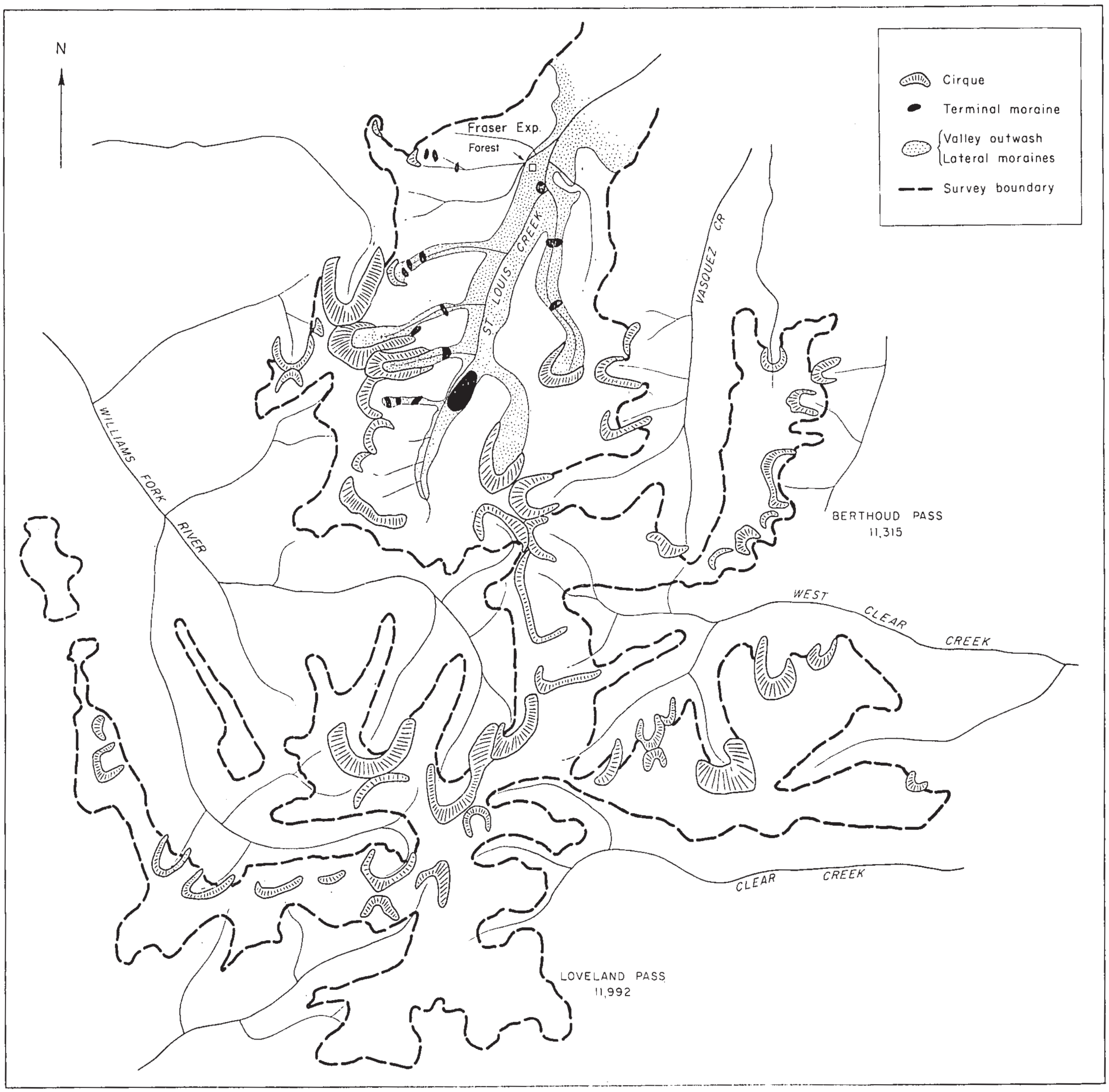



***Figure 3.*—Origin and distribution of glaciers in the Fraser Alpine Area.**

timberline, the valleys are filled with coarse till, outwash, and material left in terminal, lateral, and recessional moraines.

In association with some moraines, there are kettles marked by small bogs or lakes containing water part of the year. These landforms and the till regulate runoff and yield large amounts of water late in summer.

On the west sides of north-south ranging mountains, above timberline, there are long, gentle, relatively uniform slopes (see foreground in fig. 2) that are rarely severely dissected by drainageways. The soils of these areas support alpine sedges, grasses, and dwarf willows. These are the more important grazing lands of the alpine country.

East-west ranging mountains tend to have normal topographic development—sloping land on both sides of the

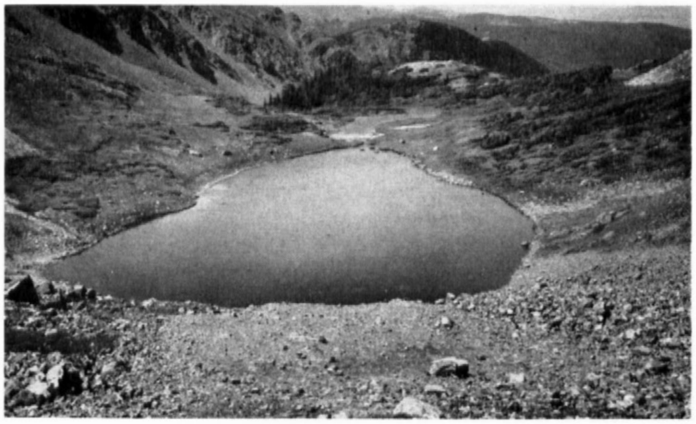


*Figure 4.*—Small glacial lakes often provide good fishing when they have been stocked.

*Figure 5.*—Lobed mass of material has moved down the slope and covered soils. Such movement is common in alpine areas.

ridgecrest and few glacial cirques. On the north slopes of these mountains, glaciers were active only behind the higher, more prominent peaks.

Elevations of 13 prominent points in the Area are approximately as follows:

| | Feet |
|---|---|
| North boundary of Fraser Experimental Forest | 8,723 |
| Fraser Experimental Forest headquarters | 9,054 |
| Bottle Pass | 10,990 |
| St. Louis Pass | 11,552 |
| Jones Pass | 12,440 |
| Loveland Pass | 11,992 |
| Berthoud Pass | 11,315 |
| Byers Peak | 12,804 |
| Vasquez Peak | 12,940 |
| Hager Mountain | 13,240 |
| Mount Parnassus | 13,576 |
| Ptarmigan Peak | 12,480 |
| Ute Peak | 12,298 |

Within the alpine area, there is a wide variety of microlandforms. The hummocks, or mounds, in bogs are evidence that frost has slowly churned the soil and rock. In many places on the bare floor of the bog areas, between hummocks, there are rock lines that indicate churning. Newly opened pits reveal, beneath the surface of these bogs, soil layers containing lenses of organic matter. These organic layers are of many thicknesses, but the normal range is from a trace to 3 or 4 inches. These layers are twisted and tortuous beneath the bog floor.

The downslope sides of the bogs are in places fronted by a sharply peaked narrow ridge. This ridge appears to have been formed by expansion of ice when open waters of the bog froze. The ridge always has a dense cover of sedges and dwarf willow. This ridging on the downhill side of bogs may explain why there are numerous and, in places, quite large "terraces" on presently well-drained soils on steep slopes. These terraces in many areas run across the slope for considerable distances, and in some places occur in groups. If these terraces were once bogs, they are well drained now.

Lobed masses of soil move down slopes in some places (fig. 5). The front of a lobe may be 2 or 3 feet high and of variable lateral dimension. The unsorted material ranges from silt to large stones and could be mistaken for glacial till. The front of the lobe overrides the downslope soils. Buried profiles are common beneath the lobes. At present, these masses appear to be moving, but very slowly. All are densely covered with sedges, and with willows in some places. Huge rock glaciers are present beneath the spalling rock walls of some of the more prominent cirque basins. Lichen on these rocks suggests considerable stability now.

Throughout the alpine area there are long, narrow lines of rock running down the slopes. These are called rock streams (fig. 6). They appear to originate through the action of runoff. During snowmelt, water probably gains a foothold on the soil through some break in the vegetation, possibly through a rodent run. The fine grains of soil are carried away by water and the larger stones are left. The soil material removed is deposited in a small fan at the base of the break, where the rate of flow is checked by dense vegetation. Later flows cut downslope through the fan and extend the rock stream farther down the steep slope. The process appears to be cyclic. The sides of the streams are covered by dense vegetation, but as the process continues, the vegetation is undercut, the suspended plants die, and the stream widens. Eventual width and length of the rock stream depend on the local situation. The process is currently active but probably very slow.

Wind is responsible for development of some microlandforms. It is most active where vegetation has been damaged or removed by grazing, and in places where topography seems to cause concentration of wind currents.

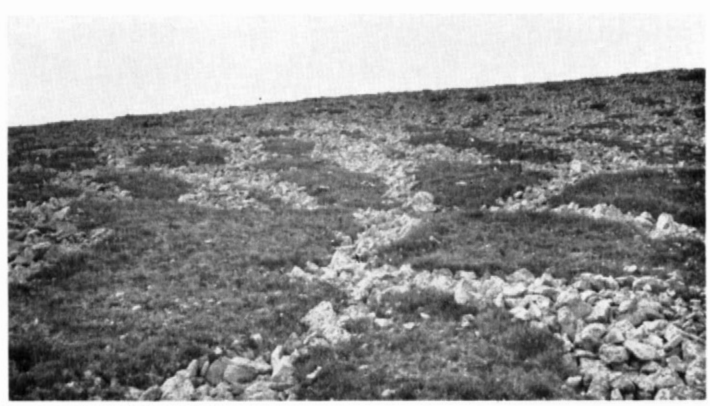


*Figure 6.*—Rock streams on steep slopes. When snow melts, these streams carry appreciable water.

## Drainage of the Area

Numbers of stream channels are an index to the behavior of water during storms and periods of snowmelt and heavy runoff. Also, their present condition is an index to past land use. Stream channels have formed during a long period and are the combined result of the geology and climate, with some modifications by vegetation.

Increased interest in hydrology, erosion, and watershed management on mountain lands makes necessary more precise methods of comparing watersheds. Study of drainage systems is one of the means by which comparison of watersheds can be achieved. For this reason, the drainage systems of the Fraser Alpine Area were carefully studied. The data derived permit comparisons among watersheds in the Area and comparisons with watersheds beyond the boundaries of this survey.

Some characteristics of stream channels are given in table 1 for the alpine areas and for the St. Louis Creek watershed. The data are presented according to the system developed by Horton (*5*). In table 2 are data on stream channels for several small watersheds within the larger St. Louis Creek watershed.

The data in tables 1 and 2 show that all areas measured, except the St. Louis Creek basin, have a maximum of four stream orders. The St. Louis Creek basin has one stream with a fifth order channel. An appreciable number of channels that develop and disappear before they join the main system are referred to in tables 1 and 2 as irregular channels. These irregular channels seldom have more than two orders, in contrast to four orders common to most regular channel systems.

The irregular channels suggest that (a) the soils and rocks are so porous that water carried in the channels is absorbed by the regolith before it reaches the main channel or (b) that a number of channels are mere relics that carried more water during the Pleistocene and that have subsequently become relatively inactive. In fact, many channels in the area are of such size as to suggest that they are relics of the Pleistocene. None of the irregular channels, and only a few of the regular, carry perennial flow.

Gullies or raw channels are rare. Most of these are on the steep faces of cirques and in passes where sheep trailing has been destructive. The resistant underlying rocks give gullies little opportunity to become deeply entrenched. Where gullies form, they are usually in straight lines down steep slopes.

There are 27 lakes within the alpine area, most of them at or near the lower boundary. They are all small. Most are shallow, but a few are deep. All appear to have originated through glacial action, aided perhaps by local slides in some places, and by construction of beaver dams in others. These small lakes cover a total of 59 acres.

## Climate

The consistent pattern of climate is one of long, cold winters and short, cool summers. Elevation ranges from about 8,700 feet to 13,500 feet within the Area; consequently, climate differs according to altitude. In alpine grassland areas the effect of elevation is not modified by trees as it is at lower elevations.

Fragmental weather records are available for the sur-

TABLE 1.—*Some characteristics of streams in the Fraser Alpine Area*[1]

| Item | Regular streams[2] | | | | | Irregular streams | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Stream orders[3] | | | | | Stream orders | | | |
| | 1 | 2 | 3 | 4 | 5 | 1 | 2 | 3 | 4 |
| Alpine lands (68,561 acres):[4] | | | | | | | | | |
| Number of streams | 575 | 178 | 46 | 5 | -------- | 389 | 51 | 7 | -------- |
| Total length (miles) | 117.17 | 68.27 | 28.97 | 5.74 | -------- | 67.75 | 16.13 | 3.32 | -------- |
| Average stream length (miles) | .20 | .38 | .63 | 1.15 | -------- | .17 | .32 | .47 | -------- |
| Stream-length ratio[5] | -------- | .53 | .60 | .55 | -------- | -------- | .53 | .68 | -------- |
| Bifurcation ratio[6] | -------- | 3.2 | 3.9 | 9.1 | -------- | -------- | 7.6 | 7.3 | -------- |
| Physiographic index[7] | -------- | .16 | .15 | .06 | -------- | -------- | .07 | .09 | -------- |
| St. Louis Creek watershed (22,120 acres): | | | | | | | | | |
| Number of streams | 54 | 20 | 8 | 3 | 1 | 153 | 37 | 12 | 1 |
| Total length (miles) | 13.60 | 10.10 | 5.18 | 6.72 | .63 | 34.65 | 19.49 | 10.78 | .66 |
| Average stream length (miles) | .25 | .50 | .65 | 2.24 | .63 | .23 | .53 | .90 | .66 |
| Stream-length ratio[5] | -------- | .50 | .77 | .29 | 3.55 | -------- | .43 | .59 | 1.36 |
| Bifurcation ratio[6] | -------- | 2.7 | 2.50 | 2.67 | 3.0 | -------- | 4.13 | 3.08 | 12.0 |
| Physiographic index[7] | -------- | .18 | .31 | .11 | 1.8 | -------- | .10 | .19 | .11 |

[1] All perennial and ephemeral streams.

[2] Regular streams are those that join other streams to form part of the regular system, as contrasted to irregular streams, which run for some distance and then fade out or disappear in a rock field.

[3] Stream orders according to the system developed by R. E. HORTON (*5*).

[4] Includes 5,166 acres of alpine land in the St. Louis Creek watershed.

[5] Stream-length ratio (Horton's rl) is the ratio between average stream length of a given order and average stream length of the next lower order; that is, $\frac{\text{order 1}}{\text{order 2.}}$

[6] Bifurcation ratio (Horton's rb) is the ratio between the number of streams of a given order to the number of streams of the next lower order; that is, $\frac{\text{order 1}}{\text{order 2.}}$

[7] Physiographic index is ratio of rl/rb.

TABLE 2.—*Basic stream data for several small watersheds within the St. Louis Creek watershed*

| Small watersheds | Regular streams | | | | Irregular streams | | Watershed— | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Channel orders | | | | Channel orders | | Elevations | | Approximate acreage | Length in miles |
| | 1 | 2 | 3 | 4 | 1 | 2 | Top | Bottom | | |
| *Deadhorse:* | | | | | | | | | | |
| No. of channels | 27 | 7 | 1 | 1 | 4 | 1 | 11, 588 | 9, 200 | 925 | 2. 27 |
| Total miles | 3. 88 | 3. 07 | 1. 02 | 1. 72 | . 44 | . 16 | | | | |
| Average miles | . 14 | . 44 | 1. 02 | 1. 72 | . 41 | . 16 | | | | |
| *West St. Louis:* | | | | | | | | | | |
| No. of channels | 19 | 4 | 1 | 1 | 12 | 2 | 11, 600 | 900 | 2, 070 | 3. 79 |
| Total miles | 4. 36 | 1. 79 | 1. 0 | 2. 38 | 2. 70 | . 48 | | | | |
| Average miles | . 23 | . 45 | 1. 0 | 2. 38 | . 23 | . 24 | | | | |
| *Byers:* | | | | | | | | | | |
| No. of channels | 13 | 3 | 1 | 1 | 7 | ------- | 12, 400 | 9, 300 | 846 | 2. 65 |
| Total miles | 2. 51 | 1. 11 | . 78 | 2. 31 | 1. 51 | ------- | | | | |
| Average miles | . 19 | . 37 | . 78 | 2. 31 | . 22 | ------- | | | | |
| *Iron:* | | | | | | | | | | |
| No. of channels | 32 | 11 | 1 | 1 | 31 | 6 | 12, 690 | 9, 460 | 1, 848 | 3. 32 |
| Total miles | 6. 83 | 5. 06 | . 64 | 3. 30 | 4. 45 | 1. 70 | | | | |
| Average miles | . 21 | . 46 | . 64 | 3. 30 | . 14 | . 28 | | | | |
| *Lunch:* | | | | | | | | | | |
| No. of channels | 8 | 1 | 1 | ------- | 27 | 1 | 12, 700 | 9, 560 | 808 | 2. 46 |
| Total miles | 2. 27 | . 38 | 2. 13 | ------- | 3. 83 | . 08 | | | | |
| Average miles | . 28 | . 38 | 2. 13 | ------- | . 14 | . 08 | | | | |
| *Gordon:* | | | | | | | | | | |
| No. of channels | 10 | 4 | 1 | ------- | 19 | 3 | 12, 700 | 9, 880 | 738 | 1. 99 |
| Total miles | 2. 05 | 1. 70 | 1. 84 | ------- | 2. 79 | . 72 | | | | |
| Average miles | . 21 | . 43 | 1. 84 | ------- | . 15 | . 24 | | | | |
| *Mine:* | | | | | | | | | | |
| No. of channels | 17 | 1 | 1 | 1 | 13 | ------- | 12, 440 | 10, 040 | 666 | 161 |
| Total miles | 3. 23 | . 44 | . 80 | 1. 59 | 1. 99 | ------- | | | | |
| Average miles | . 19 | . 44 | . 80 | 1. 59 | . 15 | ------- | | | | |
| *Fool:* | | | | | | | | | | |
| No. of channels | 9 | 3 | 1 | ------- | 5 | ------- | 11, 440 | 9, 600 | 714 | 2. 18 |
| Total miles | 1. 90 | 2. 03 | 1. 67 | ------- | 1. 42 | ------- | | | | |
| Average miles | . 21 | . 67 | 1. 67 | ------- | . 28 | ------- | | | | |

vey area, but no continuous long-term records. The discussion of climate is therefore based largely on data from adjacent stations, which provide a good picture of the climate in this Area. In table 3 are data from the village of Fraser, and from Corona, at Rollins Pass.

Temperatures recorded at the U.S. Weather Bureau station in Fraser are usually 5 to 7° F. below temperatures at the Fraser Experimental Forest headquarters, which is 5 miles from Fraser and 600 feet higher. The lower temperatures at Fraser result from a temperature inversion. Average annual precipitation at Fraser averages 18.7 inches, as compared to an annual average of 24 inches at the headquarters of the Fraser Experimental Forest. The range in annual precipitation at the headquarters is from 15 to 30 inches.

Corona, at Rollins Pass and about 6 miles from the Area, is at an elevation of 11,660 feet. Data from the weather station at Corona should be representative of the climate in the alpine lands of this Area.

Strong winds are characteristic of this Area. The best continuous records on wind (1873-88) are for Pikes Peak, at an elevation of 14,136 feet and approximately 80 miles southeast of the Area. These data, summarized by Retzer (*7*), show that winds in excess of 100 miles per hour were recorded, and that very strong winds occur every month of the year. These winds are dominantly westerly, with a strong southwesterly trend. Elsewhere, winds stronger than this were measured recently. During winter considerable areas of soil on the windward side of ridges and peaks are bare.

Alexander and Buell (*1*) have shown that the dominant winds are westerly in the subalpine areas. Wind in subalpine areas is responsible for many windthrown trees.

Appreciable quantities of dust from the deserts to the west are deposited when westerly winds are strong. It is not known whether the dust accumulates on the surface of the soil or is removed with waters from the melting snow.

Snow patterns are varied because of differences in elevation, vegetation, and topography. The alpine lands receive as much snow, and probably more, than the areas at lower elevations that are covered with trees. Wind, however, removes snow from ridges and exposed areas

TABLE 3.—*Average monthly and annual precipitation and temperatures at Corona and Fraser stations*

| Month | Corona station [1] | | Fraser station [2] | |
|---|---|---|---|---|
| | Precipitation | Temperature | Precipitation | Temperature |
| | *Inches* | *Degrees F.* | *Inches* | *Degrees F.* |
| January | 3. 93 | 11. 5 | 1. 65 | 12. 6 |
| February | 5. 10 | 13. 3 | 1. 53 | 15. 6 |
| March | 4. 78 | 18. 8 | 1. 72 | 21. 1 |
| April | 5. 36 | 23. 2 | 2. 05 | 31. 2 |
| May | 4. 78 | 30. 9 | 1. 85 | 41. 2 |
| June | 1. 63 | 42. 2 | 1. 36 | 49. 0 |
| July | 2. 64 | 48. 8 | 1. 95 | 54. 2 |
| August | 2. 24 | 48. 4 | 1. 68 | 52. 3 |
| September | 2. 20 | 40. 0 | 1. 15 | 45. 4 |
| October | 2. 92 | 30. 2 | 1. 16 | 35. 6 |
| November | 2. 60 | 18. 0 | 1. 23 | 22. 9 |
| December | 3. 42 | 9. 4 | 1. 32 | 13. 9 |
| Average annual | 41. 60 | 27. 9 | 18. 65 | 32. 9 |

[1] Nine years of record; elevation 11,660 feet; precipitation was about eight-tenths snow.

[2] Fifty years (1908–58) of record; elevation 8,560 feet; precipitation was about two-thirds snow.

and deposits it in cirque basins, or moves considerable amounts to the tree-covered areas below timberline. Also, a considerable amount of snow accumulates as cornices and snowbanks on the lee side of cirques and high ridgetops. Snowslides, or avalanches, often originate in these deep deposits (fig. 7). Snowslides usually run the same course many times. On the aerial photographs used as a base for the soil map, the courses of snowslides are marked by thin, white, straight lines extending from the alpine through the timbered zone below.

In timbered areas snow stays where it falls because winds can move only the portion that lodges in the branches of the trees.

Slope aspect, or direction in which a slope faces, markedly affects patterns of snow accumulation at low elevations. South-facing slopes normally are free of snow 30 days or more before north-facing slopes, and on south-facing slopes some melting or sublimation seems to occur throughout the winter. The distribution of snow in the St. Louis Creek basin has been studied by Brown (*2*).

The occurrence of frozen soil is interesting. Within the timber, where the surface is protected by a thick layer of litter, the soils often do not freeze until spring. Frequently these soils are dry when winter starts, and not infrequently, are covered with a blanket of snow early in fall. When the snow melts in spring, the soil may freeze to a depth of a few inches.

The pattern of freezing above timberline is not well known. Undoubtedly those areas swept free of snow are frozen to a considerable depth. In willow fields and depressions, however, snow accumulates and soil freezing probably is not so severe. Permafrost occurs in alpine areas, but not enough is known about its occurrence to be able to predict its presence by kind of soil or by topographic features. Permafrost does seem to occur more often beneath the Ptarmigan than the Vasquez soils.

***Figure 7.*—Snowslides are common in the alpine. They cause some erosion, destroy timber, and sometimes take human lives. These slides normally start where snow accumulates over rock on very steep slopes.**

## Vegetation

In alpine areas, there is grassland above the beaten, scarred "bent timber" zone that marks the transition from grass to the spruce forest at lower elevations (see fig. 2). The grassland above timberline is marked with low, shrubby patches of alpine willows, which grow in depressional and moist areas.

Below timberline, the forest cover is a mixture of Engelmann spruce, subalpine fir, and quaking aspen. Ordinarily, at an elevation of about 10,000 feet, lodgepole pine intermingles with this mixed forest. On steep south-facing slopes, however, lodgepole pine extends to much higher elevations and in a few places grows near timberline. On steep north-facing slopes, spruce and fir grow as far down as 9,000 feet, but below this elevation on north slopes, young stands of lodgepole pine are predominant.

The scientific and common names of the principal indigenous plants in the Fraser Alpine Area are given in the following list, which was compiled by C. H. Wasser, Dean, College of Forestry, Colorado State University.

## ALPINE VEGETATION

### Shrubs

| *Scientific name* | *Common name* |
|---|---|
| *Dryas octopetala* | Mount Washington dryad. |
| *Kalmia polifolia* | Bog kalmia. |
| *Potentilla fruticosa* | Shrubby cinquefoil. |
| *Salix glauca* and vars | Grayleaf willow. |
| *Salix petrophila* | Skyland willow. |
| *Salix planifolia* and vars | Planeleaf willow. |
| *Salix pseudolapponum* | False Lapland-willow. |
| *Salix nivalis* | Snow willow. |

### Grasses and Sedges

| | |
|---|---|
| *Agropyron scriberni* | Scribner wheatgrass. |
| *Agrostis humilis* | Alpine bentgrass. |
| *Helictotrichon mortoniana* | Alpine oatgrass. |
| *Deschampsia caespitosa* | Tufted hairgrass. |
| *Festuca ovina* | Sheep fescue. |
| *Festuca brachyphylla* | Alpine fescue. |
| *Poa alpina* | Alpine bluegrass. |
| *Poa arctica* | Arctic bluegrass. |
| *Poa lettermani* | Letterman bluegrass. |
| *Poa rupicola* | Timberline bluegrass. |
| *Trisetum spicatum* | Spike trisetum. |
| *Carex arapahoensis* | Arapaho sedge. |
| *Carex chalciolepis* | (sedge; no common name.) |
| *Carex drummondiana* | Drummond sedge. |
| *Carex elynoides* | (Kobresia-like sedge; no common name.) |
| *Carex nigricans* | Black alpine sedge. |
| *Carex scopulorum* | (sedge; no common name.) |
| *Eriophorum angustiofolium* | Narrowleaf cottonsedge. |
| *Juncus drummondi* | Drummond rush. |
| *Kobresia bellardi* | Kobresia. |
| *Luzula spicata* | Spike woodrush. |

### Forbs

| | |
|---|---|
| *Actinea grandiflora* | Graylocks actinea. |
| *Agoseris aurantiaca* | Orange agoseris. |
| *Antennaria microphylla* * | Littleleaf pussytoes. |
| *Arenaria sajanensis* * | Siberian sandwort. |
| *Artemisia scopulorum* | Alpine sagebrush. |
| *Caltha leptosepala* | Elkslip marshmarigold. |
| *Castilleja occidentalis* | Western painted-cup. |
| *Cerastium alpinum* * | Alpine cerastium. |
| *Cirsium drummondii acaulescens* | Birdsnest thistle. |
| *Cirsium scopulorum* | Lions-head thistle. |
| *Claytonia megarrhiza* | Alpine springbeauty. |
| *Draba crassifolia* var. *typica* * | Draba. |
| *Draba fladnizensis* * | Arctic draba. |
| *Erigeron melanocephalus* | Black-headed fleabane. |
| *Erigeron simplex* * | One-flower fleabane. |
| *Eriogonum flavum* * | Yellow eriogonum. |
| *Eritrichum elongatum* var. *argenteum* * | Alpine forget-me-not. |
| *Gentiana romanzovii* | Romanzoff gentian. |
| *Geum rossi* | Golden avens. |
| *Lloydia serrotina* | Alplily. |
| *Mertensia alpina* | Alpine bluebells. |
| *Oreoxis alpina* | Alpine oreoxis. |
| *Oxyria digyna* | Alpine mountain-sorrel. |
| *Oxytropis* spp | Crazyweeds. |
| *Paronychia pulvinata* * | Rocky Mountain nailwort. |
| *Pedicularis scopulorum* | Rocky Mountain pedicularis. |
| *Penstemon harbouri* | Harbours penstemon. |
| *Phacelia sericea* | Silky phacelia. |
| *Phlox caespitosa* and vars.* | Tufted phlox. |
| *Polemonium confertum* | Skypilot polemonium. |
| *Polygonum bistortoides* | American bistort. |
| *Polygonum viviparum* | Viviparous bistort. |
| *Potentilla quinquefolia* * | Cinquefoil. |
| *Primula angustifolia* | Colorado primrose. |
| *Primula parryi* | Parry primrose. |
| *Ranunculus adoneus* | Alpine buttercup. |
| *Saxifraga caespitosa* * | Mat saxifrage. |
| *Sedum integrifolium* | Kings-crown stonecrop. |
| *Senecio soldanella* | Alpenglock groundsel. |
| *Sibbaldia procumbens* | False-strawberry. |
| *Silene acaulis* * | Moss silene (campion). |
| *Thalictrum alpinum* | Alpine meadowrue. |
| *Thlaspi alpestris* | Mountain pennycress. |
| *Trifolium nanum* * | Dwarf clover. |
| *Trifolium parryi* | Parry clover. |

* These are cushion plants.

## SUBALPINE VEGETATION

### Trees

| | |
|---|---|
| *Picea engelmanni* | Engelmann spruce. |
| *Abies lasiocarpa* | Subalpine fir. |
| *Pinus flexilis* | Limber pine. |
| *Pinus contorta* | Lodgepole pine. |
| *Populus tremuloides* | Quaking aspen. |

### Shrubs

| | |
|---|---|
| *Arctostaphylos uva-ursi* | Kinnikinnick. |
| *Artemisia tridentata* | Big sagebrush. |
| *Betula glandulosa* | Bog birch. |
| *Potentilla fruticosa* | Shrubby cinquefoil. |
| *Salix glauca* and vars | Grayleaf willow. |
| *Salix planifolia* and vars | Planeleaf willow. |
| *Shepherdia canadensis* | Canada buffaloberry. |
| *Vaccinium myrtillus* | Myrtle whortleberry. |
| *Vaccinium scopanium* | Grouseberry. |

### Grasses and Sedges

| | |
|---|---|
| *Agropyron subsecundum* | Bearded wheatgrass. |
| *Agropyron trachycaulum* | Slender wheatgrass. |
| *Bromus anomalus* | Nodding brome. |
| *Bromus marginatus* | Mountain brome. |
| *Calamagrostis purpurascens* | Purple reedgrass. |
| *Danthonia intermedia* | Timber danthonia. |
| *Deschampsia caespitosa* | Tufted hairgrass. |
| *Elymus glaucus* | Blue wildrye. |
| *Festuca ovina* | Sheep fescue. |
| *Festuca thurberi* | Thurber's fescue. |
| *Phleum alpinum* | Alpine timothy. |
| *Poa pratensis* | Kentucky bluegrass. |
| *Poa fendleriana* | Muttongrass. |
| *Stipa columbiana* | Subalpine needlegrass. |
| *Stipa lettermani* | Letterman needlegrass. |
| *Trisetum wolfi* | Wolf trisetum. |
| *Carex aquatalis* | Water sedge. |
| *Carex festivella* | Ovalhead sedge. |
| *Carex geyeri* | Elk sedge. |
| *Carex nebraskensis* | Nebraska sedge. |
| *Juncus balticus* | Baltic rush. |
| *Luzula parviflora* | Millet woodrush. |

### Forbs

| | |
|---|---|
| *Achellea lanulosa* | Western yarrow. |
| *Anemone zephyra* | Narcissus anemone. |
| *Antennaria rosea* | Rose pussytoes. |
| *Arenaria congesta* | Ballhead sandwort. |
| *Arnica cordifolia* | Heartleaf arnica. |
| *Artemisia borealis* | Boreal sagebrush. |
| *Campanula rotundifolia* | Harebell. |
| *Castilleja brachyantha* | Paintcup. |
| *Delphinium barbeyi* | Barbey larkspur. |
| *Epilobium angustifolium* | Fireweed. |
| *Erigeron machranthus* | Rocky Mountain wild daisy. |
| *Eriogonum subalpinum* | Subalpine eriogonum. |
| *Fragaria ovalis* | Wild strawberry. |
| *Iris missouriensis* | Rocky Mountain iris. |
| *Gentiana parryi* | Parry gentian. |
| *Geranium richardsoni* | Richardson geranium. |
| *Lathyrus leucanthus* | Aspen peavine. |

| *Scientific name* | *Common name* |
|---|---|
| *Leontodon taraxacum* | Dandelion. |
| *Mertensia ciliata* | Mountain bluebell. |
| *Oxytropis sericea* | Silky crazyweed (locoweed). |
| *Pedicularis groenlandica* | Elephanthead. |
| *Penstemon whippleanus* | Whipple penstemon. |
| *Potentilla glaucophylla* | Herbaceous cinquefoil. |
| *Primula parryi* | Parry primrose. |
| *Saxifraga rhomboidea* | Saxifrage. |
| *Sedum rhodanthum* | Queenscrown stonecrop. |
| *Senecio triangularis* | Arrowleaf butterweed. |
| *Thalictrum fendleri* | Fendler meadowrue. |
| *Trifolium rydbergi* | Rydberg clover. |
| *Vicia americana* | American vetch. |

The distribution of most of the major plant species below timberline appears to result from a combination of factors; among them are slope, exposure, elevation, and the soils. Soils seem to exert a dominant influence on plant species only where they are moist and wet.

Here are some observed relationships between vegetation and factors of the environment:

(1) Subalpine fir occurs in the overstory of old, mature stands of spruce, and it also occurs in the understory of most stands of lodgepole pine.

(2) The roots of spruce and lodgepole pine are shallow. Most are in the top 10 inches of soil, though some feeder roots go as deep as 30 to 40 inches, and a very few, to a depth greater than 60 inches.

(3) Canada buffaloberry does not grow on Bottle fine sand, and the line between this soil and others is frequently sharply defined by presence or absence of this shrub.

(4) Grouseberry, the most extensive shrub below timberline, is most vigorous and dense at high elevations on the Darling soils and least dense on the Bobtail soils at low elevations.

(5) Charcoal in the upper layers of soils leave little doubt that the entire forest was burned over at times in the past, but this was more than 300 years ago, as some of the present trees are that old. The most recent important fire, which occurred before 1900, affected 5 or 10 acres at the head of Fool Creek.

(6) Recovery from burns is extremely slow in the vicinity of timberline.

(7) Judging by the presence of old "wolf" trees, timberline is slowly advancing into the alpine.

(8) Logged areas have a good stand of regrowth timber.

## Wildlife [2]

Big game animals, smaller mammals, and birds occur in the Fraser Alpine Area, but no one species in great abundance. Trout are common in some of the streams, beaver ponds, and lakes.

The big game animals are elk *(Cervus canadensis)*, mule deer *(Odocoileus hemionus)*, and black bear *(Euarctos americanus)*.

Elk favor the alpine grasslands and high cirque basins as summer range. A small number of elk have been seen from time to time in the higher reaches of the St. Louis Creek watershed, in the Keyser Creek basin, in the vicinity of Byers Peak, on the west fork of Vasquez Creek, and elsewhere in the high country. Late in the summer of 1954, a herd of at least 100 elk was seen in the upper basin of Darling Creek. The summer grazing habits of the elk are being changed by increased research activities in the St. Louis Creek area, new logging operations on Keyser Creek, and activities related to new diversions of water on Vasquez Creek. Elk do not winter in any part of the survey area.

Mule deer, which are more common than elk, adjust more readily to changes in environment. In summer, deer are seen throughout the timbered areas, and in winter they move to lower country outside the survey area. Woody shrubs are the primary food for deer through most of the year, so they are rarely seen on alpine lands. Harvest of spruce and lodgepole pine for timber may induce increase in browse plants and thus improve the summer range for deer. The trend would be progressive with increase in timber harvest. Winter range for deer remains critical, but such range is not within the boundary of this survey area.

Black bear are shy and rarely seen. Judging from their sign along streams and trails, there are comparatively few bear in the Area. The evidence indicates that they migrate through the alpine areas during summer and fall and den up for winter at lower elevations.

Marten, weasel, mink, muskrat, red fox, coyote, and bobcat are the small fur-bearing mammals. Rutherford (*8*) investigated the relation of habitat and wildlife for a 2-year period on the north and south courses of the Williams Fork River. He found very few mink, and comparatively few muskrat, apparently because the elevation of 10,000 feet imposed living conditions that were too severe. The mink and muskrat in this area preferred habitats along streams, particularly sites near multiple beaver dams and ponds. Weasels preferred open meadow and open coniferous timber. Martens were concentrated in dense stands of Engelmann spruce. Coyotes and red foxes ranged through all the habitat areas under consideration.

Rutherford found that the snowshoe hare *(Lepus bairdi)* preferred the edge zone, or border, between meadows and stands of lodgepole pine, and that its preference was for high ground rather than low, moist areas.

Pine squirrel, or Fremont's chickaree *(Sciurus fremonti)*, are numerous; they feed on the seeds of the coniferous trees that normally grow in upland areas.

Beaver *(Castor canadensis)* are common in all streams, lakes, and mountainside seeps. Their primary requirements are water, a food supply consisting largely of willows and similar shrubs, and streams having low gradients. They are active in nearly all places that provide these. Beaver are found in alpine lakes and in streams draining these, but are much less common than at lower elevations. The ponds behind beaver dams are some of the better sites for trout fishing in this region.

Mountain lions almost certainly are in the Fraser Alpine Area, and they undoubtedly move up to alpine elevations at times. Their preference, of course, is for rimrock and broken country in forested areas where deer are abundant.

[2] By DR. LEE E. YEAGER, Colorado Wildlife Research Unit, Colorado State University.

Aside from waterfowl, ptarmigan *(Lagopus leucurus)* and dusky grouse *(Dendragapus obscurus)* are the only game birds on alpine lands and areas adjacent. The ptarmigan is on alpine land, and the dusky grouse is always in or near timber stands at lower elevations; that is, in stands of spruce and down to the stands of aspen-lodgepole pine. Rutherford found a significantly greater number of ducks, mostly mallards, on beaver ponds than on other bodies of water. He did not find that other birds or animals had any particular preference for the beaver ponds. Waterfowl nest mainly on the beaver ponds and the natural lakes having shallow water and shoreline vegetation.

## People and Their Use of the Land

The Fraser Alpine Area, in comparison with cultivated lands, has been little disturbed. No part of it has ever been cultivated. No roads touched it until the U.S. Highway No. 6 over Loveland Pass was constructed and the Jones Pass road was located to aid in carrying out developments planned by the Denver Water Board. Roads are now being built in the St. Louis Creek watershed to facilitate activities in the Fraser Experimental Forest and in areas of the Denver Water Board diversion. Except in these places, the Area is accessible only by horse and foot trails.

Early hunters and trappers left no recognizable scars on the land. Early mining was concentrated along Mine, Iron, and Bobtail Creeks and disturbed the land relatively little. Four cabins marked the focal points of early mining activities on the St. Louis Creek watershed. Two were up Iron Creek, one up Mine Creek below St. Louis Lake, and one at the head of Fool Creek. Apparently the cabin on Fool Creek was a herdsman's cabin. All these cabins were reached by trails.

Eastrom (*3*) reports that clear-cut logging started about 1902 or 1904 on the north end of the Fraser Experimental Forest, on what was then private land. Other reports date this operation in 1906. The logs were removed by a standard-gage railroad and milled at Fraser. In 1907, a 500-acre fire resulted from this operation and covered a portion of the area now in the northern part of the Fraser Experimental Forest.

Some logging was done in the lower reaches of St. Louis Creek between 1910 and 1926. The logs were transported about 8 miles to the mills at Fraser through flume constructed along St. Louis Creek in 1911-12. Remains of this flume are still present.

Logged areas now have a good stand of regrowth timber, and apparently the logging has had no severe detrimental effect on the land. Likewise, the area burned over is now covered with young lodgepole pine.

The Arapaho National Forest was established in 1908, and the Byers Ranger station was built in 1910 to supervise logging on national forest lands in that vicinity (fig. 8). The station stood at the junction between West St. Louis and main St. Louis Creeks. It was closed as a station in 1917 and was demolished in 1950.

The Fraser Experimental Forest was established in 1937, with headquarters just south of the old Byers Ranger station. With expansion of forest and water research, roads and trails began to penetrate more remote parts of the St. Louis Creek basin, particularly Fool Creek and West St. Louis Creek. The access road up main St. Louis Creek was completed in 1956.

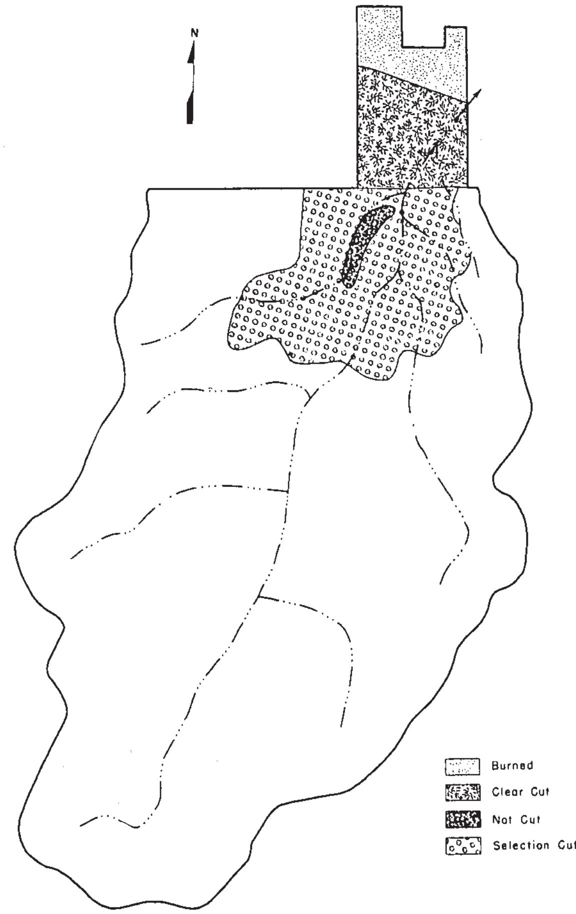



***Figure 8.*—Sketch showing early logging in the St. Louis Creek watershed.**

The Denver Water Board began developments within the watershed in 1935. These were essentially completed in 1956, when diversions from Fool, Elk, and West, East, and main St. Louis Creeks were added. The disturbance created by this activity was the most severe that ever occurred in the St. Louis Creek watershed.

All the alpine area has been heavily grazed by sheep since about 1912. At the peak of this grazing, an estimated 27,300 sheep grazed for 2½ to 3 months during summer.

When the Area was made a national forest, the alpine grazing lands were divided into grazing allotments (fig. 9) and the permitted number of sheep was specified for each.

Because of the need to protect the resource, the number permitted on the range was consistently adjusted downward to give the range a chance to recover. The record of use, together with the greatest permitted number of sheep for each allotment in any given year, is shown in table 4.

Originally, sheep entered and left the Area through the Jim Creek driveway. Sheep entering from the Winter Park driveway were held for long periods on Vasquez Ridge. This ridge originally supported a dense, herba-

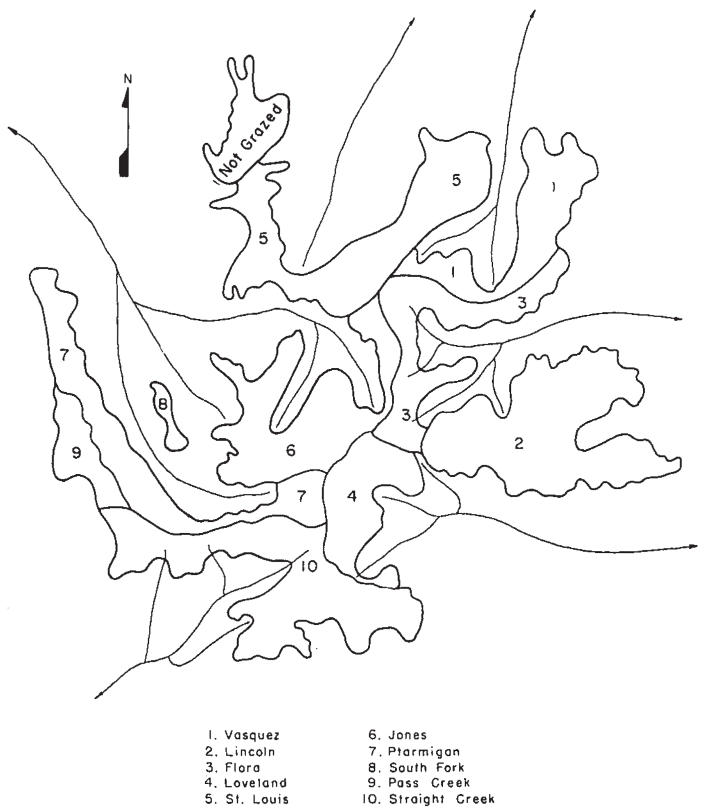



***Figure 9.*—Grazing allotments in the alpine part of the Area.**

ceous cover and had some 10 to 12 alpine bogs. The bogs were largely destroyed by wind erosion after sheep had made trails across them that gullied out and drained the water. Wind erosion has likewise been severe on well-drained areas where the turf was broken by grazing and trailing.

Cattle first grazed under national forest permit in the St. Louis Creek basin in 1916. This permit is still active.

TABLE 4.—*Grazing allotments and permitted number of sheep in the alpine part of the Area*

| Allotment | Number of sheep reported in— | | | | | Greatest number grazed in a year |
|---|---|---|---|---|---|---|
| | 1918 | 1928 | 1938 | 1948 | 1958 | |
| Jones | [1] 6, 260 | [1] 2, 520 | 360 | 1, 000 | 500 | [1] 7, 920, in 1920. |
| Ptarmigan | ------ | ------ | 950 | 1, 100 | 930 | |
| Flora | ------ | 4, 000 | 1, 820 | 900 | [2] 1, 200 | 5, 000, in 1923. |
| Vasquez | ------ | ------ | 1, 625 | 1, 500 | ------ | 2, 390, in 1936. |
| Lincoln | ------ | 1, 500 | 1, 500 | 900 | 900 | 3, 100, in 1927. |
| Loveland | 2, 000 | 1, 500 | 1, 000 | 900 | 900 | 2, 000, in 1912. |
| St. Louis | 6, 260 | 6, 000 | 1, 460 | 1, 000 | 500 | 9, 600, in 1916. |
| Straight Creek | ------ | 1, 870 | 885 | 900 | 850 | 2, 460, in 1925. |

[1] Jones and Ptarmigan combined. [2] Flora and Vasquez combined.

Only limited recreational use has been made of the Area. Campgrounds have been established along main St. Louis Creek. The alpine areas have limited use for summer hiking, but all game animals have migrated to lower elevations by the time hunting season opens in fall. Some of the larger lakes near timberline are well stocked with trout, but there are no trout in the alpine streams. Waters at these high elevations have temperatures below optimum for spawning trout, and the streams also may be lacking in food. Two ski lifts, one at Winter Park, and the other at Berthoud Pass, are focal points for winter recreation. Both are outside the survey area. There appear to be a number of opportunities to develop summer recreation, particularly hiking and riding.

# *Part II: Soils of the Fraser Alpine Area*

Part II of this report provides general and detailed information about the soils of the Fraser Alpine Area. The soils in the Area are described in detail, and their relation to climate, vegetation, and other factors of the environment is mentioned. The current uses of each soil are reported, along with some suggested modifications that would improve management.

Since the soils of the Fraser Alpine Area are representative of those in a large section in the highest part of the southern Rocky Mountains, the information in this Area can be applied in a general way to much more extensive areas where the soils have not yet been surveyed.

The land manager can gain the most from this soil survey by using Part II with Part III. Part III discusses management by soil management areas and provides separate subsections on management for grazing, forestry, water production, and other uses.

## Nature of the Soils

The soils of the Fraser Alpine Area have developed in two strongly contrasting landscapes, the alpine and the subalpine. The alpine area is a steep, windswept, rocky grassland above timberline. The subalpine area is below timberline in the St. Louis Creek watershed; it is protected from strong winds and rapid changes in temperature by the dense cover of virgin timber and the sheltering adjacent slopes and protruding landmasses. The soils of the two landscapes contrast sharply.

With few exceptions the parent material of the soils throughout the Fraser Alpine Area was derived from a mixture of gneiss and schist rocks. These rocks disintegrate slowly and produce a zone of coarse, angular gravel and stone above the bedrock. The soils are low in silt and clay in all layers of the profile. The important differences in development of the soils result more from variations in climate, vegetation, and exposure (or aspect) than from differences in parent rock.

In general, the soils of these mountain lands have much less uniform profiles than soils of more nearly level and cultivated lands. This irregularity most often takes the form of variation in thickness, texture, and consistence of horizons. Sharp differences within short distances are the rule rather than the exception. Generally, however, genetic characteristics, such as color, reaction (acidity), and structure, are more consistent. Variations in soil profiles result from (1) surface and mass movements of material down steep slopes by gravity or glaciers; (2) protruding bedrock; (3) variations in parent rock due to faulting, metamorphosis, and so on; (4) wind-

TABLE 5.—*General information about soils of the Fraser Alpine Area*

| Soils | Parent rocks or material | Type of vegetation | Landforms | Internal drainage |
|---|---|---|---|---|
| Bobtail | Gneiss-schist | Lodgepole | Steep mountain slopes | Somewhat excessively drained. |
| Bottle | Sandstone | Lodgepole-spruce | Steep mountain slopes | Well drained. |
| Darling | Gneiss-schist | Spruce-fir | Steep mountain slopes | Somewhat excessively drained. |
| Leal | Glacial till | Spruce-lodgepole | Steep mountain slopes | Somewhat excessively drained. |
| Lunch | Organic material | Sedge-woody shrubs | Hanging bogs | Very poorly drained. |
| Mine | Glacial outwash | Lodgepole | Level plains | Somewhat excessively drained. |
| Nystrom | Organic material | Sedge | Depressions | Very poorly drained. |
| Ptarmigan | Gneiss-schist | Sedge and weeds | Mountain ridgetops | Somewhat excessively drained. |
| Tabernash | Lakeshore deposits | Lodgepole | Level plains | Well drained. |
| Vasquez | Gneiss-schist | Grass-sedge-willows | Depressions in mountain ridges. | Moderately well drained. |

thrown trees; and (5) lodging of soil material behind logs as it moves down the steep slopes.

Generally speaking, the soils have low inherent fertility, somewhat excessive internal drainage, and coarse textures throughout, and range from medium acid to very strongly acid in all horizons. The peaty soils and bogs are notable exceptions, but they are not extensive.

In comparison with soils of agricultural areas, the soils of the Fraser Alpine Area might be considered to have limited use. Nevertheless, for wild, high, mountainous lands, the uses in this Area compare favorably with all other areas of similar nature. The major products of the soils in high mountain areas are timber, water, and forage. The indirect products—recreation and wildlife—sometimes exceed the value of timber and forage. Although comparisons are difficult to make, this is probably true of the Fraser Alpine Area, where hunting, fishing, summer recreation, and winter sports are important activities. The information gathered about soils and given in this survey can be used to develop these different activities harmoniously.

The main factors that limit growth of ordinary economic plants—soils, high elevations, steep topography, and climate—are about equally effective. Some of the more common information about the soils of this Area is summarized in table 5.

TABLE 6.—*Approximate acreage and proportionate extent of the soils*

| Map symbol | Soil name | Acres | Percent |
|---|---|---|---|
| Aa | Alluvial land | 1, 407 | 1. 6 |
| Ab | Alpine rimland | 8, 264 | 9. 6 |
| Ac | Alpine wind-eroded land | 2, 089 | 2. 4 |
| Ba | Bobtail gravelly sandy loam | 3, 791 | 4. 4 |
| Bb | Bottle fine sand | 236 | . 3 |
| Da | Darling gravelly sandy loam | 7, 739 | 9. 0 |
| La | Leal sandy loam | 2, 731 | 3. 2 |
| Lb | Leal sandy loam, terminal moraine | 305 | . 4 |
| Lc | Leal sandy loam and Alluvial land | 1, 881 | 2. 2 |
| Ld | Lunch peat | 284 | . 3 |
| Na | Nystrom peat | 1, 070 | 1. 3 |
| Pa | Ptarmigan loam | 1, 432 | 1. 6 |
| Pb | Ptarmigan loam, slightly bare | 4, 359 | 5. 1 |
| Pc | Ptarmigan loam, moderately bare | 4, 973 | 5. 8 |
| Pd | Ptarmigan loam, largely bare | 5, 518 | 6. 4 |
| Pe | Ptarmigan loam-Rock outcrop | 3, 866 | 4. 5 |
| Ra | Rock outcrop | 6, 323 | 7. 4 |
| Rb | Rock slides | 11, 802 | 13. 8 |
| Ta | Tabernash loam and Mine gravelly loam | 1, 385 | 1. 6 |
| Va | Vasquez loam | 699 | . 8 |
| Vb | Vasquez loam, slightly bare | 3, 252 | 3. 8 |
| Vc | Vasquez loam, moderately bare | 9, 501 | 11. 1 |
| Vd | Vasquez loam, largely bare | 2, 749 | 3. 2 |
| | Water | 59 | . 2 |
| | Total | 85, 715 | 100. 0 |

## Soil Series and Mapping Units

In this subsection the soil series and mapping units of the Fraser Alpine Area are described in detail. The use and suitability of each mapping unit are briefly discussed. The approximate acreage and proportionate extent of the mapping units are shown in table 6.

### *Alluvial land*

Some 1,400 acres in the St. Louis Creek basin consists of soils in narrow belts on the present flood plains of the main stream. These soils are 10 to 20 feet below the Mine soils of the adjacent higher terraces.

**Alluvial land** (Aa).—In this mapping unit are alluvial soils that consist of coarse-textured, cobbly, stratified alluvium. In places these soils are flooded frequently. During peak floods when snow melts in spring, the water tables are at or near the surface most of the time. Because the soils are extremely porous, the water tables drop rapidly with subsidence of streamflow.

The soils on these erratic alluvial deposits are as heterogeneous as the deposits themselves. The surface soil ranges from silts to cobbles and from a few inches to perhaps a foot in thickness. The substratum is stratified sands, gravel, and cobbles. In some places these soils have a thick surface litter of needles, leaves, wood, and moss. All these soils are noted for their variations rather than their similarities.

Included with these alluvial soils are small areas of bog and Lunch peat. Some of these areas occur where seeps enter the side of the flood plain from higher lying slopes. Others owe their origin to old beaver dams, which are in a number of places along the flood plain. Also included are small areas of bare rock and cobbles that have been dumped by streams during a flood, and which have not been covered by a layer of fine material in which soils could develop.

Seeps and springs are common along these flood plains, especially at higher elevations. They owe their origin to subsurface movement of water down the slopes from the Leal and Darling soils.

*Use and suitability.*—Most grazing of cattle in this watershed is concentrated on these alluvial soils. In wet open areas and near beaver ponds and pockets of Lunch peat, sedge and weeds grow luxuriantly and afford considerable forage. Spruce tends to encroach on these areas, and as time goes on, the area suitable for grazing will be reduced in size.

Willows, which grow in bogs and intermediately drained areas, are important in places. Most of the beaver in this watershed subsist on willows and bog birch.

Some of the area has a dense cover of virgin spruce. The trees grow on the slightly elevated areas, but where the roots readily tap the ground water. Consequently, these soils produce the largest trees and densest stand in the Area. Although most of the present stand is decadent, these soils have a relatively high potential for spruce production.

These soils are important to the hydrologic functioning of the basin. Their coarse, cobbly material prevents rapid downcutting and reduces channel erosion. In fact, channel erosion does not occur if the adjacent vegetation has not been disturbed. The thickness of these alluvial deposits is not known, but no doubt a large volume of water moves through the open, cobbly material below the stream channel.

The perennial streams on these soils are moderately well suited to trout, but they are not the best trout habitat, because the waters are cold. Natural reproduction is low, and most of the fishing results from stocking of the streams.

Because the soils are low and wet, they generally are not well suited for campgrounds. For such purposes, the higher lying Leal and Tabernash soils are better. Nevertheless, these alluvial soils play an important role in the recreational activities of this basin.

### *Alpine rimland*

A complex of soils and miscellaneous land types, covering about 8,200 acres of very steeply sloping land, was placed in one mapping unit. Most of it is just below the ridgetops on easterly exposures (fig. 10).

**Alpine rimland** (Ab).—The soils and land types of this mapping unit are usually, but not always, associated with cirque basins. Snow blown from adjacent ridgetops accumulates as narrow, elongated bands rarely more than ⅛ to ¼ mile wide but, in some places, several miles long.

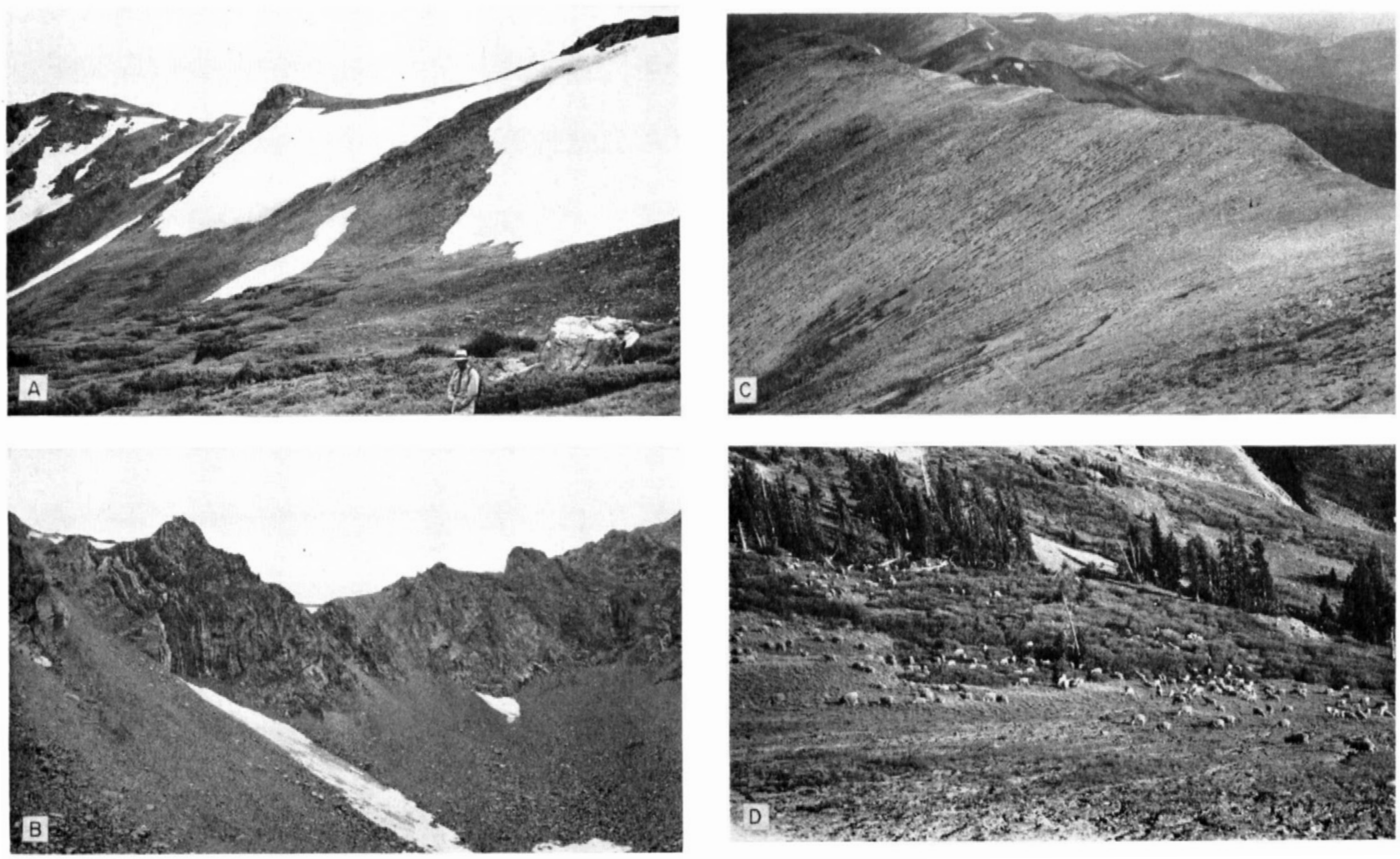



**Figure 10.—Landscapes in the Fraser Alpine Area:**

***A*, Alpine rimland makes up about 10 percent of the Area. The widely distributed areas are nearly devoid of soil, but the deep accumulations of snow yield much water.**

***B*, Rock outcrop and Rock slides together cover about 21 percent of the Area.**

***C*, Alpine wind-eroded land covers only 2.5 percent of the Area but accounts for 11 percent of all the seriously eroded land. This wind-eroded land seems to be enlarging throughout the Area.**

***D*, Three alpine soils make up about 26 percent of the Area. They have a moderate plant cover in some places, and in others are almost bare. Vegetation recovers very slowly on alpine lands.**

In more sheltered places these bands of snow remain until late in summer, and in some years do not completely melt.

These lands do not have a soil profile. They are areas of loose, sandy, gravelly, and rocky materials that in many places contain enough silt and clay to produce vegetation adapted to such environment. Snow remaining on these areas prevents the growth of most kinds of plants.

Surface erosion and slides are common, as slopes ordinarily range from 60 to 80 percent. Water from melting snowbanks causes much of the erosion. The debris that accumulates at the base of the Alpine rimland builds up large fans and fills cirque lakes and depressions. A small amount is carried away in stream channels. Generally, the fans develop some semblance of soils and support some herbaceous cover because they are less sloping.

Alpine rimland is the source of perhaps 45 percent of all the serious erosion in the alpine lands. It is geologically unstable, and the snowbanks increase this instability. Under total protection from use, erosion would still be active but somewhat less than at present. These are favorite concentration areas for sheep. They seem to prefer the few succulent plants growing below the melting snowbanks. Sheep not closely herded nearly always go to these steep, unstable areas in preference to the less steep Ptarmigan or Vasquez soils.

Alpine rimland serves as catchment areas for windblown snow and produces large quantities of water as the snows melt. It has no other use, and, considering the severe environment, there is no known way to vegetate it. Since most of the material eroded from steep banks tends to accumulate in the cirque basins and along the toe slopes, it appears that erosion of this land does little damage to water and streams below.

### *Alpine wind-eroded land*

Wind-eroded lands, concentrated along ridgetops at the heads of major valleys and in high, exposed areas, cover about 2,000 acres. These were mapped as one miscellaneous land type.

**Alpine wind-eroded land** (Ac).—Areas of this mapping unit are usually several hundred feet wide and are elongated parallel to the ridgetops. The wind sweeps away the fine soil particles and leaves only the coarsest sand, gravel, and rock. As this sterile layer thickens, it appears to act as a mulch that retards or stops further removal of material by the wind. But before this occurs, all the original surface soil has been removed and the subsoil, in some places, also has been eroded. Thus, only sterile gravel and rock is left to be revegetated.

The eroding belts appear to widen downslope by undercutting the sod. Once the wind tunnels beneath the tough sod, it is very effective in enlarging the eroded areas. A number of areas are actively deteriorating at present. Few appear to be recovering.

Some of these eroded areas are undoubtedly a natural phenomenon of the alpine region. Others appear to result from removal of turf by grazing and by the animals cutting trails in the turf along driveways and other places of concentration. There is good evidence that these wind-eroded areas were once Ptarmigan soil. The material beneath the pavement of stone and gravel is the yellowish-brown subsoil of the Ptarmigan soils, and within this material the stones are frequently coated on the under side with black organic stains, which is also typical of Ptarmigan soils.

Alpine wind-eroded land is rehabilitated extremely slowly. The plant cycle begins with lichens and proceeds through the several stages of plant succession in the alpine region. Many of the rocks and cobbles are not covered with lichens at the present time. For all practical purposes, these wind-eroded areas have been lost to grazing for all time. The task now is to prevent their enlargement by continued grazing.

### *Bobtail series*

Soils of the Bobtail series are represented in this Area by one soil type, Bobtail gravelly sandy loam. The Bobtail soils are classified as Sols Bruns Acides; they are too weakly podzolized to be classified as Podzols. They have developed from mixed gneiss and schist, which were metamorphosed from granitic rock. Weathering of rock has been slow, and as a result, the profile of these soils contains unusually large amounts of sand, gravel, and stone. These soils are mainly on steep, south-facing slopes below timberline. They also occur at lower elevations, however, and at those elevations tend to be on slopes of a lower gradient and a wider range of exposure.

Bobtail soils are moderately shallow, but there is a thick layer of weathered rock before bedrock is reached at a depth of 5 to 8 feet. The steep slopes are studded with stones and a few extrusions of bedrock. Because the soils are coarse textured and have a relatively large amount of large pores, they are rarely saturated with water. Periods of saturation are limited to a few hours during those few days in spring when snow is melting rapidly.

Nontechnical description of a profile of Bobtail gravelly sandy loam, midway on a slope of 30 percent, under a mature virgin stand of lodgepole pine (fig. 11, pp. 16–17):

Litter—
2 inches to 0, mat of undecomposed and partly decomposed pine needles, bark, and twigs.

Surface soil—
0 to 3 inches, light brownish-gray to grayish-brown gravelly sandy loam; weak blocky and granular structure; very strongly acid; soft when dry and very friable when moist.

Subsoil—
3 to 42 inches, dark-brown to light yellowish-brown gravelly coarse sandy loam; some stones; weak granular or subangular blocky structure; strongly acid to medium acid.

Substratum—
42 to 54 inches +, light yellowish-brown, structureless, gravelly coarse sandy loam; some stones; slightly acid; grades to partially weathered bedrock.

Technical description of a profile of Bobtail gravelly loam, under forest of lodgepole pine:

$A_0$–$A_{00}$ 2 inches to 0, organic mat of partially decomposed or decomposed forest litter, mainly pine needles, bark, and twigs; very strongly acid, pH approximately 5.0.

$A_2$ 0 to 3 inches, grayish-brown or light brownish-gray (10YR 5.5/2, dry) to dark grayish-brown or grayish-brown (10YR 4.5/2, moist) gravelly sandy loam; very weak, medium, platy structure breaking to weak to moderate, medium granular; soft when dry, very friable when moist; very strongly acid, pH approximately 4.7; lower boundary clear and smooth.

$B_2$ 3 to 18 inches, brown (10YR 5/3, dry) to dark-brown (10YR 4/3, moist) gravelly sandy loam; weak, medium, subangular blocky structure; slightly hard when dry, very friable when moist; very strongly acid, pH approximately 4.8; lower boundary gradual and smooth.

$B_3$ 18 to 42 inches, light yellowish-brown (10YR 6/4, dry) to yellowish-brown (10YR 5/4, moist) gravelly loamy sand; massive; slightly hard when dry, friable when moist; medium acid, pH approximately 5.5; lower boundary diffuse and smooth.

C 42 to 54 inches, light yellowish-brown (10YR 6/4, dry) to yellowish-brown (10YR 5/4, moist) gravelly sandy loam; slightly hard when dry, friable when moist; medium acid, pH approximately 5.7; lower boundary diffuse and smooth; horizon contains large amount of partially weathered fragments from the bedrock.

D 54 to 118 inches, light yellowish-brown (10YR 6/4, dry) to yellowish-brown (10YR 5/4, moist) gravelly loamy sand; horizon is only partially weathered bedrock (gneiss and schist) with some finer textured material in cracks between the stones.

*Range in characteristics.*—The surface soil ranges from 3 to 6 inches in thickness, is everywhere of coarse texture, and contains stones. It is normally brownish gray, but in a few places it is grayish brown. The surface layer contains the largest quantities of silt and clay and is the most acid part of the profile. The subsoil is distinguished from the surface soil primarily by its darker brown color. It is a zone of slight iron accumulation.

The organic-matter content is highest in the surface layer and sharply decreases in the subsoil. Acidity consistently decreases from very strongly acid in the surface layer to medium acid or slightly acid in the deeper layers. Textures are coarse throughout, but the greatest quantities of silt and clay are in the surface soil. Silts consistently decrease with depth, but clays show no consistent pattern of distribution.

*Topography.*—In the Fraser Area, Bobtail soils are on relatively smooth, steep, south-facing slopes at elevations above 9,000 feet. Slopes range from 10 percent to more than 60 percent in some places.

*Drainage and permeability.*—Bobtail soils are well drained to somewhat excessively drained. All horizons have moderately rapid to rapid permeability. Within the mapped area, seeps and areas of Lunch peat are present only as traces, and these seemingly owe their presence more to geology of the Area than to accumulation of water in Bobtail soils.

*Vegetation.*—Lodgepole pine, with a few aspen trees, is the dominant vegetation. The understory is an open stand of huckleberry and buffaloberry. The canopy provided by all plants is barely enough to cover the ground.

*Distribution.*—In this Area, Bobtail soils are mainly at elevations above 9,000 feet and below timberline. At higher elevations they occur only on south-facing slopes, and at lower elevations they tend to be in the more gently sloping areas. Soils of this series probably are widely distributed throughout the Rocky Mountain area.

*Type location.*—Bobtail soils were first recognized in the Fraser Experimental Forest. The type location is midway on a south-facing slope, on West St. Louis Creek, in approximately the NW¼ sec. 8, T. 2 S., R. 76 W., Grand County, Colo.

*Series established.*—The Bobtail series was established in 1955.

**Bobtail gravelly sandy loam** (Ba).—This soil has the profile described as typical of the Bobtail series. As mapped, it includes a fraction of 1 percent of protruding bedrock and a similar acreage of loose surface stones. Narrow bands of alluvial-colluvial deposits along the toe slopes were also included in mapping because of their limited acreage and their occurrence in narrow, intermittent bands. These included soils on toe slopes differ from the Bobtail soil and generally are more productive of timber.

*Use and suitability.*—All of this soil is under lodgepole pine. Most of the stand is over-mature, virgin timber, but some regrowth has occurred in those places where logging was done in the early days. An occasional "wolf" tree in the virgin stands has withstood fire that occurred as much as 200 years ago. A few subalpine firs grow in the understory, especially at higher elevations. At present, lodgepole pine seems to be the only commercial species suitable. Natural regeneration appears to be adequate. Clearcut experimental plots on the West St. Louis Creek watershed produced yields of 8,000 board feet per acre from pure stands.

Possibly yields could be increased by a shorter cutting cycle, but studies of the present stands have shown an extremely slow rate of growth. When logging opens a stand, the area is occupied by a thin to moderate stand of young trees or shrubs and by some weeds, grasses, and sedges. This new growth is good summer forage for deer, but deer leave the area in winter.

Observations made on the West St. Louis Creek watershed indicate that snow does not accumulate so deep on the Bobtail soil as on the Darling soil. This can be explained by the intermittent melting and evaporation that takes place during winter when the rays of the sun hit the steep southerly slopes occupied by the Bobtail soil at an angle nearly perpendicular. Likewise, it has been observed that snow melts about 30 days earlier on the Bobtail soil than on the Darling.

When snow melts on the south-facing slopes of the Bobtail soil, there is no appreciable increase in streamflow. The same general relationship appears to be true for the east-west facing slopes along Fool Creek, which are below elevations of about 10,000 feet.

### Bottle series

Soils of the Bottle series are represented in the Area by one soil type, Bottle fine sand. Bottle soils are Podzols. They have a strongly developed leached layer and a zone of iron accumulation in the B horizon. They developed in material weathered from sandstones. These sandstones are only small remnants of a deposit that was once more extensive in the survey area.

Bottle soils are shallow over sandstone bedrock, have a large amount of stone in their profile, and have fine sand or sand textures. They are at elevations below 10,000 feet and are generally on uniform slopes not exceeding 35 or 40 percent.

The Bottle soils are strongly influenced by the nature of the sandstone parent materials. Apparently these sandstones were strongly reworked and leached of nutrients when they were deposited in Cretaceous seas. The sand grains themselves are almost entirely well-rounded quartz. In this area, the strong cross-bedding of the sandstone layers suggests that the rock originated from dune sand.

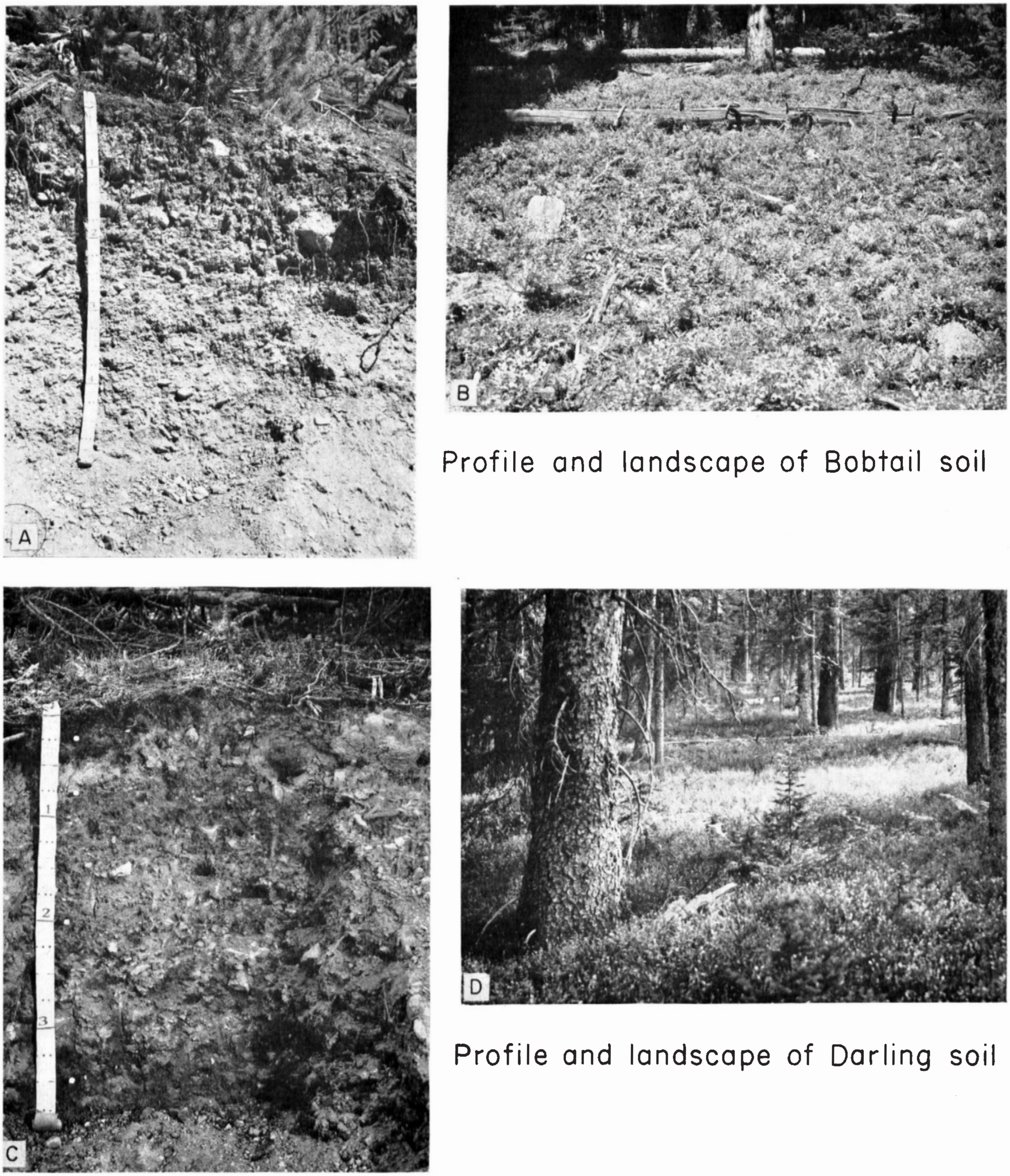
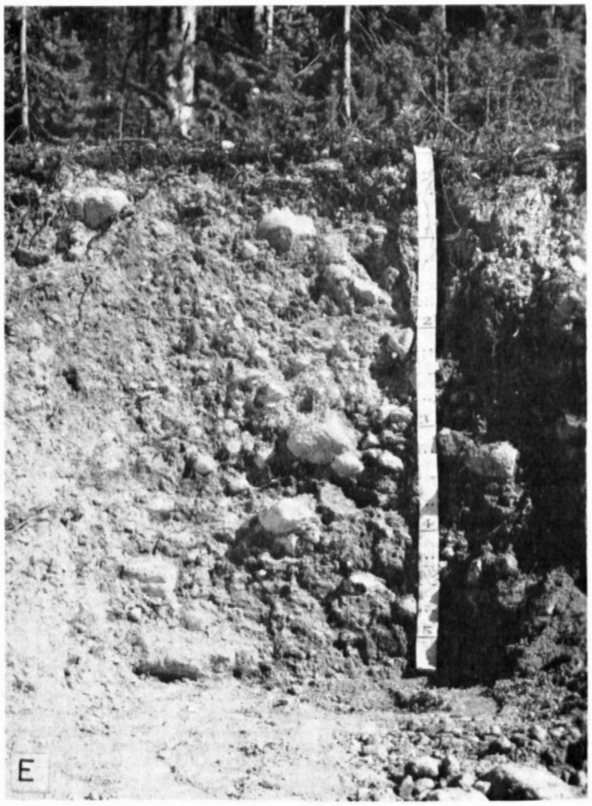
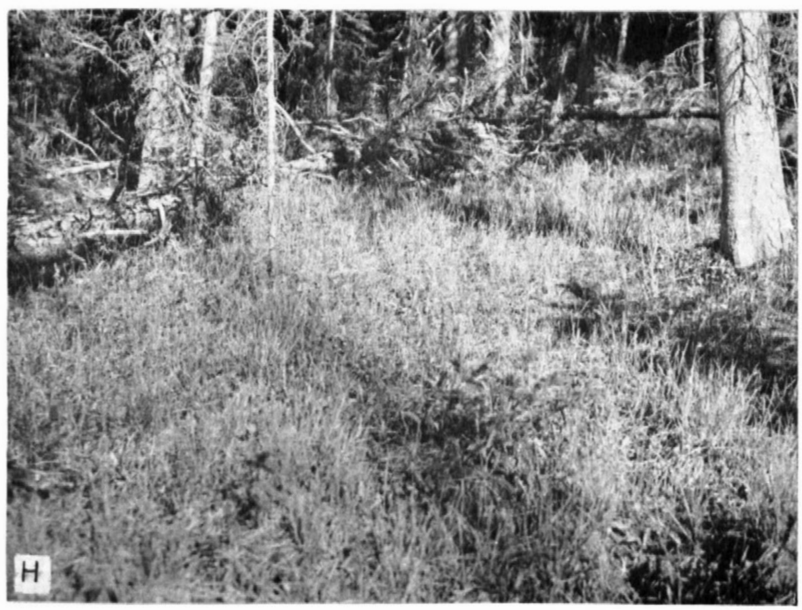



*Figure 11.*—**Four important soils and their landscapes in wooded areas below**





Profile and landscape of Leal soil


Profile and landscape of Lunch soil

**timberline: *AB*, Bobtail soil; *CD*, Darling soil; *EF*, Leal soil; and *GH*, Lunch soil.**

Bottle soils developed under a poor to medium stand of lodgepole pine. The layer of litter is thin and patchy in some places but is as much as 4 inches thick in others. In most places the gray, leached layer lies immediately beneath the needles, without an intervening darker layer. Where the darker layer is present, it is thin and discontinuous. The subsoil is distinguished from the overlying layers only by a browner color in those places where iron that leached from the surface soil has accumulated. Bottle soils are everywhere shallow and stony. They are droughty and low in inherent fertility.

Nontechnical description of a profile of Bottle fine sand under a virgin, mature stand of lodgepole pine on a north slope of 35 percent:

Litter—
2 inches to 0, undecomposed mat of needles over a thin, dark-gray, partially decomposed organic matter.

Surface soil—
0 to 6 inches, light-gray to light brownish-gray fine sand; weak, coarse, platy structure; loose, soft consistence; very strongly acid; many stones.

Subsoil—
6 to 11 inches, light yellowish-brown to yellowish-brown loamy fine sand; weak, fine, subangular blocky structure; soft, friable consistence; very strongly acid but less so than surface soil; this is a layer of iron accumulation, as evidenced by stains on the grains of sand; many stones.

Substratum—
11 to 33 inches, very pale brown fine sand weathered from sandstone, which makes up 85 percent of the layer, by volume; very strongly acid but less so than the surface soil or subsoil.

Technical description of Bottle fine sand in an area forested with lodgepole pine:

$A_{00}$ 2 to 1½ inches, undecomposed mat of needles.

$A_0$ 1½ inches to 0, very dark gray to very dark grayish-brown (10YR 3/1.5, dry) to black or very dark brown (10YR 2/1.5, moist) partially decomposed organic material ranging from 3 to 6 inches in thickness; lower boundary clear and smooth.

$A_2$ 0 to 6 inches, light-gray (10YR 7/1.5, dry) to light brownish-gray (10YR 6/1.5, moist) fine sand; weak, very coarse, platy structure breaking to weak to moderate, fine and medium, crumb structure; soft when dry, very friable when moist; very strongly acid, pH 4.8; lower boundary abrupt and wavy.

$B_{2ir}$ 6 to 11 inches, light yellowish-brown (10YR 6/4, dry) to yellowish-brown (10YR 5/4, moist) loamy fine sand; weak, fine and medium, subangular blocky structure breaking to weak, medium or coarse granular; soft when dry, very friable when moist; horizon contains many medium-sized, distinct mottles of brown (7.5YR 4/4); horizon ranges from 5 to 8 inches in thickness; pH 4.8; lower boundary clear and wavy.

$C_1$ 11 to 33 inches, very pale brown (10YR 7/3, dry) to pale brown (10YR 6/3, moist) partially weathered sandstone base rock; about 85 percent of horizon, by volume, is unweathered rock fragments; pH 4.9.

*Range in characteristics.*—The surface soil and subsoil vary considerably in thickness. The surface soil is 2 to 7 inches thick; whereas the subsoil is as little as 6 inches to as much as 30 inches thick. The content of rock and stone is characteristically very high within the profile, and on the surface. Textures are exceptionally uniform; they follow the usual pattern in this area; that is, the greatest amounts of silt and clay are in the surface soil, and decreasing amounts of each are in the deeper horizons. All the profiles studied are very strongly acid in all horizons. The most acid layer is at the surface, and the profile is less acid with depth.

Chemical data show that Bottle soils are very low in inherent fertility, in comparison with Bobtail and Darling soils. Bottle soils are strikingly deficient in calcium, magnesium, and potassium.

*Topography.*—Bottle soils have developed on uniform, moderately sloping areas undissected by drainageways or streams.

*Drainage and permeability.*—Bottle soils are somewhat excessively drained; permeability is moderately rapid to rapid.

*Vegetation.*—Bottle soils formed under a poor to medium stand of lodgepole pine and a very thin understory of vaccinium. The absence of buffaloberry is particularly noticeable on these soils.

*Distribution.*—In the Fraser Alpine Area, Bottle soils are only at lower elevations in the St. Louis Creek watershed. It is believed that they are widely distributed in nearby areas outside the limits of this survey.

*Type location.*—Bottle soils were first mapped in this Area. The site location is in the lower end of the Fool Creek watershed in approximately the SE¼SW¼ sec. 3, T. 2 S., R. 76 W., Grand County, Colo.

*Series established.*—The Bottle series was established in 1955.

**Bottle fine sand** (Bb).—The profile of this soil is that described for the Bottle series. As mapped, the soil includes a high percentage of rock outcrops. The amount of outcrop varies from place to place but is most abundant on the immediate tops of ridges and, to somewhat lesser extent, on the sloping sides of the ridges.

All of this soil is covered with a mature, virgin stand of lodgepole pine. At higher elevations in the West St. Louis Creek watershed, some spruce is present. The growth of lodgepole pine is open and of poor appearance.

This soil is apparently suitable only for lodgepole pine, which will be of poor quality and grow slowly. The chemical and physical limitations of this soil prevent its improvement by reasonable management practices.

This soil does not cover much acreage; it is not important as a source of water or a habitat for wildlife.

### *Darling series*

The Darling series consists of somewhat excessively drained, deep, coarse-textured soils. In this Area they are represented by one soil type, Darling gravelly sandy loam.

These soils are Podzols occurring at elevations between 9,500 feet and timberline in this Area. At low elevations they are only on the steep, north-facing slopes where the direct rays of the sun reach them only in midsummer. At higher elevations they tend to occupy a greater proportion of the landscape, regardless of exposure.

The Darling soils have formed in coarse-textured materials weathered from mixed gneiss and schist. An appreciable percentage of bedrock protrudes through the soils in many places. For the entire area mapped, however, these rocks probably account for no more than 2 to 5 percent of the acreage.

Darling soils range from 30 to 40 inches in thickness, but their parent material extends downward an additional 5 to 8 feet, as determined by observing deep road cuts. Because the soils are porous, surface runoff occurs only at peak periods of snowmelt. Then runoff lasts for only 2 or 3 hours in the afternoon of warm days. Surface erosion has not been observed under virgin stands of timber on these soils. A profile and landscape are shown in figure 11, *C*, *D*.

The mineral soil is covered with a dense, thick, spongy litter of the mor type. This litter is composed of needles, rotting wood, and moss. The mineral surface soil is a very thin, dark-gray to black layer of mixed mineral and organic matter over a distinct, light-gray or brownish-gray podzolic layer of irregular occurrence and thickness. The subsoil, a distinct brown or dark-brown layer of iron accumulation, is in many places as much as 20 to 30 inches thick. In the weathered material of the substratum, the color changes gradually to light grayish brown or brownish gray.

Compared with the Bobtail soils, the Darling soils are slightly more acid, contain more silt and clay, have a more uniform and thicker layer of litter at the surface, and have a more distinct and thicker subsoil. Because Darling soils are at higher elevations and on north exposures, they appear to hold more moisture for longer periods than do the Bobtail soils. Darling soils are less consistent than the Bobtail soils in thickness of horizons and in texture. Important factors in the mixing of materials in Darling soils are the many seeps and springs, the steep slopes, the slides, and the churning evidenced by overturned trees.

Nontechnical description of Darling gravelly sandy loam under mature, virgin spruce forest, midway on a slope of 35 percent that has northerly exposure:

Litter—
4 inches to 0, dark-brown layer of undecomposed and decomposed organic material made up of needles, twigs, vaccinium roots, and bark.

Surface soil—
0 to 3 inches, light brownish-gray to light-gray loam or gravelly sandy loam; weak, fine, platy to weak, fine, granular structure; very friable; very strongly acid.

Subsoil—
3 to 38 inches, brown to dark-brown gravelly, coarse sandy loam; very weak subangular blocky structure; friable when moist but weakly cemented in some places in lower part; very strongly to strongly acid.

Substratum—
38 to 80 inches +, light yellowish-brown to light olive-brown in deeper part, gravelly coarse sandy loam; an estimated 70 to 80 percent of layer, by volume, is stone and gravel; medium acid; gradual transition to less decomposed rock.

Technical description of profile of Darling gravelly sandy loam under forest cover of spruce and fir.

$A_0$–$A_{00}$ 4 inches to 0, dark-colored organic mat made up of undecomposed and partially decomposed forest litter, primarily vaccinium roots, needles, bark, and twigs.

$A_2$ 0 to 3 inches, light brownish-gray (10YR 6/2, dry) to grayish-brown (10YR 5/2, moist) gravelly sandy loam; weak to moderate, medium, platy structure; soft when dry, very friable when moist, very strongly acid, pH of approximately 4.7; lower boundary abrupt and smooth.

$B_2$ 3 to 23 inches, brown (7.5YR 5/4, dry) to dark-brown (7.5YR 4/4, moist) very gravelly sandy loam; single grained; loose when dry and moist; very strongly acid, pH approximately 4.8; approximately 75 percent of horizon is gravel; lower boundary gradual and smooth.

$B_{2ir}$ 23 to 38 inches, brown (7.5YR 5/4, dry) to dark-brown (7.5YR 4/4, moist) gravelly sandy loam; massive; very hard when dry, firm when moist; strongly acid; pH approximately 5.2; horizon weakly cemented in some places but degree of cementation is not great and varies from place to place; lower boundary gradual and smooth.

$C_1$ 38 to 48 inches, light yellowish-brown (10YR 6/4, dry) to yellowish-brown (10YR 5/4, moist) very gravelly sandy loam; massive; slightly hard when dry, very friable when moist; strongly acid, pH approximately 5.5; lower boundary diffuse and smooth.

$C_2$ 48 to 81 inches, light olive-brown (2.5Y 5/3, dry) to olive-brown (2.5Y 4/3, moist) partially weathered gneiss and schist bedrock; approximately 70 percent of horizon, by volume, is coarse stones and boulders; much of remainder is very gravelly sandy loam between boulders; pH 5.8; lower boundary diffuse and smooth.

D 81 to 116 inches +, light olive-brown (2.5Y 5/3, dry) to olive-brown (2.5Y 4/3, moist) unweathered gneiss and schist bedrock; pH 5.9.

*Range in characteristics.*—The surface soil ranges considerably in thickness. The gray layer is patchy and irregular in many places but is rarely absent. The texture of the surface layer ranges from loam to gravelly coarse sandy loam, but the soils are dominantly coarse and gravelly, and the content of stone increases in the deeper layers. The content of silt and clay is greatest in the surface soil and decreases irregularly with depth. Acidity decreases consistently with depth.

*Topography.*—Darling soils are on relatively smooth but steep slopes of 10 to 80 percent. The slopes are dissected by a relatively few, shallow drainageways. At higher elevations some slopes have been steepened by passage of glaciers down the small side valleys and the main valley of St. Louis Creek.

*Drainage and permeability.*—Darling soils are well drained to somewhat excessively drained. Nothing in their profile restricts permeability to the extent that the soils are in any class with slower drainage than moderately rapid to rapid. Surface runoff, therefore, occurs only during the peak of snowmelt late in May or in June. The moisture regime is favored somewhat by the generally northerly exposure of these soils. Exposure no doubt accounts for the main differences between the Darling and Bobtail soils, as the Bobtail soils are closely associated with the Darling, but are on southerly exposures.

*Vegetation.*—The Darling soils have a dense cover of Engelmann spruce and minor inclusions of alpine fir and aspen. The dense, low growing understory consists of vaccinium and a few minor shrubs. Thick layers of moss are common in most places. Under natural conditions, the canopy and ground cover of the Darling soils are much denser and provide appreciably more protection than the cover on the adjacent Bobtail soils.

*Distribution.*—Darling soils are widely distributed throughout the St. Louis Creek watershed. They tend to be more prevalent at higher elevations, and at lower elevations occur only on north-facing slopes. These soils probably are widely distributed at high elevations throughout the Rocky Mountains in Colorado.

*Type location.*—The type location is midway on a north-facing slope on West St. Louis Creek, about 200 yards above the diversion structure (NW¼ sec. 8 T. 2 S., R 76, W., Grand County, Colo.).

*Series established.*—The Darling series was established in 1955.

**Darling gravelly sandy loam** (Da).—The profile of this soil is like that described for the Darling series. As mapped, this soil includes less than 5 percent of protruding stones and about 2 percent of small bogs (Lunch peat) and seepy marshy areas. The small bog and seeps occur in elongated patterns that normally parallel the slope (see fig. 11, *G*, *H*). Also, on toe slopes, adjacent to drainageways, there are narrow, irregular bands of alluvial-colluvial deposits too small and irregular to be shown on a map of the scale used. The soils of these deposits are generally deeper than Darling gravelly sandy loam, and they receive additional moisture that seeps down from slopes above. These deeper soils are on milder slopes and serve to protect the flood plain and stream channel from rapid surface runoff during periods of high snowmelt.

*Use and suitability*.—Darling gravelly sandy loam is covered with a virgin stand of overmature spruce that includes lesser areas of alpine fir and a few aspen. Harvested plots on West St. Louis Creek indicate yields between 18,000 and 25,000 board feet per acre. Because the stand is overmature, the percentage of cull trees in many places is large. Within a few hundred yards of timberline, the trees are not merchantable by present logging standards.

Where cleared or burned over, Darling gravelly sandy loam has not been known to produce large quantities of herbage suitable for grazing. Buffaloberry, vaccinium, and other shrubs occupy areas that have been logged over. Production of spruce timber appears to be the highest use for this soil, but an unmanaged stand grows at a rate not exceeding 200 board feet per acre, per year, and at high elevations, yields and growth are much less. At a more intensive level of management, the annual production might be increased to 300 board feet per acre.

This soil yields important amounts of water. Many seeps and marshes occur on it. Some water may be seeping down from the higher alpine soils, but appreciable quantities originate in this soil. A system of timber management that would increase the snowpack on this soil would result in an appreciable increase in water (*3*). Water management on this Darling soil is comparatively simple because the soil is resistant to erosion. Areas cleared by logging or fire are soon revegetated except near timberline. The toe slopes, with their decreased grade and increased depth for storing water, are effective buffer zones between the steep slopes and the flood plains.

The spruce forest provides summer food and protection for elk, deer, bear, and other wildlife. Marten, weasel, and similar furbearers inhabit these areas. Pine squirrel and snowshoe rabbit are common. Blue grouse inhabit the forest exclusively; they feed on spruce buds and vaccinium in both summer and winter. Grouse in groups up to 13 have been seen frequently on the Fool Creek and West St. Louis Creek watersheds.

### *Leal series*

Soils of the Leal series are Podzols that developed in deep glacial till derived from mixed gneiss and schist. This till was deposited in lateral moraines on both sides of main St. Louis Creek and on the main tributaries south of West St. Louis Creek. In some of the valleys of the smaller tributaries to main St. Louis Creek, the till was deposited on the floors, or valley bottoms. The till has not been transported far, and a very large percentage of it consists of intimately mixed boulders, cobbles, and sand. Many of the boulders are very large (see fig. 11, *E*, *F*).

The surface is characteristically irregular in areas of Leal soils. There are many small mounds and ridges interspersed with kettles or depressions. Because the soil material is extremely porous, few of the kettles contain water.

The Leal soils are like other soils of the Area in having the highest content of silt and clay in the surface layer and decreasing amounts in layers deeper in the profile. Their reaction is also characteristic. The surface soil is extremely acid, but the subsoil and substratum are only strongly acid.

Three units of the Leal series are shown on the map of this Area. They are Leal sandy loam (a soil type), Leal sandy loam, terminal moraine (a soil phase), and Leal sandy loam and Alluvial land (a soil complex).

Nontechnical profile description of Leal sandy loam on a convex, east-facing slope of 4 percent:

Litter—
2 inches to 0, mat of undecomposed needles over very dark gray, partly decomposed, acid, organic material.

Surface soil—
0 to 2 ½ inches, thin but distinct horizon of light-gray sandy loam; weak granular structure; extremely acid.

Subsoil—
2 ½ to 16 inches, light yellowish-brown to dark yellowish-brown gravelly sandy loam; weak subangular blocky structure; soft to friable; strongly acid; many cobbles.

Substratum—
16 to 23 inches +, pale-yellow to light olive-brown coarse sandy loam; loose and soft; strongly acid; many cobbles.

Technical description of a profile of Leal sandy loam under lodgepole pine:

$A_{00}$ 2½ to 2 inches, massive, undecomposed mat of pine needles and other organic debris.

$A_0$ 2 inches to 0, very dark gray (10YR 3/1, dry) to black (10YR 2/1, moist) partly decomposed organic materials; massive; very strongly acid; horizon rests abruptly on the one below.

$A_2$ 0 to 2½ inches, light-gray (10YR 7/2, dry) to grayish-brown (10YR 5/2, moist) sandy loam; weak, very coarse, platy structure breaking to weak to moderate, fine, crumb structure; soft when dry, very friable when moist; extremely acid, pH 4.4; lower boundary clear and wavy.

$B_{2ir}$ 2½ to 11 inches, light yellowish-brown (10YR 6/4, dry) to dark yellowish-brown (10YR 5/4, moist) gravelly sandy loam; weak to moderate, fine, subangular blocky structure; soft when dry, very friable when moist; strongly acid, pH 5.1; lower boundary gradual and smooth.

$B_3$ 11 to 16 inches, light yellowish-brown (2.5Y 6/4, dry) to olive-brown (2.5Y 4/4, moist) gravelly sandy loam; very weak, medium, subangular blocky structure; soft when dry, very friable when moist; strongly acid, pH 5.3; medium-sized, distinct yellowish-brown (10YR 5/4) mottles are common; lower boundary gradual and smooth.

C 16 to 23 inches, pale-yellow (2.5Y 7/3, dry) to light olive-brown (2.5Y 5/3, moist) gravelly coarse sandy loam; massive; soft when dry, very friable when moist; pH 5.4.

*Range in characteristics*.—Leal soils vary widely, primarily because of sliding and mixing of material during and following the time it was deposited by glaciers. Irregularly and unpredictably, concentrations of very coarse material alternate with finer sand and silt.

The soils normally have a layer of litter 2 to 4 inches thick. Beneath this is a thin, gray, mineral surface layer. Commonly this gray layer is 2 to 4 inches thick, but in many places it is broken and discontinuous, and in some places it is absent or nearly so. The yellowish-brown subsoil likewise varies a great deal in thickness within short distances. The range is from 5 or 6 inches up to as much as 15 or 20 inches. At elevations above 10,500 feet, the subsoil, or B horizon, has developed color and iron accumulation approaching those of the corresponding layer in the Darling soils.

Leal soils are consistent in the respect that their content of silt and clay is greatest in the surface soil and decreases with depth. Likewise, the Leal soils are consistently coarse textured, contain large quantities of cobbles, and have been mixed through overturning of trees.

*Topography.*—Leal soils have slopes ranging from 5 to 60 percent, but slopes of 10 to 20 percent are the most common. The soils formed in glacial deposits, which were left as lateral moraines on the sides of mountains, or which were spread over the general landscape at lower elevations and buried the original topography. The relief is very irregular—small mounds, ridges, and kettles, or depressions, are numerous and without consistent pattern of any kind. Rarely do the kettles contain water.

*Drainage and permeability.*—Leal soils are well drained to somewhat excessively drained. They lack restricting lenses of fine material and, consequently, percolation of water is moderately rapid to rapid. Practically no runoff occurs.

*Vegetation.*—In most places Leal soils have a cover of virgin, overmature spruce and subalpine fir at higher elevations, and lodgepole pine at lower elevations. The ground cover is a dense to open stand of vaccinium, with lesser amounts of other shrubs. The ground cover of moss common on Darling soils, for the most part, is absent from Leal soils.

*Distribution.*—Leal soils are distributed throughout the glaciated parts of the St. Louis Creek watershed. Characteristically, they are on lower parts of the local landscapes. Leal soils are widely distributed throughout the Rocky Mountains at elevations above 8,000 feet.

*Type location.*—The type location for the Leal soils is in the main St. Louis Creek watershed, a short distance upstream from the Fraser Experimental Station headquarters (center of sec. 9, T. 2 S., R 76 W., Grand County, Colo.).

*Series established.*—These soils were first recognized in 1955.

*Remarks.*—As mapped in this Area, an estimated 2 to 10 percent of the acreage of Leal soils consists of cobblestones protruding to the surface. The Leal soils contain no important areas of Lunch peat, as is common in the Darling soils. There are many kettles, few of which contain water.

In two small areas the Leal soils formed in somewhat older till that contains a high percentage of rhyolitic rock. One of these areas lies along the ridgetop west of the main lower weir on Fool Creek; the other is on a ridge east of King Creek. The soils in these two places appear to have a more developed subsoil. Apparently the rhyolitic rock in these areas weathers more rapidly than the other rocks.

**Leal sandy loam** (La).—This soil has a profile like that described as typical of the series. The inclusions of rock or other kinds of soil are as described for the series.

*Use and suitability.*—At lower elevations, this soil has been logged and the cover now is a young stand of lodgepole pine. At higher elevations it supports virgin stands of spruce, alpine fir, lodgepole pine, and a few aspens. Lodgepole pine and spruce probably will remain dominant in the overstory. Where stands have been opened, sedges and herbaceous plants come in only as a thin cover, generally not in quantities sufficient for grazing.

Leal sandy loam has an important effect on storage of water and regulation of streamflow. The loose porous deposits are ideal for absorbing and storing water. Surface runoff and erosion have never been observed under a natural cover of trees. No streams originate within areas of Leal sandy loam. Springs and seeps are rare except at the base of the slopes. Because the deposits in which this soil formed were plastered against the valley sides, often as high as several hundred feet above the valley floors, they act as a barrier against rapid runoff from the higher mountain slopes. Water passes through Leal soil, not over it.

Leal sandy loam has no special features that make it a more favorable habitat for wildlife than the adjacent Darling and Bobtail soils. Generally, it is not topographically suitable for campgrounds or other concentrated recreational uses. The open, porous soil, however, has excellent internal drainage and contains a high percentage of coarse rock and cobbles that would resist deterioration under use.

**Leal sandy loam, terminal moraine** (Lb).—In this mapping unit is Leal sandy loam that developed on terminal moraines left by glaciers as they advanced down the valley and then retreated. These moraine areas are shown separately on the map because of their landform and their significance in managing water. In many places they form dams across the main valley, and in places the present channels drop precipitously on their lower sides. The profile of this soil is like that described for the Leal series.

In some places channels have eaten far down into the moraine, but in others this erosion is less extensive. The valley above a moraine usually is gently sloping for some distance, but below the moraine it is commonly narrow and steep. Two major terminal moraines are on main St. Louis Creek, and in both places the present channel has bypassed along one side of the moraine.

Leal sandy loam, terminal moraine, is for the most part covered with dense stands of spruce and fir. It appears that yields of timber would be high.

**Leal sandy loam and Alluvial land** (Lc).—This mapping unit consists of Leal sandy loam and alluvial soils that were not separated on the map. These soils occur along main St. Louis Creek and its tributaries on the west side of the basin. The parent material is a mixture of glacial till, glacial outwash, and recent valley fill. The topography is extremely irregular; slopes commonly range from 3 to 10 percent. Steep places in the valley floor are in many places preceded and followed by more nearly level areas upstream and downstream.

The soil profile varies, but commonly there is 3 to 4 inches of litter over the gray, coarse sandy loam surface soil. The subsoil and substratum locally are extremely variable, depending upon the kind of parent material.

The water table is near the surface in many places. Internal drainage is good to somewhat excessive because of the coarse, sandy and rocky materials. Dry spots occur locally on the higher areas of the glacial till deposits. There is no surface erosion. Some local cutting occurs along streambanks, but this is not serious.

*Use and suitability.*—These soils are covered with a virgin stand of spruce-fir and an occasional lodgepole pine. The understory is a dense growth of vaccinium. Observations indicate that the annual yield of timber on these soils might exceed the yield on Darling soils by 2,000 to 6,000 board feet per acre.

These soils are critical in management of water in the basins where they occur. The large quantity of boulders, together with the open porous nature of the soil material, reduces channel erosion and provides for ready seepage through underlying layers. Vegetation on streambanks plays a major role in retaining stability of the present channels. Any operation that would seriously interfere with protection of streambanks should be considered carefully before it is begun.

### *Lunch series*

Lunch peats consist of highly organic materials overlying mixed mineral materials. They developed in bogs and poorly drained areas. In the Fraser Alpine Area, they are nearly always associated with Darling soils and rarely occur in areas of Bobtail or Leal soils. The Lunch peats in this Area are shown as one unit on the map, and only the larger areas could be shown. Many small areas of Lunch peats are included with the Darling soils.

The Lunch peats are in bogs that owe their origin to seeps and springs, which emerge on steep mountain slopes, frequently at higher elevations of the Darling soils. Waters move down the slope, both above and beneath the surface of the areas of Darling soils, and thus produces long, narrow areas of Lunch peats.

Lunch peats have 1 or 2 feet of raw peat consisting of a mixture of wood, roots, willow leaves, pine needles, and the decomposed remains of sedges and some succulent weeds (see fig. 11, *G*, *H*). Under this organic material are subsurface layers consisting of mineral materials—silt and clay with a high proportion of gravel and stones. These mineral soil layers are strongly mottled with many colors ranging from browns to grays and blues.

The following describes a typical profile of Lunch peat:

0 to 24 inches, layer of black, raw peat composed of a mixture of wood, leaves, and needles, plus decaying parts of weeds and sedge; layer is saturated most of the year and contains some stones.

24 inches +, layers and mixtures of dense silt and clay with some stone and gravel; bluish, highly mottled, and always wet; much water moves at the interface on this layer and the overlying peat.

Because of steep slopes and the stony underlying material, there are many variations in Lunch peats as they are mapped in this Area. The surface layer is never of constant thickness, even locally. It ranges from a few inches to as much as 3 feet thick. It is thickest where it developed on relatively level benches perched on the mountainsides. It is thinnest where it occurs in the narrow stream channels that extend down the steep slopes. The material in the surface layer varies a great deal, depending on whether the peat formed in one of the larger bogs where sedges predominate, or in a small bog surrounded by spruce and alpine fir. The layers of blue clay and silt vary in thickness and in location in the profile. In some places these layers are absent, and in others they are only poorly developed. Stones in Lunch peats are of all sizes and degrees of hardness. Because of the steep slopes, considerable mixing of material has occurred. As a result, there are stones in the peaty surface layer, though they are more common in the mineral subsurface layer.

Lunch peats are acid. The average pH for six profiles was 5.52 for the surface layer, 5.36 for the second layer, and 5.35 for the third.

**Lunch peat** (Ld).—The profile of this mapping unit is that described as typical of Lunch peat. The variations in the profile are as described in the series.

Lunch peat is valuable mainly for its effect on yield of water. It acts as sponge that absorbs water emerging from springs and seeps. Thus, it reduces the velocity of flow down the steep slopes. Without the restraining influence of Lunch peat, drainage channels no doubt would be much more deeply entrenched in many places.

Spruce grows very well adjacent to this peat, and within the smaller areas, no doubt because water is abundant. The trees, however, do not grow in the larger areas.

Deer and elk frequently use these areas for browse and water. Blue grouse favor some of them, possibly because of the water.

Lunch peat is in such small areas it can be managed only with the adjacent Darling or Bobtail soils. It presents special problems in location, construction, and maintenance of trails and forest roads.

### *Mine series*

Soils of the Mine series are timbered Regosols that developed on deep, cobbly glacial outwash material. In this Area they are represented by one mapping unit, Tabernash loam and Mine gravelly loam.

In the Fraser Alpine Area, along St. Louis Creek, the glacial outwash in which these soils formed was deposited on old flood plains that now occupy well-drained terraces. In the northern end of the experimental forest, however, the deposits spread out as an outwash plain that covers an appreciable part of the Fraser Valley in this vicinity. On this plain, there are several levels of terraces.

A large proportion of the outwash consists of well-rounded cobbles, some of them very large, but the majority, 2 to 12 inches in diameter. Stratification and cross-bedding are common. The thickness of the outwash deposit is not known, but in places the present channel has entrenched itself as much as 20 feet in the original deposit.

These soils are without strong profile development. They have a litter of needles over a surface soil ranging from 3 to 8 inches in thickness. They have no B horizon. A large part of the substratum is cobbles. The quantity of silt and clay is greatest in the surface soil and tends to decrease with increasing depth.

Profile description of Mine gravelly loam under a regrowth of lodgepole pine on a glacial outwash terrace with a slope of 3 percent:

Litter—
1 inch to 0, thin layer of needles and twigs resting on very dark gray partially decomposed organic material.

Surface soil—
0 to 6 inches, grayish-brown, granular, soft loam; strongly acid to medium acid; considerable stone.

Substratum—
6 to 20 inches +, light yellowish-brown gravelly sandy loam containing cobbles; strongly acid to medium acid.

The following is a technical description of Mine gravelly loam under a forest of lodgepole pine:

$A_0$ 1 inch to 0, very dark gray (10YR 3/1, dry) to black (10YR 2/1, moist) partially decomposed organic material; thin cover of last year's needles on this horizon; abrupt transition to horizon below.

$A_1$ 0 to 3 inches, dark grayish-brown (10YR 4/2, dry) to very dark brown (10YR 2/2, moist) gravelly loam; moderate, medium and fine, crumb structure; soft when dry, very friable when moist; slightly acid, pH 6.1; horizon contains many plant roots; lower boundary gradual and wavy.

$A_3$ 3 to 6 inches, grayish-brown (10YR 5/2, dry) to very dark grayish-brown (10YR 3/2, moist) gravelly loam; very weak, medium subangular blocky structure breaking to weak to moderate, fine, granular slightly hard when dry, very friable when moist; medium acid, pH 5.8; lower boundary gradual and wavy.

$C_1$ 6 to 13 inches, light yellowish-brown (2.5Y 6/3, dry) to light olive-brown (2.5Y 5/4, moist) gravelly sandy loam; very weak, coarse and medium, subangular blocky structure; soft when dry, very friable when moist; medium acid, pH 5.9; lower boundary gradual and wavy.

$C_2$ 13 to 20 inches +, light yellowish-brown (2.5Y 6/3, dry) to light olive-brown (2.5Y 5/4, moist) gravelly sandy loam; massive; loose when dry, very friable when moist; medium acid, pH 5.8.

*Range in characteristics.*—Mine soils vary mainly because the glacial outwash was stratified when it was deposited. The quantity of stones on the surface varies from place to place. There are a few finer textured layers below the surface soil, which appear to result from stratification. Nevertheless, in some deposits on older and higher terraces, faint subsoil development may be under way. The color and texture seem to indicate development of subsoil, but these likewise may result from original stratification. The pH ranges from 5.0 to 6.0, without important differences from one horizon to the next.

*Topography.*—Mine soils developed on a relatively smooth outwash plain consisting of cobbly and gravelly glacial material. Originally, they were deposits on old flood plains; now, they are in well-drained positions at several levels. Slopes do not exceed 5 percent on the terraces, but on the faces between terraces the slopes are considerably steeper.

*Drainage and permeability.*—Mine soils are well drained; they are moderately permeable to moderately rapidly permeable in all horizons.

*Vegetation.*—Practically all areas were logged, and some areas burned, in the early part of the century. They now support a young stand of lodgepole pine. The understory in most places is a sparse growth of vaccinium, buffaloberry, and other herbaceous plants. Weeds and some grasses grow in openings within the young stands of pine.

*Distribution.*—Mine soils occur only in the extreme northern edge of the Area. Undoubtedly, they occupy a much larger acreage outside the surveyed area.

*Type location.*—The type location is about a tenth of a mile north and 30° east of the Fraser Experimental Forest headquarters, or the NE¼NE¼ sec. 4 T., 2 S., R. 76 W., Grand County, Colo.

*Series established.*—This series was established in 1955.

*Remarks.*—In this Area, Mine soils were mapped only with the Tabernash. About 80 percent of the mapping unit consists of Mine soils, and 20 percent of Tabernash.

**Tabernash loam and Mine gravelly loam** (Ta).—About 20 percent of this mapping unit consists of Tabernash loam, and 80 percent, of Mine gravelly loam. The profiles of these soils are described under the names of the respective series.

*Use and suitability.*—The two soils of this mapping unit are somewhat different in the suitability for use.

The Tabernash soil is not extensive. It occurs only in the area north of the last major turn of St. Louis Creek around the moraine that is near the Fraser Experimental Forest headquarters. The most intensive practical use of this soil seems to be for lodgepole pine. If water were available, and there were need for short-season pasture, the Tabernash soil would be the most suitable soil in the Area for such use. It is level, smooth, and not subject to erosion. Because of the fine-textured surface soil and restricted internal drainage, the Tabernash soil would not be particularly suitable for development of campgrounds or other recreational uses. It is not especially valuable as a source of water, in comparison with the Leal and Darling soils.

Mine soil occurs in rather narrow strips on stream terraces, below the Bobtail, Darling, or Leal soils. Normally, it is used with other more extensive soils. Mine soil is suitable mainly for lodgepole pine. It produces little forage because it is droughty. This soil is excellent as locations for campgrounds and other recreational uses. It is highly porous, so it does not remain muddy long after storms, and the cobbles prevent rapid deterioration of campgrounds under excessive use.

### *Nystrom series*

Nystrom peats are organic soils occurring in alpine landscapes where water is ponded. They are represented in this Area by one mapping unit, Nystrom peat.

In this Area, Nystrom peats are usually associated with the Vasquez soils or are just within the topmost extension of the spruce forest zone. In many places they are near alpine lakes.

Nystrom peats developed mainly from sedges, but in places they contain an abundance of woody materials from willows. The peat deposits are shallow or thick, depending on location. The mineral material below the peat is always saturated and highly mottled. The profile lacks uniformity.

The following describes a profile as it occurs under sedges, tufted hairgrass, and willows in a cirque basin:

Surface layer—
0 to 14 inches, very dark gray, fibrous peat; plant remains clearly visible; extremely acid; some small inclusions of mineral soil material.

14 to 34 inches +, layers of soil material, some of them showing strong, pale-brown to yellowish-brown mottles; very strongly acid; roots in all layers; saturated.

The following is a technical description of Nystrom peat:

1. 0 to 3 inches, very dark gray (10YR 3/1, dry) to black (10YR 2/1, moist) fibrous peat from grass and sedge; outlines of individual plant remains are clearly visible; extremely acid, pH 4.3; lower boundary gradual and smooth.
2. 3 to 14 inches, very dark gray (10YR 3/1.5, dry) to black (10YR 2/1, moist) fibrous peat from grass and sedge; outlines of individual plant remains are clearly visible; very strongly acid, pH 4.5; lower boundary clear and wavy.

$D_1$ 14 to 17 inches, light brownish-gray (10YR 6/2, dry) to dark grayish-brown (10YR 4/2, moist) gravelly fine sandy loam; weak, coarse, granular structure; slightly hard when dry, very friable when moist; very strongly acid, pH 4.6; lower boundary clear and wavy.

$D_2$ 17 to 23 inches, very pale brown (10YR 7/4, dry) to yellowish-brown (10YR 5/4, moist) gravelly sandy clay loam; very weak, medium, subangular blocky structure; hard when dry, friable when moist; very strongly acid, pH 4.7; medium-sized, distinct dark yellowish-brown (10YR 3.5/4 to 5/6) mottles and stains are common; lower boundary clear and wavy.

$D_3$ 23 to 29 inches, very pale brown (10YR 7/3, dry) to yellowish-brown (10YR 5/4, moist) gravelly loam; massive; slightly hard when dry, very friable when moist; very strongly acid, pH 4.9; lower boundary clear and smooth.

$D_4$ 29 to 34 inches, very pale brown (10YR 7/5, dry) to yellowish-brown (10YR 5/5, moist) gravelly sandy loam; massive; slightly hard when dry, very friable when moist; very strongly acid, pH 4.9.

*Range in characteristics.*—Nystrom soils vary a great deal in thickness of the peat layer. The mineral soil material beneath the peat is stratified because it was deposited by water. It varies widely because there has been mass movement of saturated material, and because of freezing and thawing. The variation in the mineral layers is particularly evident in cirque basins.

Bodies of water too small to map as lakes are present. Where freezing and thawing are now active, some of the areas do not have peat at the surface. Instead there is mineral material, chiefly gravel and silt.

The content of stones is large and variable, as in most alpine soils. Some areas are being destroyed by wind erosion. In others, such as those on Vasquez Ridge, sheep have cut trails that have allowed drainage and lowering of the water table. Peats deteriorate rapidly when they are drained.

*Topography.*—Nystrom peats occupy basins, most of which are small and of mixed microrelief. Frost boils and rock polygons are present in places. Small hummocks of peat occur where there has been frost heaving. Many areas are behind steep-sided, low ridges of peat that parallel slopes. Small bodies of water are behind these ridges in many areas. In some places there is a series of these low ridges, one above the other, on the mountainside. Behind the ridges are these peat soils and some small lakes. The ridges may have been formed by pressure of ice created when water behind the ridges froze.

*Vegetation.*—Nystrom soils are densely covered with sedges, herbaceous plants, and in many places, dense growths of alpine willows.

*Distribution.*—Nystrom peats occur throughout the alpine area, and as small areas in most depressions where surface waters accumulate. Probably these soils are widely distributed throughout the alpine areas of Colorado and Wyoming.

*Type location.*—The type location is approximately 1 mile east of Jones Pass along the Jones Pass road. The approximate location is NW¼NW¼ sec. 22, T. 3, S., R. 76 W., Clear Creek County, Colo.

*Series established.*—This series was established in 1955.

**Nystrom peat** (Na).—Most of this soil is in small, irregular areas. The profile is like that described for the Nystrom series. As mapped, it includes small areas of the Vasquez and the Ptarmigan soils. The action of permafrost is more evident in this soil than in any of the others on the alpine landscape of the Colorado Rockies.

*Use and suitability.*—The primary uses of Nystrom peat are for storage of water and for forage. The two uses conflict. Some areas have been overgrazed and have lost their value for storage of water and for production of forage of the bog type. Grazing should be carefully managed to insure that willows and sedges are not damaged or destroyed, and to promote their recovery where damage has occurred.

It is not known that artificial restoration of vegetation is justified on the basis of the amount of water that would be gained. If restoration can be justified, a number of bogs should receive attention.

Where the layer of peat is thick and there is no standing water, this soil may contain permafrost. Where water is flowing through or over the soil, permafrost is rarely found. The permafrost contributes to water yield when it melts in summer.

Nystrom peat has considerable value as a summer habitat for deer and elk. Beaver have been seen in willow fields, but the high elevation, with long cold winters and the deep freezing of impounded water, makes survival of beaver precarious. This soil is most valuable for its ability to store water.

### *Ptarmigan series*

The Ptarmigan soils are members of the Alpine Meadow group.[3] They developed in material weathered from gneiss and schist, under herbaceous cover, in steeply sloping well-drained areas above timberline. Because they are in exposed positions on higher lying ridgetops, these soils are subject to wind and water erosion where the protecting mat of vegetation is broken.

Ptarmigan soils have a dark-gray or black loam surface soil that has a high content of organic matter and is thickly matted with roots. Commonly, this layer is 5 to 7 inches thick and of distinctive appearance (fig. 12). The subsoil is yellowish-brown to dark yellowish-brown, loose, gravelly loam of weak subangular blocky structure. The proportion of stone, coarse gravel, and sand is high in this layer. Relatively few roots grow in the subsoil, in comparison with the number in the surface soil. The substratum is light yellowish-brown, gravelly, coarse sandy loam, which is very loose and open and contains a large proportion of rock.

[3] These soils differ somewhat from the more typical Alpine Meadow soils, however, in that they have developed under conditions of good drainage. The name "Alpine Turf soils" has been proposed for these well-drained members of the Alpine Meadow group (7).

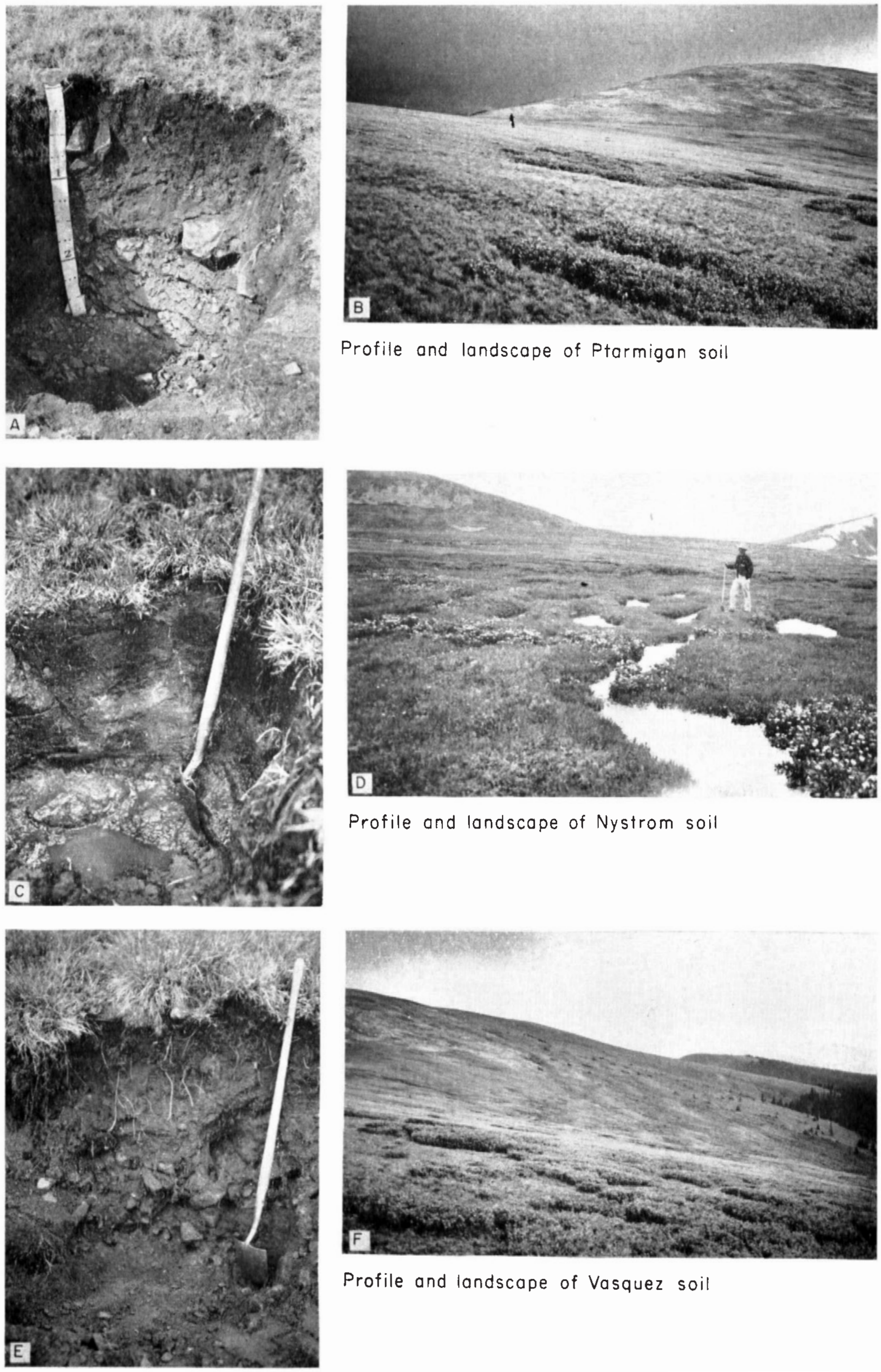



***Figure 12.*—Profiles and landscapes of three important soils of the Fraser Alpine Area: *AB*, Ptarmigan; *CD*, Nystrom; and *EF*, Vasquez.**

Ptarmigan soils are normally acid in the surface soil and throughout the rest of the profile. The content of silt and clay is highest in the surface soil and decreases with depth. Permafrost, or ground ice, occurs in the substratum in many places.

The following describes a profile of Ptarmigan loam, under virgin sod, near a ridgetop, on a slope of 8 percent:

Surface soil—
0 to 6 inches, very dark gray to black loam; medium granular structure; friable; medium acid; most obvious features of layer are dark color, high content of organic matter, and dense mat of roots.

Subsoil—
6 to 23 inches, yellowish-brown or light yellowish-brown coarse sandy loam; weak, fine, subangular blocky structure; soft and friable; strongly acid; very porous; content of gravel and rock is high.

Substratum—
23 inches +, fractured and slightly weathered gneiss and schist rocks.

Following is a technical description of a profile of Ptarmigan loam under grass vegetation:

$A_{11}$ 0 to 1½ inches, very dark gray (10YR 3/1, moist or dry) to black (10YR 2/1, moist) loam; moderate to strong, fine and medium, crumb structure; soft when dry, very friable when moist; medium acid, pH 6.0; layer thickly matted with grass and sedge roots; lower boundary clear and smooth.

$A_{12}$ 1½ to 6 inches, very dark gray (10YR 3/1, dry) to black or very dark brown (10YR 2/1.5, moist) loam; moderate to strong, medium and coarse crumb and granular structure; soft when dry, very friable when moist; medium acid, pH 5.8; horizon thickly matted with grass roots; lower boundary clear and wavy.

$B_1$ 6 to 10 inches, yellowish-brown (10YR 5.5/4, dry) to dark yellowish-brown (10YR 4.5/4, moist) gravelly loam; moderate to strong, fine and very fine, subangular blocky structure breaking to fine and medium granular; soft when dry, very friable when moist; medium acid, pH 5.6; horizon contains a very few, very thin, patchy clay films on both horizontal and vertical faces of peds; lower boundary clear and wavy.

$B_{2ir}$ 10 to 23 inches, light yellowish-brown and yellowish-brown (10YR 6/4 and 5/4, dry) to yellowish-brown (10YR 5/4, moist) gravelly sandy clay loam; moderate to strong, very fine, subangular blocky structure; slightly hard when dry, friable when moist; strongly acid, pH 5.4; horizon contains a few, thin, patchy clay films on both horizontal and vertical faces of peds; lower boundary gradual and smooth.

C 23 to 35 inches +, fractured and weakly weathered gneiss and schist rocks; pH 5.5.

*Range in characteristics.*—A uniform, persistent feature of the Ptarmigan soils is their black, highly organic surface soil. Another feature is the tendency of silt and clay to decrease with depth in the soil. The horizons in the subsoil vary considerably in thickness and content of rock. A high content of gravel is characteristic of these soils, but in some places the proportion of rock and gravel is appreciably greater than in others.

On steep, south-facing slopes the Ptarmigan soils are somewhat shallower than on the less strong north-facing slopes, and the surface soil contains less organic matter. The gravel and stones in the B horizon are coated on their under side with a black layer of organic matter. The black coating was derived from decaying roots, which in many places are matted on the under side of the stones.

*Topography.*—In this Area Ptarmigan soils are on the very top of those mountains that reach above timberline; therefore, they have exposures to all points of the compass. Slopes range from nearly level up to 70 and 80 percent, or in a few places are much steeper. On the steeper slopes the soils are held only by the dense, tough sod. Slides and other complex microrelief are common. The slides range from small to large, but in only a few places are they more than 3 or 4 feet thick. Their form indicates that they move only during periods of saturation. The moving material overrides and buries soils, so there are buried profiles in places.

*Drainage and permeability.*—These soils are well drained to somewhat excessively drained. The layer at the surface restricts movement of water the most. Since this layer is of coarse texture in most places, Ptarmigan soils are moderately permeable to rapidly permeable to water. The very coarse textures beneath the immediate surface layer in many places account for these soils being droughty in summer.

*Vegetation.*—Short-growing sedges and many kinds of weeds tolerant of alpine climate are dominant. Grasses are present, but in considerably lesser amounts than other plants. Willows growing on these soils are rarely more than 2 inches high. Where the vegetation is healthy, it forms a dense sward of immense value in preventing or reducing wind and water erosion on this high landscape.

*Distribution.*—Ptarmigan soils are widely distributed in all well-drained places throughout the Area.

*Type location.*—The type location is near the southwestern corner of sec. 2, T. 3, S., R. 77, W., Grand County, Colo. The elevation at this point is approximately 12,400 feet. The sampling area is west and slightly north of St. Louis Lake.

*Series established.*—The Ptarmigan series was established in 1955.

**Ptarmigan loam** (Pa).—This is one of the five mapping units in the Ptarmigan series mapped in the Fraser Alpine Area. Since the other four are soil phases separated on the basis of degree of plant cover, statements about this mapping unit generally apply to the other four. The essential differences are explained in the descriptions of the other units.

As mapped, this soil and the other Ptarmigan soils include perhaps 5 percent of Vasquez soils, which occur in such small areas they cannot be shown separately on a map of the scale used. Rock and stone make up an additional 5 percent, though in some localities the percentage of the surface occupied by exposed stone is much higher. A few rock slides and areas of solid rock outcrop are included with this and the other Ptarmigan soils because of their small size and the complex pattern in which they occur.

Ptarmigan loam, like the other Ptarmigan soils mapped, is used for grazing of sheep. In some places, overgrazing has resulted in serious deterioration. Repeated trailing over the same driveways likewise has produced unstable soil conditions in some places.

Elk graze frequently at the higher elevations but are more often seen in basins where Vasquez soils predominate. Deer are rarely seen on this or the other Ptarmigan soils, but these soils are the favorite habitat of the high alpine grouse, or ptarmigan. These birds appear to thrive and are present in considerable numbers in certain localities, such as on Vasquez Ridge. Other game birds have never been observed on the Ptarmigan soils. Mountain sheep have used the high ridgetops in the vicinity of Jones Pass, but if they are present now, their numbers are not known.

*Use and suitability.*—Ptarmigan loam is valuable in terms of water yield. The porous, open profile permits rapid infiltration wherever there is a protective cover of dense turf. Many seeps and springs emerge at lower elevations, especially in the general vicinity of timberline. In exposed positions, winter winds sweep much of the snow away, but in more protected places snow accumulates to a depth of several feet and melts in spring and early in summer. This soil, as well as the other Ptarmigan soils mapped, is known to contain permafrost, the surface of which melts late in summer and contributes to the supply of ground water. The distribution and general characteristics of this permafrost are relatively little known.

Ptarmigan loam, like the other Ptarmigan soils mapped, is of considerable importance as a source of forage for grazing, as catchment areas for water, and as recreational sites of unsurpassed scenic beauty. The three purposes are best served by maintaining a cover of herbaceous plants adequate to prevent deterioration and erosion. Once the top 6 inches is lost, these areas are barren fields of coarse gravel and rock. It is currently impractical, and in most places impossible, to revegetate deteriorated areas at this elevation. Therefore, the only practical management is to control practices that would destroy the present cover.

**Ptarmigan loam, slightly bare** (Pb).—This is an extensive soil in the alpine areas. It is like Ptarmigan loam, already described, but differs in that 10 to 25 percent of its total acreage has a surface bare of vegetation. The individual bare areas are normally small and isolated; that is, not touching one another. The bare areas normally have more gravel and stone than those nearby, and this is evidence that erosion is taking place.

*Use and suitability.*—This soil is used along with adjacent areas for grazing. The estimated yield of herbage is only slightly below that on Ptarmigan loam. It is important that grazing be managed to permit recovery of vegetation on the bare areas.

**Ptarmigan loam, moderately bare** (Pc).—This is an extensive soil with the characteristics of Ptarmigan loam. It differs in having bare areas that total 25 to 50 percent of the acreage. Normally, the bare areas are larger than those on Ptarmigan loam, slightly bare. The bare areas also are slightly more elongated up and down slope, and this tends to reduce the vegetated areas between the bare areas. In many places surface erosion is more severe than on Ptarmigan loam, slightly bare. This erosion has somewhat reduced the thickness of the surface soil in a few spots, but considering all of the bare spots, reduction in thickness of the surface layer is not general or uniform.

*Use and suitability.*—This soil occurs in an intricate pattern with soils used for grazing. Wherever possible, grazing should be suspended or reduced temporarily to allow natural recovery of the bare spots. This soil is well on the way to becoming a major problem in erosion and sediment control, and if the trend continues, will permanently lose most of its productivity.

**Ptarmigan loam, largely bare** (Pd).—This soil is bare to such extent that it is a major problem in management (see fig. 12, *A*, *B*). The separate bare areas have enlarged, elongated, and grown together to such extent that more than 50 percent of the acreage is estimated to be no longer covered with vegetation. Many of the bare places have lost all of their surface soil and now consist of little other than gravel and stone. The productivity of the bare areas has been largely lost and cannot be restored under present systems of management.

*Use and suitability.*—This is a problem soil in the alpine region. Its value for grazing has been greatly reduced, and so has water yield. Rapid surface runoff and accumulation of coarse gravelly debris on the lower slopes are problems that appear to be growing more severe. Since artificial revegetation is impractical, the only feasible course appears to be to stop use entirely and allow natural revegetation, which will require a great number of years.

**Ptarmigan loam-Rock outcrop** (Pe).—This soil is intimately associated with other Ptarmigan soils. An estimated 50 percent or more of its surface is occupied by rock and stone. Otherwise, this soil does not differ from Ptarmigan loam in characteristics or in required use and management.

*Use and suitability.*—This soil is grazed along with adjacent soils. The stones undoubtedly reduce yields of herbage in some degree. It was observed, however, that herbage grew more vigorously in the immediate vicinity of protruding stones. Probably plants in this position receive more moisture, as some moisture runs off the stones and there is also less evaporation of soil moisture. In computing carrying capacity for this soil, however, considerable reduction should be made for the stones.

### Rock outcrop

Mapped as one miscellaneous land type are those areas of rock outcrop large enough to be delineated separately on the map.

**Rock outcrop** (Ra).—This is a miscellaneous land type consisting of great masses of rock, such as those at mountain peaks, and those forming the nearly vertical walls of cirques. It also includes individual rocks, some of mammoth size and others small, that lie on the surface of the soil or thrust to the surface through it (see fig. 10, *B*).

Rock outcrop accounts for about 6,300 acres in the Fraser Alpine Area. This mapping unit, however, does not include all the rock and stone, for these occupy a high proportion of the alpine land. Individual masses of rock and stone, too small to map separately, probably occupy an acreage just as large, or larger, than the acreage mapped as Rock outcrop.

Rocks that protrude from a soil undoubtedly tend to stabilize soil and to retard landslides, soil creep, and soil erosion. Large masses of rock outcrop, however, are likely places for the many snowslides that carry down large quantities of stone that bury the lower lands.

Melting snow and summer rains quickly run from rock faces. Much of the water, however, is caught in rock fields, or rock slides, at the base of the steep slopes and, in most places, does little damage. These slides are mapped in another miscellaneous land type, called Rock slides.

Rock outcrop is almost useless except for the water and scenery it provides. Much of the majesty of the alpine landscape depends on these great masses of rock. The rock faces are relatively stable and do not present the problems of erosion encountered in areas of Alpine rimland or Alpine wind-eroded land.

### *Rock slides*

On this miscellaneous land type are the slides mentioned in the description of Rock outcrop.

**Rock slides** (Rb).—This mapping unit consists of accumulations of loose rock ranging from immense single stones to coarse gravel. The slides take the form of fans or aprons, depending on how the rocks fall from cliffs or are carried down in snowslides, in rock glaciers, or in other ways. Some of the slides appear to be stable; others are not. The rocks in a stabilized slide normally have dull surfaces and a cover of lichens. The slides not stabilized are moved by snowslides or by gravity when a downcutting channel undermines their base. Some of the slides, especially those near the face of cliffs, are in precarious equilibrium, at the angle of repose or steeper, and are therefore dangerous to walk across.

Rock slides may be thick or thin. In falling and in subsequent movement, they override the original surface soil. Where the rock layer is thin, weeds may grow up through the rocks. At timberline, scattered stands of spruce and alpine fir may grow through openings between the rocks. Also, rock slides may pass around small areas of soil and thus leave islands that continue to support their original cover. For the most part, however, rock slides are barren.

Areas of rock slide are exceptionally good catchment areas for water. They absorb all the rain or snow that falls, and there is no runoff or erosion. The waters emerge downslope as seeps and springs, either at the base of the slide or farther down. Runoff from heavy rains or rapidly melting snow is seldom so rapid as on adjacent lands. The slides absorb the shock of the rapid runoff that courses down the faces of the solid masses of rock above. These slides therefore protect the less erosion resistant soils at lower elevations.

Small mammals and a few birds live on rock slides. These slides require no attention whatever from the land manager.

### *Tabernash series*

The Tabernash are Gray Wooded soils, represented in this Area by one mapping unit, Tabernash loam and Mine gravelly loam. The Tabernash soils developed from glacial outwash deposited along the shores of an extinct lake along the north side of the survey area. This outwash was sorted and reworked, and as a result, there are fine-textured layers between layers of coarse gravel. The soils are smooth and nearly level.

Tabernash soils are overlain by a thin litter of pine needles. The light-gray or light-brown surface soil is of loam or silt loam texture and is rarely more than 6 or 7 inches thick. The clay or clay loam subsoil is in most places easily identified by its blocky to prismatic structure and its distinct color. The substratum is a mixture of gravel and cobbles with sand, silt, and clay. Enough of the fine material is present to make the substratum hard when dry.

It is questionable that the subsoil, though distinctive in color and structure, indicates the ultimate soil development in this Area. Rather, it appears more likely that the fine-textured layers were deposited along the ancient lakeshore, and that they have since been altered to some degree by the processes of soil development.

The following describes a profile of Tabernash loam under a regrowth of lodgepole pine, on an east-facing slope of 4 percent, and over lakeshore deposits:

Litter—
1 inch to 0, thin mat of undecomposed to partially decomposed pine needles.

Surface soil—
0 to 6 inches, brown loam; weak platy and granular structure; friable to soft; medium acid.

Subsoil—
6 to 27 inches, brown to dark-brown clay loam; blocky structure; very hard when dry; medium acid to slightly acid.

Substratum—
27 to 36 inches +, brown, gravelly or cobbly sandy clay loam; hard when dry; medium acid.

The following is a technical description of a profile of Tabernash loam under a forest of lodgepole pine:

$A_0$–$A_{00}$ 1 inch to 0, gray (10YR 5/1, dry) to black (10YR 2/1, moist) thin mat of decomposed and partially decomposed organic materials; surface one-fourth inch consists almost entirely of last year's fall of pine needles; horizon rests abruptly on horizon below.

$A_1$ 0 to 1½ inches, grayish-brown (10YR 5/2, dry) to very dark grayish-brown (10YR 3/2, moist) loam; weak to moderate, medium and coarse, crumb structure; soft when dry, very friable when moist; slightly acid, pH 6. 2; horizon not of uniform color and contains streaks and mottles of black and dark grayish-brown (10YR 2/1 and 4/2) materials; lower boundary clear and smooth.

$A_2$ 1½ to 5½ inches, very pale brown (10YR 7/3, dry) to brown (10YR 5/3, moist) loam; weak, coarse, platy structure breaking to weak to moderate, coarse and medium, crumb structure; soft when dry, very friable when moist; medium acid, pH 5.9; lower boundary gradual and wavy.

$B_1$ 5½ to 8 inches, pale-brown (10YR 6/3, dry) to brown (10YR 5/3, moist) clay loam, weak to moderate, fine, subangular blocky structure; slightly hard when dry, friable when moist; medium acid, pH 6.0; thin, nearly continuous clay films; surfaces of aggregates coated with light-gray (10YR 7/2) materials probably from the horizon above; lower boundary clear and wavy.

$B_{21}$ 8 to 15 inches, light-brown (7.5YR 6/3, dry) to brown (7.5YR 4/4, moist) heavy clay loam or light clay; moderate to strong, fine subangular blocky structure; very hard when dry, firm when moist; slightly acid, pH 6.1; moderate, continuous clay films; surfaces of aggregates thinly coated with light-gray (10YR 7/2) materials; lower boundary gradual and smooth.

$B_{22}$ 15 to 23 inches, brown (7.5YR 5/4, dry) to dark-brown (7.5YR 4/4, moist) heavy clay loam or light clay; moderate, coarse, prismatic structure breaking to strong, medium, angular blocky; very hard when dry, firm when moist; slightly acid, pH 6.2; strong, continuous clay films; surfaces of aggregates coated with light-gray (10YR 7/2) materials; coatings principally on vertical faces; lower boundary gradual and smooth.

$B_3$ 23 to 27 inches, brown (7.5YR 5/4, dry) to dark-brown (7.5YR 4/4, moist) gravelly clay loam; weak, coarse and medium, subangular blocky structure; hard when dry, friable when moist; medium acid, pH 5.9; horizon contains thin, patchy films; about 30 percent of horizon, by volume, is cobbles and gravel; lower boundary gradual and smooth.

D 27 to 36 inches, pale-brown (10YR 6/3, dry) to brown (10YR 5/3, moist) cobbly sandy loam; massive; hard when dry, firm when moist; about 70 percent of horizon, by volume, is cobbles and gravel; horizon appears to be weakly cemented; pH 5.7.

*Range in characteristics.*—Based on the small acreage mapped in the Fraser Alpine Area, Tabernash soils are much as described in the foregoing profile. Considering the source of the parent material and manner of formation, however, variations in texture and in distinctness of the subsoil can be expected when larger areas are studied. In the area studied, the degree of subsoil development appears to decrease somewhat at successively lower levels of the old lakeshore deposits. Possibly two other levels of the old lakeshore exist, in addition to the one studied in this Area.

*Topography.*—Tabernash soils are on relatively level, old, lakeshore deposits. They are not dissected by drainageways, and significant differences in microrelief are restricted to the faces of lake terraces, several of which occur in the Area.

*Drainage and permeability.*—Tabernash soils appear to be well drained, although if excessive moisture were present, drainage might be somewhat more restricted. Because the subsoil is fine textured, the permeability of the Tabernash soils is not greater than moderate.

*Vegetation.*—The present cover is a young growth of lodgepole pine. All of the original timber was removed by logging and fire in the early part of the century. The open parklike places on these soils may have resulted from logging. Although these open areas now support a mixed stand of weeds and grasses, it seems certain that they eventually will be covered by lodgepole pine.

*Distribution.*—In this Area, Tabernash soils cover limited acreage, and only in the extreme northern part. These same soils likely occupy appreciably greater acreage along the old lake terraces outside the survey area.

*Type location.*—The Tabernash site location is in the northernmost part of the Area, approximately 1.8 miles north and 30° east of the Fraser Experimental Forest headquarters, or NE¼SE¼ sec. 27, T. 1 S., R. 76 W.

*Series established.*—The Tabernash series was established in 1955.

*Remarks.*—In the Fraser Alpine Area, Tabernash soils were mapped with the Mine soils as Tabernash loam and Mine gravelly loam. The mapping unit is described under the Mine series. An estimated 20 percent of this mapping unit consists of Tabernash soil. Some small areas of Tabernash soil may be included with other soils at lower levels outside the survey area.

### Vasquez series

Soils of the Vasquez series are in depressed areas and basins above timberline (see fig. 12 *E*, *F*). They belong to the Alpine Meadow group. These soils are well distributed throughout the alpine area but are dominantly in the large cirque basins and are usually below the Ptarmigan soils.

Vasquez soils were derived from highly stratified mixed materials of alluvial-colluvial origin. These materials have been washed or have fallen into basins from the adjacent Ptarmigan soils and Alpine rimland. Depending on locality, the various lenses or strata in the parent material range from coarse sand and rock to fine sandy loam and silt. These soils are wet or moist most of the year.

The following describes a profile of Vasquez loam under willows and tufted hairgrass on a slope of 20 percent:

Surface soil—
0 to 11 inches, grayish-brown to dark-gray clay to fine sandy loam; weak, coarse, granular structure; soft to very friable; very strongly acid.

Substratum—
11 to 31 inches +, pale brown to very pale brown coarse sandy loam; weak granular structure or structureless; very strongly acid to strongly acid; highly stratified; contains appreciable quantity of large rocks; mottled.

The following is a technical description of Vasquez loam:

$A_{11}$ 0 to 1½ inches, dark-gray (10YR 4/1, dry) to very dark-brown (10YR 2/2, moist) loam; weak to moderate, coarse, granular structure; soft when dry, very friable when moist; pH 4.8; lower boundary clear and smooth.

$A_{12}$ 1½ to 4 inches, gray (10YR 5/1, dry) to very dark grayish-brown (10YR 3/2, moist) stony loam; weak, coarse, granular structure; soft when dry, very friable when moist; pH 4.6; lower boundary clear and smooth.

AC 4 to 11 inches, grayish-brown (10YR 5/2, dry) to dark brown (10YR 3/3, moist) stony sandy loam; weak, fine and medium, subangular blocky structure breaking to weak, coarse, granular; slightly hard when dry, friable when moist; pH 4.8; approximately 15 percent of this horizon, by volume, is stone; lower boundary abrupt and wavy.

$C_1$ 11 to 21 inches, very pale brown (10YR 7/3, dry) to brown (10YR 5/3, moist) cobbly sandy clay loam; massive; slightly hard when dry, friable when moist; pH 4.9; a few medium-sized, distinct, yellowish-brown (10YR 5/6) mottles; approximately 20 percent of horizon, by volume, is stone; lower boundary gradual and smooth.

$C_2$ 21 to 31 inches +, very pale brown (10YR 7/4, dry) to light yellowish-brown (10YR 6/4, moist) very fine sandy loam in which there are strata and lenses of coarse sand; massive; slightly hard when dry, very friable when moist; pH 5.5; horizon contains a few medium-sized, distinct, yellowish-brown (10YR 5/4) mottles; approximately 50 percent of horizon, by volume, is rock and stone; at time of sampling, ground water was at a depth of 24 inches.

*Range in characteristics.*—Vasquez soils vary considerably in thickness, color, and texture of their surface soil because of their mode of origin and their position on the landscape. The substratum is variable because sediments were deposited in strata in the basins.

In many places the microrelief of these soils suggests that slides and local soil creep have overridden some of the original surface soil.

The cover of vegetation varies a great deal, primarily because heavy grazing has largely eliminated the once extensive willow fields.

In some places the loam surface soil contains an exceptionally large amount of organic matter and tends to be somewhat peaty. Under destructive grazing, these highly organic layers tend to become thinner and to disappear. In many areas, the quantity of gravel and coarse gravel varies widely within short distances.

Mottling and degree of saturation are extremely variable. There is evidence of frost action in some places. The soils are extremely acid to strongly acid, but there is little difference in the acidity of the different horizons.

Mottling and degree of saturation are extremely variable. In some places mottling of the solum and substratum is faint or absent, and in others it is prominent.

*Topography.*—Vasquez soils are in moist to wet areas in the alpine landscape. In some places they are in relatively level or basin-shaped areas that have slow surface drainage. In other areas they are adjacent to drainageways within larger acreages of Ptarmigan soils, and in these places they have appreciable slope. The microrelief of the Vasquez soils is very irregular in some places because of frost action and accumulation of materials brought down from higher elevations.

*Drainage and permeability.*—These soils range from imperfectly drained to moderately well drained. Where they are closely associated with Nystrom soils, they tend to be poorly drained. Permeability of the solum and underlying material varies according to the nature of the material in the local layers. The range in permeability is from slow to moderately rapid, but in most places it is moderately slow.

Differences in permeability account for the wide range of mottling in the deeper soil layers but cannot be predicted by examining the surface soil. In many areas the deeper layers are kept wet by seepage. Possibly this seepage comes from permafrost melting beneath the adjacent Ptarmigan soils. Because of their location, Vasquez soils are usually saturated during spring runoff, but they contain much less moisture the rest of the year.

*Vegetation.*—The normal cover is a dense growth of shoulder-high willows, coarse sedges, and tufted hairgrass, plus many kinds of lesser herbaceous plants. Because this dense vegetation catches sediments from higher areas, it has been largely responsible for deposits that in many places are 10 feet or more in depth. In addition to the plants already named, there are many kinds of weeds, grasses, and herbaceous plants on these soils.

*Distribution.*—Vasquez soils are widely distributed throughout the alpine area, but the greater part of the acreage is at lower elevations than the Ptarmigan soils. Vasquez soils probably occur throughout the Rocky Mountains wherever there is restricted drainage above timberline.

*Type location.*—The type location is in the SW¼ NW¼ sec. 22, T. 3 S., R. 76 W., Clear Creek County, Colo., on the Jones Pass road, about one-half mile above timberline.

*Series established.*—The Vasquez series was established in 1955.

*Remarks.*—Four units of the Vasquez series are shown on the soil map. An estimated 2 percent of the acreage of these soils is covered by stones. In some places stones are concentrated and cover more than 2 percent of an area. Included small areas of Ptarmigan soils cover an estimated 5 percent of the total area. These Ptarmigan soils always are on slightly elevated, better drained areas, and nearly always can be distinguished by a different kind of vegetation.

Where Vasquez soils are in cirque basins, there may be included piles of loose stones and raw soil material at the places where Vasquez soils join the Alpine rimland.

Where large willow fields have not been damaged by grazing, there is a coarse, peaty layer composed largely of willow leaves and twigs. This layer is often 7 to 10 inches thick, but the areas having it are small and few.

Included with the Vasquez soils are areas of Nystrom peat that cover less than 1 percent of the total acreage.

**Vasquez loam** (Va).—This soil has a profile like that described for the Vasquez series. It varies in the manner described for the Vasquez series, and it includes areas of other soils as mentioned for the series.

This soil, like the other Vasquez soils mapped, is used entirely for grazing of sheep. Deer occasionally browse the willow fields, and elk frequent this soil during summer.

The vegetation is a luxuriant growth made up of many kinds of grasses and weeds. Tufted hairgrass is the most common and most noticeable of the grasses. Yields of herbage are high on this and other Vasquez soils, but there is considerable variation from place to place. The average yield on this soil is estimated to be 2,000 pounds per acre. Less than 10 percent of this soil is bare of vegetation.

Vasquez loam is in critical topographic position so far as yield of water is concerned. Most of the water that leaves the alpine land passes over or through this soil and the other Vasquez soils. Normally, the small drainage channels work their tortuous way down slopes through willow fields and dense growths of sedge. When the cover is removed by grazing, the drainage channels tend to straighten and to become gullies. The depth of the gullies, and their destructiveness, depends on the thickness of the soil and the number of boulders present. The gullies induced by grazing lower the water table, reduce the original plant cover, and allow growth of other plants requiring less moisture. The result, therefore, is decrease in value of the soil for both grazing and storage of water.

Control of erosion on areas of Vasquez loam that have deteriorated is not practical at present. This soil, like the other Vasquez soils mapped, is rocky, steep, and irregular; furthermore, the growing season is short. The only feasible method of rehabilitation appears to be that of reducing present use and permitting native vegetation to grow back.

**Vasquez loam, slightly bare** (Vb).—This soil is like Vasquez loam in all respects except extent of plant cover. From 10 to 25 percent of this soil is bare of vegetation, as contrasted to 10 percent or less for Vasquez loam. This soil is still used for grazing but it needs management that will assure recovery of the vegetation.

**Vasquez loam, moderately bare** (Vc).—This soil is like Vasquez loam but covers a larger acreage, of which 25 to 50 percent is bare of vegetation. The bare areas are larger and more numerous than on Vasquez loam, slightly bare.

This soil is on the verge of becoming a severe problem in management. If the present trend continues, loss of soil material will be great and recovery of natural vegetation will be very difficult. Grazing management will need to consider carefully these factors in developing management plans. In order to obtain vegetative recovery in some areas, it may be necessary to provide complete protection from grazing for several years. Because elevations are high, vegetation will recover slowly.

**Vasquez loam, largely bare** (Vd).—Except for areas bare of vegetation, which account for more than 50 percent of the total acreage, this soil is like Vasquez loam.

Many of the bare areas are quite large, and they tend to become much larger by growing together. Small rills and gullies are common. In order to obtain vegetative recovery and to protect the water values of the soil, it appears necessary that it be given complete protection from grazing until revegetation occurs.

## Genesis and Morphology of Soils

Soils are the product of their environment, just as are plants, animals, and people. All the factors of environment act on a kind of rock or parent material and eventually produce a kind of soil. The major factors influencing formation of soils are (a) climate and (b) living organisms, which act on (c) parent material to form a kind of soil over (d) a period of time. Topography, or relief, is also a soil-forming factor. In reality, topography, through aspect and position, modify the local climate; that is, cause more or less water and heat to gather in a certain area. Thus, on very steep slopes, topography may account for formation of shallow, stony soils. Similarly, high elevations and high latitudes modify local climate and markedly affect soil development.

Fundamentally, soils are formed through physical, chemical, and biological action on a kind of rock or parent material. The climatic factor supplies heat and water, and the living plants and organisms contribute compounds essential to the reaction. Eventually, the soils we work with are produced by these interacting processes. A small variation in one of the factors will produce a different kind of soil.

In the Fraser Alpine Area there are extremes in climate, topography, elevation, and kinds and numbers of living organisms. Consequently, there are great differences among the soils. This Area is probably representative of several million acres at higher elevations in the Rocky Mountains.

*Parent materials.*—A high percentage of the soils in this Area have developed from parent materials derived from gneiss and schist. The degree of metamorphism varies from place to place, but probably the greater proportion of the rock tends to be gneissic. The common minerals are quartz, biotite, and feldspars, with lesser amounts of muscovite and other minerals.

The rock formations have been fractured by an extensive and complex system of faults associated with the elevation of the mountain mass. Prominent intrusive dikes are the exception.

Advanced weathering of the rocks has not taken place, because the rocks are hard and the climate is not favorable. Much weathering appears to have been mechanical rather than chemical. No doubt, much of the mechanical weathering occurred during the Pleistocene, when local glaciers were active.

The soils of this Area are considered to be residual, or to have developed in place from underlying rocks. This premise, however, is subject to qualification. Most of materials have been and still are subject to slope creep. Slopes are very steep; the steepness has been accentuated by repeated passage of glaciers. The amount and rate of slope creep no doubt have varied from time to time. The movement of material down the steep slopes is evident, however, in a belt, or apron, that has accumulated at the base of the slopes and above the present flood plain of the streams.

The original rocks were sufficiently different to provide wide local variation in parent materials, and slope creep has mixed these materials. Slope creep partly accounts for the general lack of uniformity in thickness of soil horizons in the Darling and Bobtail soils.

Chemical weathering is slow, partly because of low temperatures. The rate of weathering can be appraised partly by studying analyses of the ground waters (table 7). Samples were collected from flowing springs and Fool Creek between approximate elevations of 9,600 and 11,200 feet. The data in table 7 show that chemical weathering is considerably less than that generally occurring in warmer, more humid areas.

Though chemical weathering is slow, it has been important in some places. In the bogs mapped as Lunch peat or Nystrom peat, it has produced appreciable quantities of silt and clay. Furthermore, where pits are dug in Ptarmigan soils, there is in many places a layer 10 to 20 inches thick above the permafrost that contains stones so much altered by weathering that they are readily crushed in the fingers. This layer above the permafrost

TABLE 7.—*Chemical analyses of waters from springs and the main channel of Fool Creek, Fraser Experimental Forest, in 1953* [1]

| Item | Spring No. 23 | Spring No. 33 | Spring No. 41 | Spring No. 3 | Lower weir [2] | Upper weir |
|---|---|---|---|---|---|---|
| Conductivity (EC×$10^6$ at 25° C.) | 39. 2 | 43. 1 | 36. 9 | 42. 2 | 63. 1 | 37. 0 |
| Soluble sodium ... percent | 42 | 33 | 33 | 33 | 27 | 38 |
| Boron (B) ... p.p.m. | . 02 | . 01 | . 01 | . 02 | . 02 | . 02 |
| Sum of cations ... meq./1 | . 48 | . 46 | . 42 | . 46 | . 71 | . 40 |
| Calcium (Ca) ... meq./1 | . 14 | . 17 | . 15 | . 15 | . 35 | . 15 |
| Magnesium (Mg) ... meq./1 | . 12 | . 12 | . 10 | . 14 | . 15 | . 08 |
| Sodium (Na) ... meq./1 | . 20 | . 15 | . 14 | . 15 | . 19 | . 15 |
| Potassium (K) ... meq./1 | . 02 | . 02 | . 03 | . 02 | . 02 | . 02 |
| Sum of anions ... meq./1 | . 49 | . 49 | . 44 | . 45 | . 71 | . 43 |
| Carbonate ($CO_3$) ... meq./1 | . 00 | . 00 | . 00 | . 00 | . 00 | . 00 |
| Bicarbonate ($HCO_3$) ... meq./1 | . 30 | . 34 | . 28 | . 28 | . 55 | . 28 |
| Sulfate ($SO_4$) ... meq./1 | . 04 | . 05 | . 06 | . 07 | . 06 | . 05 |
| Chloride (Cl) ... meq./1 | . 15 | . 10 | . 10 | . 10 | . 10 | . 10 |
| Nitrate ($NO_3$) ... meq./1 | ---------- | ---------- | ---------- | ---------- | ---------- | ---------- |

[1] Analyzed by J. T. HATCHER, MARY G. KEYES, and G. W. AKIN, U.S. Salinity Laboratory, Rabidoux Unit, Riverside, Calif.

[2] Elevation of lower weir in Fool Creek is 9,600 feet; elevation of upper weir is 10,500 feet.

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appears to be continuously saturated with seep water when it is not frozen. Above this layer the stones retain a high degree of hardness.

Extensive areas of glacial till and alluvium are the parent materials of several soils at lower elevations in this Area. All of this till and alluvium was derived from the gneiss-schist country rock and has essentially the same mineral and chemical composition as the rock.

Bottle soils developed from material weathered from fine-grained sandstone at the lower elevations. These rocks are very low in minerals other than quartz, and the Bottle soils are therefore excellent examples of the podzolic process.

A very small area of volcanic tuff is exposed east of the Fraser Experimental Forest headquarters. It may be a lakeshore deposit that was later covered by glacial till in most places. Though they were not delineated on the map, a few soils were found in this vicinity that had a strongly developed, thick clay B horizon. This clay B horizon attests to the fact that the tuff weathers rapidly.

Westerly winds pick up silt as they pass over the deserts to the west and constantly deposit it in the Fraser Alpine Area. These deposits are noticeable only during winter when they are caught on the snow. The deposits are always thin, and they vary a great deal in quantity from year to year. In many years they are hardly noticeable. It is not known to what degree this dust influences soil development, or to what extent it is responsible for the silt and clay measured in the soil profiles.

In summary, parent materials play a major role in determining soil characteristics in this area.

*Topography.*—The effect of topography on soil formation is discussed here. A general discussion of topography is given in Part I.

There is no level land in this Area. In large part, the slopes are steeper than 25 percent, and many are at or beyond the angle of repose. These steep slopes affect development of soils in two important ways. First, on this mature terrain, they greatly facilitate downslope movement of soil materials. This movement is more evident on bare soil areas in the alpine, on alpine rimlands, and on slopes overly steepened by glaciation. Surface movement is least apparent under a dense stand of timber, but there must be appreciable movement when these timbered areas are laid bare by fires, as they have been many times in the past. The movement of materials downslope has had appreciable effect in keeping the soils at a relatively early stage of development.

Second, the extreme topography has produced northerly and southerly exposures, which are markedly different in their effect on soil development. The effect of differences in exposure is most noticeable below timberline, in the St. Louis Creek watershed. Aspect, or direction of slope, has less effect in the alpine part of the Area because most of this is on ridgetops.

*Living organism.*—Numbers and kinds of flora and fauna have significantly influenced soil development in this Area. The alpine part supports mixed grasses, forbs, willows, and sedges. Sedges are dominant in both well-drained and moist areas, but in the moist areas a higher proportion of the vegetation is grass. Roots rarely penetrate more than 20 inches, and in fact, 90 to 95 percent of them are in the top 5 to 8 inches.

The Ptarmigan soils are typical of the alpine areas. The high concentration of organic matter at the surface of the Ptarmigan soils can be attributed to low temperatures, to a very short and usually dry summer, possibly to a population of microflora that is little known, and perhaps to a type of organic residue from the sedges that resists decay and persists longer than that in most of the better known grassland soils. At any rate, the organic matter in Ptarmigan and other alpine soils appears darker in color and more grainy than in the grassland soils of the Brunizem group. The top 5 to 8 inches of the alpine soils is tightly held together by a dense mat consisting of living roots and dead but undecayed roots. This mass of organic material eventually breaks down. Evidence of this is the dark stain on the under side of stones that lie well below the zone where roots are concentrated.

In the Vasquez soils, which also occur in the alpine areas, the organic matter is distributed deeper in the profile than in the Ptarmigan. This organic material is from willows as well as grasses. Sedgelike plants, however, are less dominant on Vasquez soils than on the Ptarmigan. Likewise, sediment from higher areas has thickened the surface layer on the Vasquez soils.

Below timberline, the coniferous vegetation and the understory apparently have much the same effect on soil development, whether the stand is spruce or lodgepole pine. The residues are 2 to 4 inches thick under spruce, but somewhat less under lodgepole pine. The leachate from this forest mat is sufficiently acid to remove iron from the mineral surface soil and to deposit it in the B horizon. This concentration of iron in the B horizon is most prominent in the Darling and Bottle soils and least evident in the Bobtail soils. The accumulation of iron is evidenced by color of the B horizon, and this color is the main distinguishing feature of the subsoil in the well-drained residual soils below timberline.

The scarcity of fauna in the alpine landscape has caused it to be called a biological desert. The paucity of burrowing insects, rodents, and similar fauna in the alpine apparently explains the large concentration of organic matter in the surface layer of the Ptarmigan soils and the abrupt termination of this at a depth of about 6 inches.

Below timberline, worms, insect larvae, and the like are not so scarce as they are in the alpine. There are a few mice and shrews below timberline that may mix soil materials, but the mixing is not extensive. Along the flood plains, beaver build ponds, which raise the water table nearby and collect sediments brought down by streams.

*Climate.*—The main features of climate are discussed in Part I. Here, the local modifications of the gross climate that affect soil development are mentioned.

Precipitation is least at the lower elevations. It increases about 7 inches for each 1,000 feet increase in elevation. Roughly two-thirds of the precipitation is snow. At lower elevation and on south slopes, snow melts rapidly from April to mid June. During this time the soils are saturated or nearly saturated most of the time. They are never saturated again during the year.

This single wet-dry cycle strongly contrasts with the periods of wetness and dryness that may be repeated several times in a year in humid areas at lower elevations. Because of this single wet-dry cycle, soil development must be appreciably slower in this Area than in humid regions at lower elevations.

Records on climate show that the average annual temperature is about 33° F. at lower elevations and 28° at higher elevations. Average monthly temperatures are below freezing 6 months of the year at low elevations, and below freezing for 8 months at higher elevations. The growing season at low elevations is about 75 days. At the high elevations, the season is appreciably shorter. Freezing temperatures are recorded in every month of the year. The quantity of heat available to speed the chemical and physical soil-forming processes is very low.

Repeated freezing and thawing of the soils is not common. Below timberline, snow falls early and frequently remains until spring. Because snow accumulates to a depth of several feet, the soils may not freeze during the entire winter. As the snow melts in spring, some local and shallow freezing occurs.

In the alpine areas, strong winds sweep many of the ridges bare. The soils on these ridges no doubt freeze deeply, and at these elevations, remain solidly frozen the entire winter.

Another curious phenomenon is that the soils are often quite dry at the time the first snow falls. Then, if no melting occurs, they remain loose and powdery throughout the winter, though their temperature may be low.

The temperature of water from springs in the alpine commonly ranges between 33° and 36° F. These temperatures may be influenced by the melting permafrost, but tests of water temperature are not conclusive. On the Fool Creek watershed, well below timberline and below the permafrost zone, temperature of water from 102 flowing springs ranged from 36° to 38° when measured in October.

As shown in table 8, a number of pits were dug at representative locations in the Darling, Bobtail, Ptarmigan, and Vasquez soils for the purpose of installing thermistors to measure temperature. The meters were installed in 1952, and the data in table 8 were recorded late in the fall of 1956. Previous readings deviated little from the values shown in table 8.

The Bobtail and Darling soils at the sites where pits were dug were on steep slopes that faced each other across a narrow valley. The Darling soils faced north and the Bobtail soils faced south. The pits dug in the Ptarmigan and Vasquez soils were in the alpine and within a quarter of a mile of each other.

The temperatures were remarkably similar, both within the profile of each soil and between the different soils. It is suspected that temperatures early in spring would be appreciably different from those in fall, but spring readings were not made.

When the pit was dug in the Ptarmigan soil, permafrost was encountered at 67 inches, but 4 years later, the permafrost had not reinvaded the pit. When the pit was dug in the Vasquez soil, the temperature was near 32° F. in the deeper part of the profile, but 4 years later the temperature at 10 feet was well above freezing.

The exposure of a slope markedly influences the quantity of solar radiation it receives. The contrast is indicated in table 9, in which are calculated sine A values for latitude 38° on typical slopes of this Area with either south or north exposure. The data in table 9 have not been adjusted for atmospheric conditions, elevation, reflection, or vegetative cover. The data indicate that a slope of 70 percent or more that faces north receives no direct solar radiation from November on. Even in June, a north-facing slope with a gradient of 40 percent or more receives considerably less solar energy than a south-facing slope of comparable gradient. Thus, energy the year round is less on north-facing slopes than on south-facing slopes. This difference in solar energy is great enough to produce distinctly different soil and vegetation on the north slopes than on the south slopes.

The total quantity of precipitation in this Area is low, and it falls mostly in 8 months of the year. Most of the precipitation falls as snow, which melts rapidly in a short period. Consequently, there is a deficiency of soil moisture during summer.

The south slopes are much drier than the north slopes because they receive more heat. They therefore have less dense stands of timber, support different kinds of plants, and are sites for the poorly developed, shallower Bobtail soils.

TABLE 8—*Temperature of six soil profiles as measured by permanently installed thermistors*

| Darling soil | | | Bobtail soil | | | Ptarmigan soil | | Vasquez soil | |
|---|---|---|---|---|---|---|---|---|---|
| Meter depth | Temperature | | Meter depth | Temperature | | Meter depth | Temperature | Meter depth | Temperature |
| | Site 1 [1] | Site 2 [2] | | Site 1 [3] | Site 2 [4] | | | | |
| *Inches* | *°F.* | *°F.* | *Inches* | *°F.* | *°F.* | *Inches* | *°F.* | *Inches* | *°F.* |
| 4 | 51.8 | 47.1 | 4 | 49.5 | 48.2 | 4 | 47.4 | 4 | 49.1 |
| 24 | 53.0 | 48.1 | 24 | 48.3 | 47.1 | 12 | 47.5 | 18 | 47.9 |
| 54 | 55.6 | 46.9 | 54 | 47.9 | 48.6 | 24 | 47.3 | 30 | 48.7 |
| 84 | 50.6 | 47.8 | 84 | 47.2 | 45.9 | 40 | 45.8 | 60 | 48.7 |
| 120 | 51.8 | 45.6 | 120 | 45.6 | 50.5 | 55 | 45.8 | 90 | 48.3 |
| | | | | | | [5] 70 | 44.1 | 120 | 48.5 |
| | | | | | | 100 | 42.9 | | |

[1] Profile on north exposure near steep ridgetop.
[2] Profile on north exposure, in mid-slope position.
[3] Profile on south exposure near steep ridgetop.
[4] Profile on south exposure, in mid-slope position.
[5] Permafrost at depth of 67 inches when pit was dug.

TABLE 9.—*Calculated daily values of maximum direct solar radiation on north and south exposures at latitude 38° N., at 12:00 o'clock noon* [1]

| Date | Level (0 pct.) | Percentage and exposure of slope | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | 10 pct. | | 40 pct. | | 70 pct. | | 100 pct. | |
| | | North | South | North | South | North | South | North | South |
| June 21 | 0.9703 | 0.9414 | 0.9896 | 0.8111 | 0.9907 | 0.6567 | 0.9336 | 0.5151 | 0.8572 |
| July 24 | .9511 | .9156 | .9771 | .7683 | .9978 | .6019 | .9563 | .4540 | .8910 |
| Aug. 22 | .8988 | .8507 | .9379 | .6717 | .9973 | .4849 | .9877 | .3256 | .9455 |
| Sept. 21 | .7880 | .7228 | .8454 | .5030 | .9603 | .2925 | .9986 | .1219 | .9926 |
| Oct. 20 | .6691 | .5919 | .7397 | .3453 | .8973 | .1220 | .9743 | | .9986 |
| Nov. 23 | .5299 | .4429 | .6117 | .1771 | .8070 | | .9205 | | .9744 |
| Dec. 21 | .4695 | .3797 | .5550 | .1080 | .7648 | | .8909 | | .9563 |

[1] Calculated sine A values, without atmospheric correction.

The Darling soils, in contrast, are on north slopes or at higher elevations than the Bobtail. They receive less heat, contain more moisture, and support a better cover of plants. Most of the residual soils at this elevation and latitude would have characteristics like those of the Darling soils, if it were not for the steep southerly slopes.

Excess heat resulting in dryness seems to be the factor dominant in development of the Bobtail soils. Measurement of heat and evaluation of its influence are not simple; they are discussed for the Fraser Experimental Forest by Garstka et al (*4*).

Other factors significant in the genesis of these soils are the large quantity of gravel, the bulk density of the soil material, and the large pores in the gravelly soils. A number of samples for bulk density taken from the Leal, Darling, and Bobtail soils revealed no significant differences among soil types. For all soils sampled, the bulk density of the surface soil was 1.27, and the bulk density of the subsoil and substratum was 1.60. In the subsoil and substratum, however, no difference in bulk density was indicated.

Stones and gravel occupy a large part of the profile of the soils in the Fraser Alpine Area. Table 10 shows the percentage of gravel, by weight, in four soils. There are no significant differences among the soils sampled; all contain large amounts of gravel. In addition, all the soils contain stones; which are not considered in table 10, but which occupy appreciable volume in the soil profile. The values for content of gravel and stone indicate the problem of expressing soil textures for mountain soils, according to conventional practice, which is in terms of content of sand, silt, and clay.

The percentage of gravel and stones is so large in these soils, whether expressed by weight or by volume, that they tend to be much more droughty than their textures, as conventionally reported, would indicate. The pores are of larger size because of the gravel and stones, and this accounts for rapid absorption but little storage of water. Thus, stones and moisture affect the moisture regime in a way that retards development of the soils.

To sum up, it appears that climate, as influenced by high elevations, is the major soil-forming process in the Fraser Alpine Area. Limited moisture, heat, and a very short growing season are controlling factors related to climate.

TABLE 10.—*Percentage of gravel, by weight, in the profiles of four soils*

| Soil | Surface soil | Subsoil | Substratum |
|---|---|---|---|
| | *Percent* | *Percent* | *Percent* |
| Darling (4)[1] | 29 | 40 | 61 |
| Bobtail (6) | 30 | 48 | 46 |
| Leal (3) | 43 | 56 | 55 |
| Lunch (1) | 50 | 66 | 21 |
| Average | 38 | 53 | 46 |

[1] Number of profiles in sample.

Parent materials are essentially uniform throughout the Area and thus have little effect in determining differences among the soils.

Elevation, however, has distinct influence on soil formation. The difference of elevation within the Area is 4,500 feet. The aspect of slopes brings about appreciable variation of climate locally. Furthermore, many slopes are so steep that there is mass movement of material downslope, even in places protected by vegetation. The downslope movement of soil, either by erosion or slides, is a factor in maintaining the relative youth of the soils.

### *Soil series classified by higher categories*

The soil series of the Fraser Alpine Area are classified by great soil groups as follows:

| | *Remarks* |
|---|---|
| Podzols: | |
| Darling | Strongly developed. |
| Bottle | Strongly developed. |
| Leal | Moderately developed. |
| Sols Bruns Acides: | |
| Bobtail | Very weak podzolization. |
| Gray Wooded soils: | |
| Tabernash | Strongly developed. |
| Alpine Meadow soils. | |
| Ptarmigan | Well-drained; comparable to "Alpine Turf" soils. (7) |
| Vasquez | Imperfectly drained. |
| Bog soils: | |
| Nystrom | Alpine bog with permafrost. |
| Lunch | Subalpine bog. |
| Regosols: | |
| Mine | |

Profiles of the soil series in this Area are described on pages 14 to 29, and analytical data are presented in table 11. All the soil series listed were correlated in this Area for the first time. Most of them can be expected to occur throughout the Rocky Mountain region.

Below the alpine, podzolization is strongly expressed in the Darling and Bottle soils by a prominent $A_2$ horizon and a distinctive accumulation of iron in the B horizon. These characteristics are less well developed in the Leal soils, possibly because of the youth of the glacial deposits. In the Bobtail soils, podzolization is weakly expressed because they are on a southern and dry exposure.

Ptarmigan soils, in the alpine, also exhibit an accumulation of iron in the B horizon, but the color is normally much less intense than in the Darling soils. In fact, analyses show that iron has accumulated in the subsoil to greater or less extent in all the soils in the Area.

Except for the Tabernash, all the soils contain unusually large amounts of stone and gravel. The greatest amount of silt and clay is normally concentrated in the topmost mineral layer. The amount of silt plus clay is low for all soils except the Tabernash, and it would be lower if computed for the entire profile rather than for some of the sand, silt, and clay fractions.

The soils are most acid in the A horizon and there is a consistent tendency for pH to increase with depth.

All the soils except the Nystrom, Lunch, and Vasquez have developed under moisture deficits. The Nystrom and Lunch formed under the influence of excess water, and the Vasquez, under moist conditions and occasional saturation.

# *Part III: Soil Use and Management*

Part III is designed to provide technical information about soils that will aid in planning the use and management of wildlands.

Planning, public or private, involves consideration of many factors. Among the more important to be evaluated are the time at which there is demand for products and the quantity in which they are needed; competitive demands for the same piece of land; amount of capital available; the system of management or rotation; present and expected improvements in technology; managerial ability; and, perhaps most of all, the potential ability of soils to respond and produce the desired product.

Thus, successful planning and management require information from many sources, one of which is the soil survey. A soil survey increases the efficiency of planning, since soils are the fabric of the landscape with which the manager must work if he is to do his job effectively and profitably.

## Soil Management Areas

The soils of this Area, like those of others, could be grouped in many ways, depending on the present and probable use. The present use of the soils in this Area, as well as the probable future use, is not intensive. The soils, therefore, have been grouped geographically for broad management and planning. The groups are called soil management areas, and they are shown on the colored map at the back of this report. In making these groupings, those factors were taken into account that likely would have an important effect on one or more kinds of land use in the Area. The boundaries of the management areas were drawn on the small-scale colored map with consideration of the kinds of soil, type of rock or soil parent material, topography, and climate.

The soils of each management area will respond to management in a generally similar way. Within each management area, however, there are included some soils that are markedly different. These are included because their acreage is small, or because they are in small, scattered individual areas. In each management area, however, there is a uniform, distinctive pattern of soils on the landscape.

The soil management areas cannot be used effectively in intensive planning or management of small areas. These management areas, however, are useful for ranger district planning, or for county, State, or regional planning, provided the planning is for broad uses such as production of water, growing of timber, or managing range for grazing. Each of the five soil management areas in the Fraser Alpine Area is shown on the colored map at the back of this report and is discussed in the following pages.

### *Alpine rock and wasteland area*

This soil management area is made up of Rock outcrop, Rock slides, Alpine rimland, and Alpine wind-eroded land. Collectively, these land types cover 33 percent of the Area, or 43 percent of its alpine part.

The land types in this management area are devoid of soil, or nearly so. In some places, Alpine wind-eroded land and Alpine rimland have enough soil material to support a scanty cover of plants. These land types are not stable and continue to lose fine soil material. Rock outcrop and Rock slides are barren and in many places are of large size.

Alpine rimland is on the leeward side of the high peaks and ridges, where snow accumulates deeply; it is a prime source of water during summer.

The large areas of Rock slides are prime watershed lands because they collect all incoming moisture, without allowing surface runoff or erosion, and deliver it slowly and safely to the drainage system below. This is not true of the large areas of Rock outcrop, which discharge water rapidly. Fortunately, areas of Rock outcrop are fringed by Rock slides at their base.

Wind-eroded land commonly has little or no vegetation. Strong winds keep it swept free of snow, and it contributes little to the water supply.

Considering this soil management area as a whole, it is wasteland, and little can be accomplished by conventional methods of land management.

### *Ptarmigan-Vasquez soil area*

This soil management area consists of steep, rocky, shallow, gravelly sandy loam soils of the alpine that have developed under grass. It is a complex mixture of Ptarmigan and Vasquez soils, with isolated, small spots of Nystrom peat that together make up a small proportion of the total acreage. Also included are small areas of rock and loose stones and small alpine lakes. The total extent of this soil management area is 37,500 acres.

TABLE 11.—*Mechanical and*

[Absence of an entry in a column

| Soil name and depths of sampling, in inches | Horizon | Particle size distribution (in mm.) | | | | | | | | | | pH | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Very coarse sand 2–1 | Coarse sand 1–0. 5 | Medium sand 0. 5–0. 25 | Fine sand 0. 25–0. 10 | Very fine sand 0. 10–0. 05 | Silt 0. 05–0. 002 | Clay <0. 002 | 0. 2–0. 02 | 0. 02–0. 002 | >2 | Saturated paste 1:1 | 1:5 |
| | | Pct. | Pct. | Pct. | Pct. | Pct. | Pct. | Pct. | Pct. | Pct. | Pct. | | |
| Bobtail gravelly sandy loam: | | | | | | | | | | | | | |
| 2 to 0 | $A_0$–$A_{00}$ | ------ | ------ | ------ | ------ | ------ | ------ | ------ | ------ | ------ | ------ | ------ | ------ |
| 0 to 3 | $A_2$ | 12. 0 | 14. 7 | 7. 6 | 13. 2 | 8. 4 | 35. 4 | 8. 7 | 30. 2 | 20. 6 | ------ | 4. 9 | ------ |
| 3 to 18 | $B_2$ | 12. 4 | 16. 3 | 8. 2 | 14. 9 | 9. 6 | 31. 5 | 7. 1 | 30. 8 | 18. 2 | ------ | 5. 1 | ------ |
| 18 to 42 | $B_3$ | 46. 7 | 20. 6 | 5. 8 | 8. 3 | 4. 4 | 11. 0 | 3. 2 | 13. 0 | 6. 6 | ------ | 5. 9 | ------ |
| 42 to 54 | C | 19. 5 | 19. 0 | 10. 0 | 15. 8 | 9. 2 | 17. 7 | 8. 8 | 26. 4 | 9. 4 | ------ | 6. 1 | ------ |
| 54 to 118 | D | 24. 0 | 19. 7 | 8. 4 | 12. 7 | 8. 4 | 19. 6 | 7. 2 | 23. 2 | 11. 9 | ------ | 6. 3 | ------ |
| Bottle fine sand: | | | | | | | | | | | | | |
| 1½ to 0 | $A_0$ | ------ | ------ | ------ | ------ | ------ | ------ | ------ | ------ | ------ | ------ | ------ | ------ |
| 0 to 6 | $A_2$ | 1. 1 | 4. 3 | 13. 7 | 42. 8 | 9. 3 | 25. 1 | 3. 7 | 43. 1 | 12. 8 | 5. 7 | 4. 8 | ------ |
| 6 to 11 | $B_{2ir}$ | 2. 4 | 4. 4 | 10. 1 | 54. 8 | 11. 8 | 12. 7 | 3. 8 | 50. 7 | 6. 6 | 13. 2 | 4. 8 | ------ |
| 11 to 33 | C | 3. 1 | 3. 6 | 10. 1 | 67. 7 | 9. 1 | 4. 6 | 1. 8 | 51. 0 | 2. 4 | 16. 1 | 4. 9 | ------ |
| Darling gravelly sandy loam: | | | | | | | | | | | | | |
| 4 to 0 | $A_0$–$A_{00}$ | ------ | ------ | ------ | ------ | ------ | ------ | ------ | ------ | ------ | ------ | ------ | ------ |
| 0 to 3 | $A_2$ | 8. 8 | 7. 9 | 4. 0 | 6. 7 | 5. 3 | 52. 1 | 15. 2 | 30. 6 | 30. 2 | ------ | 4. 7 | ------ |
| 3 to 23 | $B_2$ | 12. 2 | 14. 5 | 7. 6 | 13. 7 | 8. 8 | 30. 0 | 13. 2 | 29. 1 | 16. 7 | ------ | 4. 8 | ------ |
| 23 to 38 | $B_{2ir}$ | 33. 7 | 19. 7 | 6. 6 | 9. 4 | 5. 0 | 17. 4 | 8. 2 | 17. 0 | 10. 0 | ------ | 5. 2 | ------ |
| 38 to 48 | $C_1$ | 39. 6 | 21. 2 | 6. 5 | 8. 4 | 4. 3 | 15. 9 | 4. 1 | 14. 6 | 9. 6 | ------ | 5. 5 | ------ |
| 48 to 81 | $C_2$ | 14. 8 | 16. 7 | 10. 1 | 20. 2 | 11. 7 | 22. 4 | 4. 1 | 33. 8 | 11. 1 | ------ | 5. 8 | ------ |
| 81 to 116+ | D | 24. 9 | 21. 7 | 9. 0 | 14. 3 | 7. 2 | 16. 4 | 6. 5 | 21. 5 | 9. 1 | ------ | 5. 9 | ------ |
| Leal sandy loam: | | | | | | | | | | | | | |
| 2 to 0 | $A_0$ | ------ | ------ | ------ | ------ | ------ | ------ | ------ | ------ | ------ | ------ | ------ | ------ |
| 0 to 2½ | $A_2$ | 18. 0 | 10. 7 | 6. 8 | 11. 5 | 10. 0 | 34. 7 | 8. 3 | 33. 9 | 17. 2 | 15. 7 | 4. 4 | ------ |
| 2½ to 11 | $B_{2ir}$ | 17. 7 | 13. 0 | 7. 3 | 11. 4 | 10. 2 | 30. 9 | 9. 5 | 31. 5 | 16. 0 | 18. 3 | 5. 1 | ------ |
| 11 to 16 | $B_3$ | 24. 7 | 15. 5 | 7. 8 | 11. 5 | 10. 0 | 23. 9 | 6. 6 | 28. 4 | 11. 9 | 25. 0 | 5. 3 | ------ |
| 16 to 23+ | C | 21. 6 | 16. 6 | 9. 4 | 13. 7 | 10. 9 | 23. 2 | 4. 6 | 30. 2 | 11. 5 | 15. 9 | 5. 4 | ------ |
| Mine gravelly loam: | | | | | | | | | | | | | |
| 0 to 3 | $A_1$ | 8. 4 | 9. 4 | 7. 1 | 13. 7 | 11. 6 | 40. 4 | 9. 4 | 40. 2 | 19. 7 | 5. 8 | 6. 1 | ------ |
| 3 to 6 | $A_3$ | 8. 5 | 9. 7 | 6. 8 | 14. 4 | 13. 9 | 39. 1 | 7. 6 | 44. 0 | 17. 6 | 7. 6 | 5. 8 | ------ |
| 6 to 13 | $C_1$ | 7. 8 | 10. 9 | 10. 1 | 19. 5 | 15. 7 | 30. 6 | 5. 4 | 43. 9 | 13. 8 | 12. 5 | 5. 9 | ------ |
| 13 to 20+ | $C_2$ | 9. 8 | 14. 4 | 10. 0 | 17. 2 | 14. 2 | 28. 6 | 5. 8 | 39. 9 | 12. 9 | 16. 5 | 5. 8 | ------ |
| Nystrom peat: | | | | | | | | | | | | | |
| 0 to 3 | 1 | [2]47. 1 | 13. 1 | 2. 6 | 2. 7 | 1. 5 | 12. 9 | 20. 1 | 1. 0 | 14. 8 | 5. 3 | ------ | 4. 3 |
| 3 to 14 | 2 | [2]12. 9 | 8. 6 | 2. 9 | 4. 2 | 2. 8 | 40. 5 | 28. 1 | 23. 7 | 22. 0 | 5. 1 | ------ | 4. 5 |
| 14 to 17 | $D_1$ | 43. 5 | 18. 6 | 4. 6 | 5. 3 | 3. 1 | 11. 8 | 13. 1 | 10. 3 | 7. 4 | 8. 5 | 4. 6 | ------ |
| 17 to 23 | $D_2$ | 51. 0 | 10. 2 | 3. 9 | 6. 5 | 2. 0 | 11. 7 | 14. 7 | 8. 8 | 8. 1 | 24. 7 | 4. 7 | ------ |
| 23 to 29 | $D_3$ | 69. 7 | 9. 2 | 1. 3 | 1. 5 | 1. 0 | 8. 1 | 9. 2 | 3. 8 | 6. 1 | 52. 1 | 4. 9 | ------ |
| 29 to 34 | $D_4$ | 40. 1 | 14. 2 | 5. 2 | 7. 2 | 5. 2 | 17. 9 | 10. 2 | 15. 7 | 11. 5 | 32. 9 | 4. 9 | ------ |
| Ptarmigan loam: | | | | | | | | | | | | | |
| 0 to 1½ | $A_{11}$ | 13. 3 | 6. 4 | 2. 9 | 5. 4 | 6. 0 | 47. 8 | 18. 2 | 29. 8 | 27. 2 | 6. 6 | ------ | 6. 0 |
| 1½ to 6 | $A_{12}$ | 15. 4 | 9. 2 | 4. 0 | 6. 6 | 7. 1 | 38. 7 | 19. 0 | 27. 9 | 21. 8 | 19. 4 | ------ | 5. 8 |
| 6 to 10 | $B_1$ | 36. 2 | 11. 9 | 3. 6 | 5. 1 | 6. 3 | 25. 0 | 11. 9 | 20. 3 | 14. 1 | 28. 6 | 5. 6 | ------ |
| 10 to 23 | $B_{2ir}$ | 26. 1 | 11. 5 | 4. 3 | 8. 1 | 9. 9 | 27. 4 | 12. 7 | 25. 9 | 16. 5 | 18. 2 | 5. 4 | ------ |
| 23 to 35+ | C | 76. 9 | 8. 2 | 7 | 8 | 1. 0 | 7. 4 | 5. 0 | 3. 9 | 5. 0 | 71. 3 | 5. 5 | ------ |
| Tabernash loam: | | | | | | | | | | | | | |
| 0 to 1½ | $A_1$ | 7. 2 | 7. 2 | 3. 6 | 6. 3 | 11. 3 | 54. 2 | 10. 2 | 42. 5 | 26. 8 | 3. 4 | 6. 2 | ------ |
| 1½ to 5½ | $A_2$ | 7. 3 | 7. 8 | 3. 9 | 6. 8 | 11. 8 | 50. 6 | 11. 8 | 40. 9 | 25. 5 | 4. 4 | 5. 9 | ------ |
| 5½ to 8 | $B_1$ | 7. 9 | 7. 6 | 3. 7 | 6. 5 | 9. 2 | 35. 6 | 29. 5 | 30. 1 | 18. 5 | 2. 5 | 6. 0 | ------ |
| 8 to 15 | $B_{21}$ | 5. 9 | 4. 7 | 3. 0 | 6. 4 | 9. 5 | 37. 1 | 33. 4 | 31. 2 | 19. 2 | 1. 9 | 6. 1 | ------ |
| 15 to 23 | $B_{22}$ | 3. 0 | 3. 9 | 2. 9 | 6. 4 | 9. 4 | 39. 4 | 35. 0 | 32. 0 | 20. 6 | . 9 | 6. 2 | ------ |
| 23 to 27 | $B_3$ | 16. 1 | 10. 6 | 6. 0 | 8. 9 | 9. 1 | 28. 9 | 20. 4 | 28. 7 | 14. 2 | 9. 6 | 5. 9 | ------ |
| 27 to 36 | D | 22. 9 | 14. 6 | 8. 2 | 12. 9 | 9. 1 | 18. 0 | 14. 3 | 24. 9 | 9. 1 | 30. 5 | 5. 7 | ------ |
| Vasquez loam: | | | | | | | | | | | | | |
| 0 to 1½ | $A_{11}$ | [2]10. 6 | 8. 0 | 3. 8 | 5. 2 | 3. 0 | 37. 8 | 31. 6 | 18. 2 | 25. 4 | 2. 7 | ------ | 4. 8 |
| 1½ to 4 | $A_{12}$ | 23. 0 | 14. 0 | 5. 7 | 7. 9 | 4. 1 | 26. 3 | 19. 0 | 17. 7 | 16. 8 | 11. 4 | 4. 6 | ------ |
| 4 to 11 | $A_3$ | 36. 4 | 14. 4 | 4. 6 | 6. 1 | 3. 7 | 18. 5 | 16. 3 | 14. 6 | 10. 9 | 17. 8 | 4. 8 | ------ |
| 11 to 21 | $C_1$ | 19. 0 | 15. 1 | 7. 9 | 13. 6 | 9. 9 | 20. 9 | 13. 6 | 26. 6 | 12. 0 | 29. 3 | 4. 9 | ------ |
| 21 to 31+ | $C_2$ | 24. 9 | 17. 6 | 7. 2 | 11. 2 | 8. 9 | 21. 4 | 8. 8 | 23. 5 | 13. 2 | 18. 6 | 5. 5 | ------ |

[1] Determination made but amount was below minimum reportable.

*chemical analyses of several soils*

indicates determination was not made]

| Organic matter: Organic carbon | Organic matter: Nitrogen | Organic matter: C/N | Free iron $Fe_2O_3$ | Moisture tensions: 1/10 Atmos. | Moisture tensions: 1/3 Atmos. | Moisture tensions: 15 Atmos. | Cation exchange capacity $NH_4Ac$ | Extractable cations (meq./100 gm.): Ca | Mg | H | Na | K | Base sat. $NH_4$ Ac | Base sat. on sum +H | Sum −H | Sum +H | Ca/Mg |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Pct. | Pct. | | Pct. | Pct. | Pct. | Pct. | | | | | | | Pct. | Pct. | | | |
| 1.78 | 0.056 | 31.8 | ------ | ------ | ------ | ------ | 15.0 | 4.3 | 1.1 | 6.9 | 0.1 | 0.5 | 40 | 46 | 6.0 | 12.9 | 3.9 |
| .84 | .037 | 23 | ------ | ------ | ------ | ------ | 13.0 | 4.4 | 1.0 | 7.9 | .1 | .4 | 45 | 43 | 5.9 | 13.8 | 4.4 |
| .09 | .006 | 15 | ------ | ------ | ------ | ------ | 6.9 | 4.7 | .6 | 2.1 | .1 | .2 | 81 | 73 | 5.6 | 7.7 | 7.8 |
| .10 | ------ | ------ | ------ | ------ | ------ | ------ | 19.5 | 12.0 | 1.6 | 2.2 | .1 | .3 | 72 | 86 | 14.0 | 16.2 | 7.5 |
| .18 | ------ | ------ | ------ | ------ | ------ | ------ | 11.5 | 10.3 | 1.3 | 2.6 | .2 | .2 | 100 | 82 | 12.0 | 14.6 | 7.9 |
| | | | | | | | | | | | | | | | | | |
| .97 | .029 | 33.4 | 0.4 | 14.8 | 9.4 | 2.5 | 6.5 | 2.5 | .6 | 4.7 | .2 | .2 | 54 | 43 | 3.5 | 8.2 | 4.2 |
| .25 | .010 | 25.0 | .5 | 8.6 | 5.0 | 1.4 | 3.4 | 1.1 | .2 | 2.9 | .1 | .1 | 44 | 34 | 1.5 | 4.4 | 5.5 |
| .23 | .007 | 32.8 | .3 | 5.0 | 2.6 | 1.0 | 1.7 | .5 | [1] | 2.0 | .1 | [1] | 35 | 23 | .6 | 2.6 | [1] |
| | | | | | | | | | | | | | | | | | |
| 3.83 | .154 | 24.9 | ------ | ------ | ------ | ------ | 28.9 | 5.2 | 2.6 | 19.3 | .1 | .9 | 30 | 31 | 8.8 | 28.1 | 2.0 |
| 1.35 | .062 | 21.8 | ------ | ------ | ------ | ------ | 20.6 | 6.9 | 1.2 | 14.1 | .1 | .4 | 42 | 38 | 8.6 | 22.7 | 5.8 |
| 1.00 | .043 | 23.2 | ------ | ------ | ------ | ------ | 13.1 | 5.0 | .6 | 10.6 | .1 | .3 | 46 | 36 | 6.0 | 16.6 | 8.3 |
| .47 | ------ | ------ | ------ | ------ | ------ | ------ | 10.3 | 4.3 | .6 | 6.8 | .1 | .2 | 50 | 43 | 5.2 | 12.0 | 7.2 |
| .31 | ------ | ------ | ------ | ------ | ------ | ------ | 14.4 | 10.0 | 1.4 | 3.7 | .1 | .3 | 82 | 76 | 11.8 | 15.5 | 7.1 |
| .27 | ------ | ------ | ------ | ------ | ------ | ------ | 13.9 | 10.6 | 1.3 | 3.9 | .1 | .3 | 88 | 76 | 12.3 | 16.2 | 8.2 |
| | | | | | | | | | | | | | | | | | |
| 2.52 | .076 | 33.2 | 1.0 | ------ | ------ | ------ | 12.7 | 2.6 | .8 | 10.8 | .1 | .6 | 32 | 28 | 4.1 | 14.9 | 3.2 |
| .66 | .031 | 21.3 | 1.2 | 21.6 | 14.7 | 5.7 | 10.9 | 2.7 | .8 | 8.8 | .1 | .3 | 36 | 31 | 3.9 | 12.7 | 3.4 |
| .17 | .012 | 14.2 | .8 | 15.6 | 10.5 | 3.9 | 7.3 | 2.5 | .6 | 4.4 | .1 | .2 | 46 | 44 | 3.4 | 7.8 | 4.2 |
| .09 | .009 | 10.0 | .7 | 14.3 | 9.2 | 3.0 | 5.7 | 2.2 | .6 | 3.1 | .1 | .1 | 53 | 49 | 3.0 | 6.1 | 3.7 |
| | | | | | | | | | | | | | | | | | |
| 1.82 | .088 | 20.7 | 1.4 | 29.7 | 23.6 | 6.8 | 18.1 | 11.2 | 2.0 | 9.2 | .1 | .7 | 77 | 60 | 14.0 | 23.2 | 5.6 |
| .70 | .044 | 15.9 | 1.4 | 24.0 | 18.3 | 5.2 | 11.9 | 5.6 | 2.0 | 5.8 | .1 | .5 | 69 | 58 | 8.2 | 14.0 | 2.8 |
| .33 | .018 | 18.3 | 1.3 | 19.8 | 15.0 | 4.3 | 9.4 | 4.1 | 1.6 | 3.5 | .1 | .4 | 66 | 64 | 6.2 | 9.7 | 2.6 |
| .20 | .012 | 16.7 | 1.2 | 18.6 | 13.0 | 4.1 | 8.2 | 4.4 | 1.3 | 2.9 | .1 | .4 | 76 | 68 | 6.2 | 9.1 | 3.4 |
| | | | | | | | | | | | | | | | | | |
| 27.80 | 1.662 | 16.7 | ------ | 126.4 | 118.9 | 50.9 | 48.7 | 12.1 | 1.7 | 44.7 | .2 | .6 | 30 | 25 | 14.6 | 59.3 | 7.1 |
| 23.53 | 1.104 | 21.3 | ------ | 99.1 | 62.8 | 26.0 | 40.8 | 6.3 | .2 | 54.6 | .1 | .1 | 16 | 11 | 6.7 | 61.3 | 32.0 |
| 1.54 | .097 | 15.9 | 1.8 | 20.4 | 17.9 | 7.0 | 14.0 | 1.4 | .4 | 16.9 | .1 | .1 | 14 | 10 | 2.0 | 18.9 | 3.5 |
| .73 | .048 | 15.2 | 3.1 | 17.5 | 14.6 | 6.6 | 7.5 | .9 | .4 | 14.9 | .1 | .1 | 20 | 9 | 1.5 | 16.4 | 2.2 |
| .51 | .026 | 19.6 | 2.2 | 13.9 | 12.1 | 4.8 | 7.9 | 1.0 | .4 | 8.5 | .1 | .2 | 22 | 17 | 1.7 | 10.2 | 2.5 |
| .32 | .018 | 17.8 | 2.5 | 16.9 | 13.7 | 4.5 | 6.8 | 1.0 | .1 | 6.9 | .1 | .1 | 19 | 16 | 1.3 | 8.2 | 10.0 |
| | | | | | | | | | | | | | | | | | |
| 16.53 | 1.187 | 13.9 | ------ | 85.7 | 62.8 | 39.7 | 58.0 | 39.1 | 6.9 | 22.5 | .3 | 1.0 | 82 | 68 | 47.3 | 69.8 | 5.7 |
| 12.96 | .978 | 13.2 | 1.6 | 72.1 | 48.6 | 29.4 | 42.0 | 30.6 | 5.4 | 22.6 | .3 | 1.0 | 89 | 62 | 37.3 | 59.9 | 5.7 |
| 3.41 | .300 | 11.4 | 2.0 | 36.4 | 25.7 | 10.7 | 22.6 | 12.4 | 2.8 | 13.7 | .1 | .4 | 69 | 53 | 15.7 | 29.4 | 4.4 |
| .58 | .048 | 12.1 | 3.1 | 22.9 | 18.2 | 7.7 | 18.6 | 7.4 | 1.6 | 7.2 | .2 | .2 | 50 | 57 | 9.4 | 16.6 | 4.6 |
| .25 | .016 | 15.6 | 1.3 | 9.9 | 8.2 | 3.9 | 4.3 | 2.7 | .7 | 2.0 | .2 | .1 | 86 | 65 | 3.7 | 5.7 | 3.8 |
| | | | | | | | | | | | | | | | | | |
| 2.25 | .108 | 20.8 | 1.4 | 34.1 | 23.5 | 6.3 | 15.8 | 10.3 | 1.7 | 7.5 | .1 | 1.0 | 83 | 64 | 13.1 | 20.6 | 6.0 |
| .47 | .029 | 16.2 | 1.3 | 23.8 | 18.3 | 4.6 | 8.7 | 5.0 | 1.3 | 4.2 | .1 | .4 | 78 | 62 | 6.8 | 11.0 | 3.8 |
| .51 | .029 | 17.6 | 1.6 | 23.7 | 19.6 | 10.5 | 20.1 | 13.4 | 4.3 | 5.3 | .1 | .5 | 91 | 78 | 18.3 | 23.6 | 3.1 |
| .34 | .024 | 14.2 | 1.8 | 32.0 | 25.7 | 13.4 | 24.6 | 18.1 | 5.7 | 5.1 | .1 | .4 | 99 | 83 | 24.3 | 29.4 | 3.2 |
| .27 | .017 | 15.9 | 1.6 | 37.5 | 30.0 | 14.8 | 27.4 | 22.1 | 6.5 | 5.6 | .2 | .3 | 100 | 84 | 29.1 | 34.7 | 3.4 |
| .19 | .013 | 14.6 | 1.4 | 22.3 | 18.0 | 8.2 | 15.9 | 10.9 | 3.1 | 3.8 | .1 | .2 | 90 | 79 | 14.3 | 18.1 | 3.5 |
| .19 | .010 | 19.0 | 1.1 | 20.5 | 15.8 | 7.3 | 15.9 | 11.4 | 3.1 | 4.0 | .1 | .1 | 92 | 79 | 14.7 | 18.7 | 3.7 |
| | | | | | | | | | | | | | | | | | |
| 15.83 | .971 | 16.3 | ------ | 76.0 | 59.8 | 37.6 | 37.6 | 12.1 | 2.4 | 35.2 | .3 | 1.0 | 42 | 31 | 15.8 | 51.0 | 5.0 |
| 5.94 | .365 | 16.3 | 2.0 | 39.5 | 30.2 | 15.7 | 23.2 | 4.0 | .2 | 21.7 | .2 | .3 | 20 | 18 | 4.7 | 26.4 | 20.0 |
| 3.02 | .238 | 12.7 | 2.2 | 32.8 | 24.5 | 11.5 | 16.6 | 2.4 | .2 | 19.3 | .1 | .2 | 17 | 13 | 2.9 | 22.2 | 12.0 |
| .56 | .050 | 11.2 | 2.4 | 20.6 | 15.8 | 6.4 | 10.6 | 2.2 | .1 | 8.7 | .1 | .1 | 24 | 22 | 2.5 | 11.2 | 22.0 |
| .20 | .015 | 13.3 | 1.8 | 15.3 | 12.4 | 3.0 | 3.3 | 1.2 | .2 | 1.6 | .1 | .1 | 48 | 50 | 1.6 | 3.2 | 6.0 |

[2] Not dried prior to dispersing.

The soils, in most places, are less than 20 inches thick. They are porous because they contain so much gravel and stone. They are droughty, are low in fertility status, and generally have low capacity to produce range herbage. Because they are porous, they erode excessively only where swept by wind or where grazing has reduced the protective cover. Erosion by wind, however, is extensive on the Ptarmigan soils.

The drainage system is poorly developed, and few of the channels are gullied. The Nystrom soils have restricted internal drainage and are frequently wet for a considerable part of the year.

The soils of this management area make up the most extensive grazing lands in the Fraser Alpine Area. Their annual production is not great, and the grazing season is limited to 2½ months in midsummer. Extensive areas have deteriorated because the protective vegetation has been damaged. These lands are grazed only by sheep attended by a herder.

The soils of this management area have high value for water yield. All of them except the Nystrom soil are permeable. Most of the water, therefore, moves underground and emerges as springs at or near timberline.

Because of its scenic value and climate, this management area is valuable for summer recreation. Elk graze on it during summer, and other forms of wildlife are present.

In summary, the chief problems in this area are revegetation of bare tracts, increasing yield of herbage through management of grazing, and increasing yield of water by applying practices that will allow deeper accumulation of snow during winter.

### *Bobtail-Darling soil area*

The Bobtail-Darling soil management area is composed of shallow, stony, gravelly soils on steep slopes, below timberline, in the St. Louis Creek watershed. The soils generally are low in fertility and in moisture-holding capacity. They are well drained to somewhat excessively drained, but because of their depth to bedrock, can store considerable water during snowmelt. This soil management area occupies about 11,800 acres.

The Darling surface soil is protected by a dense stand of vaccinium and moss. Less vegetation grows on the Bobtail soils. Erosion is limited on soils of this management area because most of the precipitation comes as snow, and because the soils are porous enough to absorb large amounts of water rapidly. On a comparative basis, erosion is not severe, even where the steep slopes are not well protected by vegetation. There are few drainageways, and these are not unstable in the sense of gullying.

Included in this soil management area are a number of small areas of protruding bedrock and rock slides, as well as numerous, small, scattered areas of Lunch peat and a small acreage of the Bottle soils.

Because slopes in this soil management area are steep, there tends to be more moisture on the lower than on the upper reaches of the slopes. The best trees grow on the toe slopes.

Soils of this management area support a mature stand of Engelmann spruce, in which there are some included areas of subalpine fir, lodgepole pine, and aspen. At the lower elevations, and particularly on the Bobtail soils, the dominant tree is lodgepole pine. The soils of this management area are only moderately productive. The understory of shrubs is browsed by elk and deer during summer, but there is little vegetation livestock can use.

Areas logged during the early part of the century (see fig. 8) now have young stands of spruce and lodgepole pine. Under any system of management now foreseeable, soils of this management area will be used primarily for growing timber and production of water. Recreational opportunities appear limited. In terms of erosion, the soils of this management area are very stable.

### *Leal soil area*

This soil management area consists of stable soils that are sandy and gravelly and have a deep, loose, permeable subsoil. They are low in fertility and in water-holding capacity, but because they are deep, they hold considerable water. This management area occupies about 4,000 acres.

The Leal soils, dominant in this management area, formed in coarse-textured, deep, stony glacial till derived largely from gneiss and schist rocks. Because of this, they are somewhat excessively drained. Nevertheless, they are very stable so far as surface erosion is concerned.

The terrain is made up of lateral and terminal moraines that are strongly pitted in some places. Kettle lakes occur in a few places, but most of the pits contain water only a part of the year. Some of the glacial deposits have been locally reworked by streams, but without significant change in important features.

There is a wide range in slope. The lateral moraines are plastered on steep mountainsides, but these moraines are much less steep on their tops. Terminal and valley moraines range widely in slope but are generally less steep than the lateral moraines.

Included in this soil management area are appreciable amounts of exposed stones, and some small areas of alluvial soils (mapped as Alluvial land). In places where the till is thin or patchy, there are some spots of Darling or of Bobtail soils.

The soils of this management area are timbered with virgin stands of lodgepole pine and Engelmann spruce. Engelmann spruce dominates at higher elevations. Willow fields and sedges grow in small openings along the drainageways, but the quantity of these is too small to be of much significance in forest grazing.

The soils of this management area are significant because they are subject to practically no surface runoff or erosion. Because the soils are so permeable, springs or seeps emerge only where these soils join the present flood plains. Under any management now foreseeable, these soils are best suited to production of timber and water.

### *Alluvial soils-Tabernash-Mine area*

This soil management area is made up of relatively stable soils of the Tabernash and Mine series and of alluvial soils (mapped as Alluvial land). This management area occupies about 2,800 acres.

The soils of this management area have moderate fertility and good water-holding capacity. Their productivity for native plants is moderately high. These are deep soils with textures ranging from loams to gravelly loams.

The Tabernash and Mine soils have a finer textured subsoil and contain less stone than the alluvial soils.

The soils are mostly level to nearly level. There are more irregularities in the alluvial soils than in the others. The hazard of surface erosion is low for all of these soils, and there are no gullies.

Some of this management area has been logged, and a part has been burned. A new growth of lodgepole pine is establishing itself in these places. Under any future management now foreseeable, these soils probably will remain in timber. Nevertheless, there are good opportunities for developing recreation sites in some places. Some cattle graze the open areas, but these areas may get smaller as the young stand of timber continues to grow.

The soils of this management area are significant in management of water, as all the water from the watershed must pass over or through them. Deer and elk graze in this area during summer.

## Suitability Classification of Soils

The soils of the Fraser Alpine Area are not suitable for cultivation. According to the system of capability grouping used by the Soil Conservation Service, all of them are in classes VII and VIII. Nevertheless, the soils are valuable for many kinds of wildland use. Some of the more important current uses are listed in table 12, together with ratings that indicate the relative suitability of each soil for the specified use. Leal sandy loam and Alluvial land (Lc) is not listed in table 12; its suitability for specified uses can be determined by referring to its components. The ratings in table 12 are based on the extensive management now practiced. Data are not adequate to permit more precise ratings. The response of several of the soils under current uses is discussed in the following pages.

### *Range use and management*

The major grazing in this Area is in the alpine part, where sheep are brought for about 2½ months in midsummer (fig. 13). The subalpine lands are grazed mainly while the sheep are being moved to and from the alpine. A few cattle graze along the stream flood plains at lower elevations in the St. Louis Creek watershed.

As mentioned in Part I, many kinds of plants grow above timberline. A large part of the usable forage

TABLE 12.—*Estimated relative suitability of the soils for production of water, timber, and range herbage, their inherent erodibility, and hydrologic groups*

| Map symbol | Soil, land type | Inherent erodibility | Water | | | Timber [1] | | | Range herbage | Hydrologic groups |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Infiltration | Percolation | Storage space | Englemann spruce-subalpine fir | Lodgepole pine | Aspen | | |
| Aa | Alluvial land | Medium | High | High | High | High | | High | High | B |
| Ab | Alpine rimland | High | Medium | Low | Low | | | | Low | B |
| Ac | Alpine wind-eroded land | High | High | Medium | High | | | | Low | B |
| Ba | Bobtail gravelly sandy loam | Low | High | High | High | Low | Medium | Low | Low | B |
| Bb | Bottle fine sand | High | High | High | High | Medium | Medium | Low | Low | B |
| Da | Darling gravelly sandy loam | Low | High | High | High | High | Low | Medium | Low | B |
| La | Leal sandy loam | Low | High | High | High | High | High | Medium | Low | B |
| Lb | Leal sandy loam, terminal moraine | Low | High | High | High | High | High | Medium | Low | B |
| Ld | Lunch peat | High | High | High | High | Medium | | Medium | Medium | D |
| (2) | Mine gravelly loam | Low | High | High | High | Medium | High | Medium | Medium | B |
| Na | Nystrom peat | High | High | High | High | | | | Medium | D |
| Pa | Ptarmigan loam | High | High | High | High | | | | Medium | B |
| Pb | Ptarmigan loam, slightly bare | High | High | High | High | | | | Low | B |
| Pc | Ptarmigan loam, moderately bare | High | High | High | High | | | | Very low. | B |
| Pd | Ptarmigan loam, largely bare | High | High | High | High | | | | Very low. | B |
| Pe | Ptarmigan loam-Rock outcrop | Medium | High | High | High | | | | Low | B |
| Ra | Rock outcrop | | | | | | | | | |
| Rb | Rock slides | | High | High | High | | | | | A |
| Ta | Tabernash loam [3] | Medium | Medium | High | High | Low | High | Medium | Medium | C |
| Va | Vasquez loam | Medium | High | High | High | | | | Medium | B |
| Vb | Vasquez loam, slightly bare | High | High | High | High | | | | | B |
| Vc | Vasquez loam, moderately bare | High | High | High | High | | | | | B |
| Vd | Vasquez loam, largely bare | High | High | High | High | | | | | B |

[1] Absence of rating indicates tree does not grow on the soil specified.
[2] Mapped with Tabernash loam.
[3] Mapped as Tabernash loam and Mine gravelly loam.

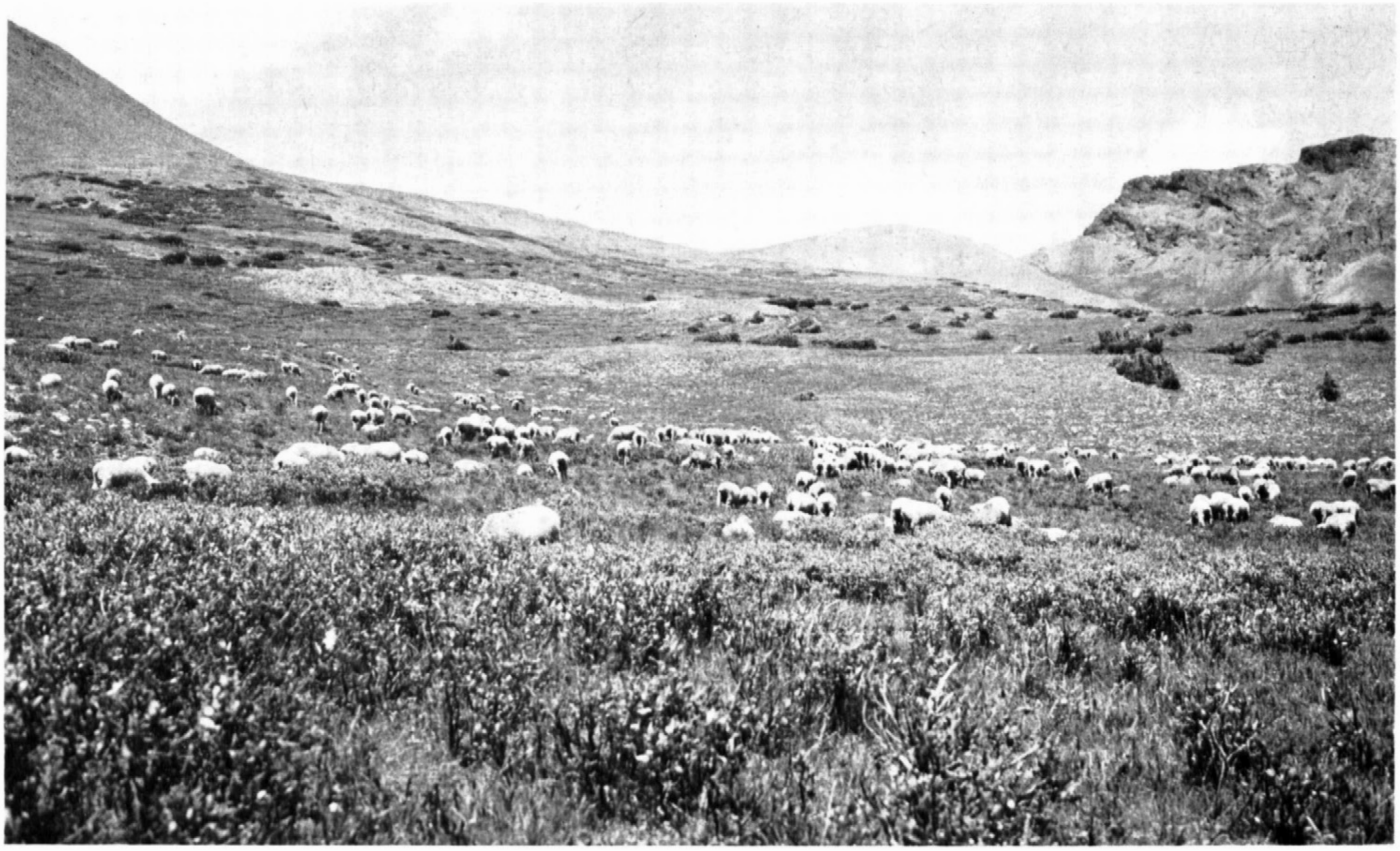

*Figure 13.*—**Sheep grazing on Ptarmigan and Vasquez soils.**

comes from sedges, rather than grasses. The kind of herbage, and its yield, differs on the different soils.

The Ptarmigan soils, most extensive of those in the alpine, are well-drained, shallow soils that have a black surface soil and a porous, gravelly subsoil. The most common plant on Ptarmigan soils is kobresia (*Kobresia bellardi*), a sedgelike plant growing on level areas and north slopes. Carex (*Carex elynoides* and *C. drummondiana*) grow in drier areas. Alpine bluegrasses, such as *Poa alpina*, and forbs, such as mountain bluebells (*Mertensia alpina*) and alpine clover (*Trifolium dasyphyllum*), are important.

The management of Ptarmigan soils is best directed toward establishing a turf that contains appreciable quantities of the plants just named. At this time there is no known way to improve the composition of the plant cover, other than to control grazing. Even with such control, improvement in range likely would be slow.

A good stand of kobresia should produce about 600 to 800 pounds of air-dry forage per acre, annually. The sedges on slightly drier areas will produce an estimated 400 to 500 pounds of herbage. Paulsen (*6*) reported that annual production of forage on soils similar to the Ptarmigan averaged 363 pounds per acre, air-dry weight, and that yields of 595 pounds per acre, air dry, were obtained where the plant cover exceeded 60 percent of the surface area.

The Vasquez soils are in low places and are moist longer than the Ptarmigan soils. They have a fine-textured surface soil and are deep in many places. The most common plants on these soils are tufted hairgrass (*Deschampsia caespitosa*), Parry clover (rose clover) (*Trifolium parryi*), and American bistort (*Polygonum bistortoides*). Several sedges (*Carex* spp.) make up a large proportion of the forage. Several kinds of alpine willows (*Salix* spp.) grow 2 to 5 feet tall and occupy appreciable areas of the Vasquez soils.

Grazing management of Vasquez soils could be best directed toward establishing a good mixture of the plants just named. When use is so heavy that the willows are removed, most of the other desirable herbaceous plants are also removed. The average meadow, in excellent condition, should produce 800 to 1,200 pounds of air-dry forage per acre on Vasquez soils. The average annual yield should be in excess of 1,000 pounds per acre. Paulsen (*6*) reported a range of 132 to 1,108 pounds per acre and an average of 626 pounds per acre, air dry, from soils similar to the Vasquez.

Below timberline, the soils generally have low potential to produce herbage. Among the soils are the Bottle, Leal, Darling, and Bobtail. They produce limited forage because they are coarse and gravelly, low in fertility, and highly acid. The Tabernash and Mine soils at the north end of the Fraser Experimental Forest will produce a moderate amount of herbage where cleared, but these soils rapidly revert to lodgepole pine. The alluvial soils (Alluvial land) along stream channels produce the most herbage. Lunch peat, in the vicinity of seeps on mountainsides, produces some herbage, most of it consisting of sedges (*Carex* spp.), with a few weeds and some brome and bluegrass.

The Nystrom soils are dominantly organic or peat soils that are permanently wet. Open water is common. Although these soils occupy less than 2 percent of the Area, they are a distinctive feature of the landscape. The vegetation is dominated by the small alpine willows (*Salix* spp.) and sedge, chiefly *Carex scopulorum*. Marsh marigold (*Caltha leptosepala*) is also a common plant. Management could be best directed to maintaining these plants. Excessive grazing has done much harm to these soils in places. Where bogs have been overgrazed and drained, the area reverts to dryland plants with a much lower productive capacity. This has happened on Vasquez ridge west of Berthoud Pass. The Nystrom soils in excellent herbage condition should produce in excess of 1,000 pounds of air-dry herbage per acre.

Other soils and land types in the alpine part of the Area produce no vegetation or an amount so small that it is better used to protect the surface soil than for grazing. Among the land types are Alpine rimland, Alpine wind-eroded land, Rock outcrop, and Rock slides.

Everywhere except in the true peat bogs, trees tend to take over on the soils below timberline. As the trees grow, they continue to fill in areas that have been logged or burned. Eventually, the areas now producing herbage will be eliminated if the present trend continues.

The soils of the Fraser Alpine Area have been rated according to their estimated inherent ability to produce herbage (see table 12). The estimates are based largely on field observations, plus a few measurements, and should be accepted only as relative comparisons. The ratings do not consider possible competition between plants for a particular area. The general relationships between ratings and yields of herbage are as follows: A soil with a rating of *high* will produce more than 1,000 pounds per acre annually; one with a *medium* rating will produce 400 to 1,000 pounds; and one with a rating of *low* or *very low* will produce less than 400 pounds per acre annually.

*Summary.*—Range management in this Area concerns the lands above timberline, as these are the ones grazed. The only means of checking deterioration of these lands appears to be to remove grazing in severely affected areas and to reduce grazing in those areas so far not so seriously affected. It is not known how rapidly natural revegetation will take place, but much more time will be required than in landscapes where climate is less severe. Artificial revegetation or fertilization has not been tried on these soils.

### *Forest use and management*

Lodgepole pine, Engelmann spruce, and subalpine fir are the three commercial species in the St. Louis Creek watershed. The subalpine fir, a minor species, mixed with Engelmann spruce, presently has less commercial value than either spruce or lodgepole pine. The aspen trees have no commercial value, and their growth is sparse.

Engelmann spruce grows best in this Area at elevations between 10,000 and 11,000 feet on well-drained Darling soils. At lower elevations it grows well only on the alluvial soils (Alluvial land), in the moist areas on Lunch peat, and on north-facing slopes. By present standards, the growth of spruce is noncommercial on the shallow rocky soils and in a narrow band fringing the alpine area. In most places, the stand of spruce is about 300 to 350 years old, is over-mature, and is becoming decadent.

Subalpine fir grows in intimate association with Engelmann spruce. It appears to respond to different soils in about the same way as the spruce. It commonly occurs as an understory beneath the spruce. Young fir trees also grow under lodgepole pine at the higher elevations.

Lodgepole pine grows best below the general elevation of 10,000 feet. Above that elevation it ordinarily grows only on the Bobtail soils, which are on south-facing slopes. Within the area mapped, lodgepole pine definitely prefers well-drained soils; that is, soils of the Bobtail, Leal, Tabernash, Mine, and Bottle series. Wet and moist places, even at these lower elevations, support spruce rather than lodgepole pine.

Aspen does not grow well on any soils in the Area, considering their growth on soils elsewhere in Colorado. Aspen trees need moist, fertile soils and abundant sunlight. On the dense spruce-pine forests of this Area, aspen is generally absent.

Few accurate measurements of timber yields have been made in the Area, but 243 acres, or half of the merchantable timber on Fool Creek, was clear cut. All trees down to 4 inches in diameter at breast height (d.b.h.) were harvested. The average acre yield was 14,650 board feet, of which 12,000 board feet had a d.b.h. of 10 inches or more. This stand, 250 to 300 years old, consisted of 55 percent lodgepole pine and 45 percent spruce-fir. The dominant soils in the area harvested were the Darling and Bobtail, though there were very minor areas of Lunch peat and of alluvial soils (Alluvial land).

The older trees in the stands of spruce on the Darling soils in the West St. Louis Creek watershed are 350 to 400 years of age. The common range for these uneven-age stands, however, is 250 to 275 years. Yields on harvested areas were about 18,000 board feet per acre. About 25 percent of the stand is affected by rot. The annual net increment is about 120 board feet per acre, but it is estimated that the net increment could be brought to 300 board feet per acre annually if more intensive management were applied. At higher elevations on the Darling soils, the annual growth rate is reduced, and at timberline, it is 50 board feet or less per acre.

Mature stands of lodgepole pine on the Bobtail soils in the West St. Louis Creek watershed range from 250 to 300 years old. Yields from pure stands in the areas harvested were about 9,000 board feet per acre. Rot affects an estimated 35 percent of the stand. The annual growth rate is near 20 to 30 board feet per acre. Under more intensive management, this annual rate might be increased to 100 to 150 board feet per acre.

Yields of lodgepole pine on the Bottle soils appear to be somewhat lower than on the Bobtail soils. On the Tabernash, Mine, and Leal soils, yields can be expected to be equal to or somewhat greater than those on the Bobtail soils.

Shown in table 12 are ratings indicating the estimated relative suitability of the several soils for Engelmann spruce, lodgepole pine, and aspen. The ratings are for only those soils in the St. Louis Creek watershed. The ratings are based on observations and are not supported by measurements. In making these ratings, the following rough guides were used:

| | Site index class | | Thousand board feet per acre | |
|---|---|---|---|---|
| Rating: | *Spruce-fir* | *Lodgepole* | *Spruce-fir* | *Lodgepole* |
| High | 1 & 2 | 1 & 2 | 25–40 | 2–25 |
| Medium | 3 & 4 | 3 & 4 | 15–25 | 10–20 |
| Low | 5 & 6 | 5 & 6 | 5–15 | 5–10 |

Much experimental work on thinning, harvesting, and managing of spruce and lodgepole pine has been done in the Area. Most of the work has been on the Darling and Bobtail soils.

### *Water behavior and management*

Water is one of the important products of the Fraser Alpine Area. It is discussed here as a product that can be measured and transported. Water used by plants is not considered.

Behavior of water is affected by the geologic makeup of the Area, by drainage patterns, by topography, and by soils. In studying water supply, the entire regolith, or the weathered part of the earth's surface, must be considered. The soils also need to be taken into account. They are a thin surface layer on the regolith, but they control the rate at which water moves into the regolith, and the amount of water that moves.

The geologic composition of the Area has been discussed in Part I. In this Area the extensive fracturing and faulting, and the intrusion of pegmatite dikes, undoubtedly affect subsurface movement of water, but data indicating their quantitative effects are lacking.

Weathering of rock is certainly significant in behavior of waters in this Area. At this altitude and climate, rock weathering is largely mechanical. Thus, an abundance of coarse sand, gravel, and rock is produced, but little silt and clay. Because the materials are coarse, there are large pores in the regolith through which water moves readily. The effective thickness of the regolith varies from zero, where bedrock protrudes, to 20 or 30 feet as seen in some road cuts. Possibly the average depth is about 10 feet (fig. 14).

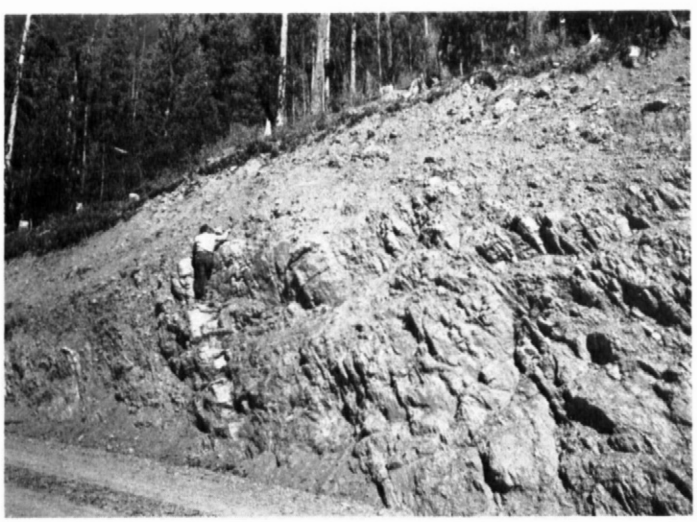

***Figure 14.*—The average depth of soil material available for storage of water is about 10 feet in the Fraser Alpine Area.**

The regolith is deeper at the base of steep slopes, where loose material has accumulated. This deeper regolith at the base of slopes effectively retards what would otherwise be rapid discharge of surface and subsurface water into stream channels. Possibly even more effective in slowing discharge are the till and coarse outwash that glaciers have plastered on the sides of the valleys or dropped on the floors of the valleys (see fig. 3). Till and coarse alluvial deposits fill all the major valleys to an unknown depth. Unquestionably, large quantities of water move out through these materials, in addition to the amount that moves in surface channels.

By studying drainage patterns, much can be learned about how water moves from a landscape. Under a given climate, the drainage pattern will be dense if water is disposed of over the surface, and sparse if most of the water moves away through the regolith. Detailed data on drainage patterns given in tables 1 and 2, in Part I, indicate that both number and density of streams are low, even though slopes are steep. This indicates that most of the water is disposed of through the regolith. This is reasonable to expect, since all soils in the Area, including those in the alpine, are coarse-textured and exceptionally porous. They absorb surface water very rapidly and permit rapid downward percolation. The only interference to rapid percolation is solid rock, or permafrost, or in some of the bogs, a high water table. Even the Tabernash soil, which has a fine-textured subsoil, shows no evidence of restricted drainage. For these reasons, surface runoff is rare, even when snow is melting rapidly in spring.

Water enters the soil and is detained by it, but it must eventually emerge and enter a stream. It may emerge on the same watershed where it entered, or may emerge elsewhere. The number of springs emerging on a watershed indicates what becomes of water that enters the soils. For this reason, the number and characteristics of springs in the Fool Creek watershed were studied. This watershed covers 714 acres and lies entirely below timberline between elevations of 9,588 and 11,505 feet. The springs located were plotted on a map (fig. 15).

The study was made late in fall, and all places where water emerged at the surface were called a spring, even if water was not flowing. Then, on basis of estimated flow, the springs were placed in five classes, *dry, very slow, slow, rapid,* and *very rapid.* The number of springs in each class and the temperature of the water are shown in table 13.

The data in table 13 indicate one spring for every 5.85 acres in the Fool Creek watershed. Comparison of this watershed with watersheds in other landscapes indicates that this is an exceptionally large number of springs. Fool Creek seems to be a reasonable sample of the pattern of springs in the St. Louis Creek watershed. The exceptions might be steep south-facing slopes, which appear to have few springs. Fool Creek flows north and the watershed therefore has east- and west-facing slopes. At any rate, this study suggests that a very large proportion of the annual precipitation that passes through the regolith emerges later as springs, and that this is probably the situation in all of the St. Louis Creek watershed.

Samples of water were collected from four springs in the Fool Creek watershed, from the main channel at the

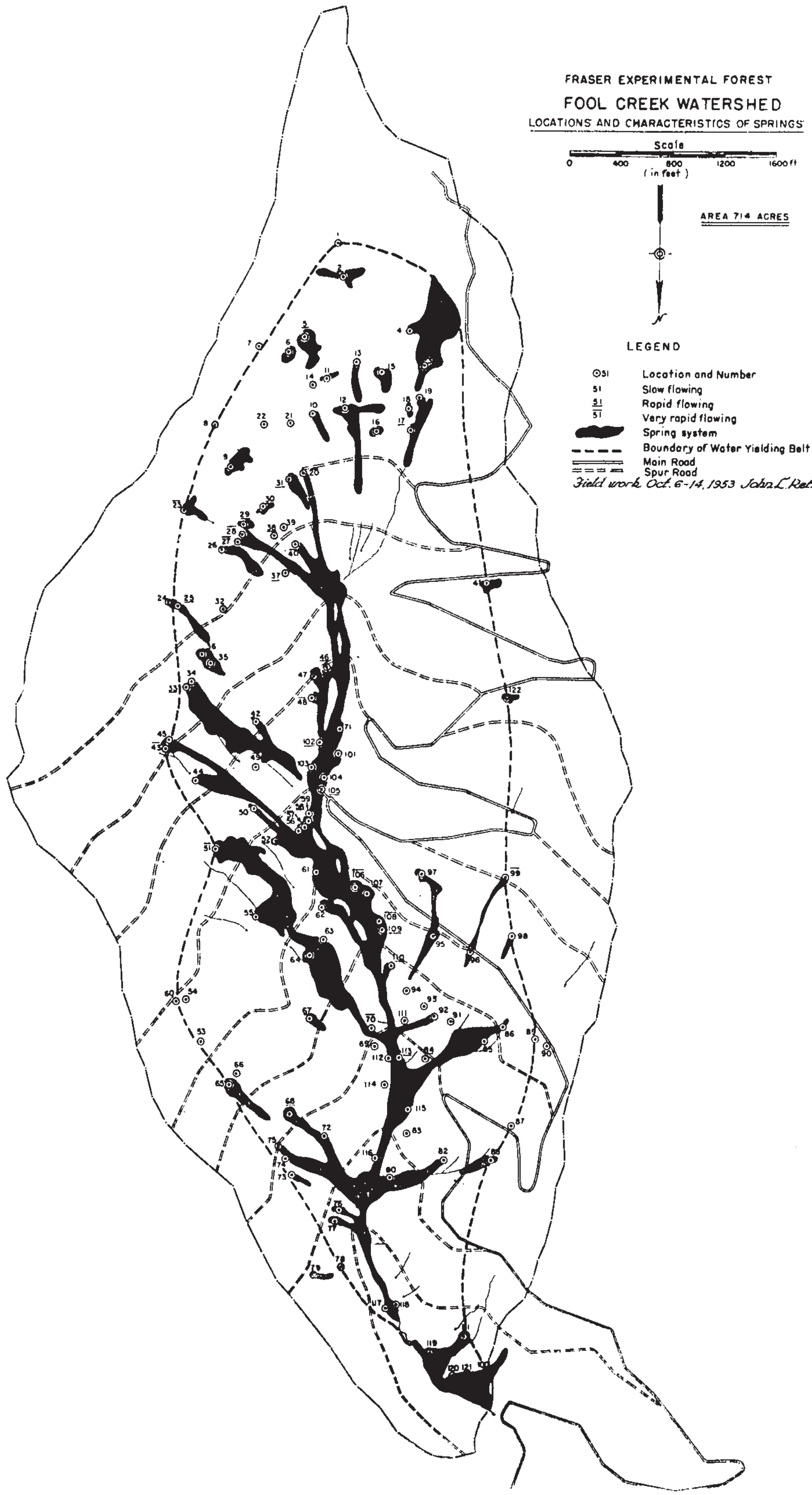


***Figure 15.*—Location of springs in the Fool Creek watershed, Fraser Experimental Forest.**

lower weir, and from the main channel at the upper weir. Analyses indicate high purity of these waters (table 7).

Water temperatures averaged 37.3° F. for all springs sampled (table 13). These are remarkably low temperatures, compared with those of springs at lower elevations. Other studies at higher elevations in the alpine showed temperatures to be about 1° cooler than for rapidly flowing springs in the Fool Creek watershed.

TABLE 13.—*Class of springs, and number and temperature of springs in each class* [1]

| Spring class | Number | Temperature [2] |
|---|---|---|
| | | ° *F.* |
| Dry | 20 | (3) |
| Very slow | 38 | 38. 0 |
| Slow | 29 | 37. 4 |
| Rapid | 21 | 37. 1 |
| Very rapid | 14 | 36. 8 |

[1] Measurements in October 1953.
[2] Average temperature for all springs in each class.
[3] Not sampled.

Springs are easily located in this landscape of dense timber because distinctive kinds of herbaceous vegetation grow around them. The major distinctive species are as follows:

*Senecio triangularis* (arrowleaf butterweed).
*Calamgrostis scribneri* (Scribner reedgrass).
*Carex aquatalis* (water sedge).
*Juncus martenstonus* (rush).
*Lycopodium annotinum* (stiff clubmoss).

Late in summer, the bright yellow flowers of the butterweed are especially effective indicators of springs. Typical emergence of a spring, the topography, and the vegetation are shown in figure 16.

*Distribution and pattern of spring emergence.*—The distribution of springs, as shown in figure 15, is interesting. At no place do they approach closer than 260 feet to the watershed boundary, and the common distance is greater. The outer belt devoid of springs constitutes 41 percent of the watershed area and apparently is the area in the Fool Creek watershed necessary for gathering

*Figure 16.*—**Typical spring and surrounding vegetation on the Fool Creek watershed.**

water before springs develop. Within the boundary of the water-yielding belt occur several large areas that are devoid of springs. If these areas were excluded, the gathering area would be increased to 50 or 60 percent of the watershed. Some springs tend to cluster, but in general they are fairly well distributed within the delineated belt, except on the central west side. Both clustering and the lack of springs on the west side suggest geologic controls that are not readily apparent. Although 122 springs were located, additional ones no doubt emerge beneath the alluvium of the main channel and beneath areas of Lunch peat that are so closely associated with the water system.

The pattern of spring emergence and movement of the waters to and down the main channel is referred to as the water "system." It consists of ill-defined channels, broad seep areas, and accumulations of peat (see fig. 11, *G*, *H*). The system is a narrow elongated one because of the steep slopes and geologic controls. Most but not all branches of the system are fed by rapidly or very rapidly flowing springs at or near the top. It is characteristic that water moving down these slopes flows on the surface and then submerges only to reappear farther down. The spring system occupies 8 percent of the watershed.

Most of the springs emerge at the base of short, steep slopes (see fig. 11, *G*, *H*) that may range from 3 to 30 feet long but most often are 10 to 15 feet long. The springs emerge at the base of some of these short slopes in a number of places that are parallel across the slope and a few feet apart. Then, the water flows directly downslope in a narrow system, or it spreads over a level bench or terrace. If it spreads on a bench, a bog forms, and gives rise to Lunch peat. The base of these benches is slowly permeable, blue silt and clay; the surface is saturated moss or peat.

In many places a raised rim forms on the outer perimeter of the bog, and this retards drainage. The rim may be formed by ice that shoves out when the water in the bog freezes. These marshy areas around springs may appreciably retard delivery of water. They certainly reduce the velocity of flow and thus retard the formation of gullies and deeply entrenched drainageways.

### HYDROLOGIC FUNCTION OF THE SOILS

The hydrologic function of the soils in this Area is to be considered in relation to precipitation. The yearly precipitation ranges from about 24 inches at lower elevations to more than 30 inches at higher elevations. This amount, however, must be studied in relation to the pattern of delivery. About two-thirds of the precipitation comes as snow, which melts in a rather short period beginning about mid May, peaking about mid June, and subsiding about mid July. But in this period, meltwater runs near the surface for only a short time in the afternoon. The rest of the time, it is absorbed by the porous soils. The soils, therefore, are hydrologically effective, as is shown graphically in figure 17. The watersheds of the streams for which the hydrographs are shown are mainly on Darling, Bobtail, and Lunch soils. The diagram indicates that these soils are capable of absorbing all the water during peak periods of melt, excluding brief periods on very warm days, when some surface runoff occurs.

Summer rains are sporadic and probably contribute

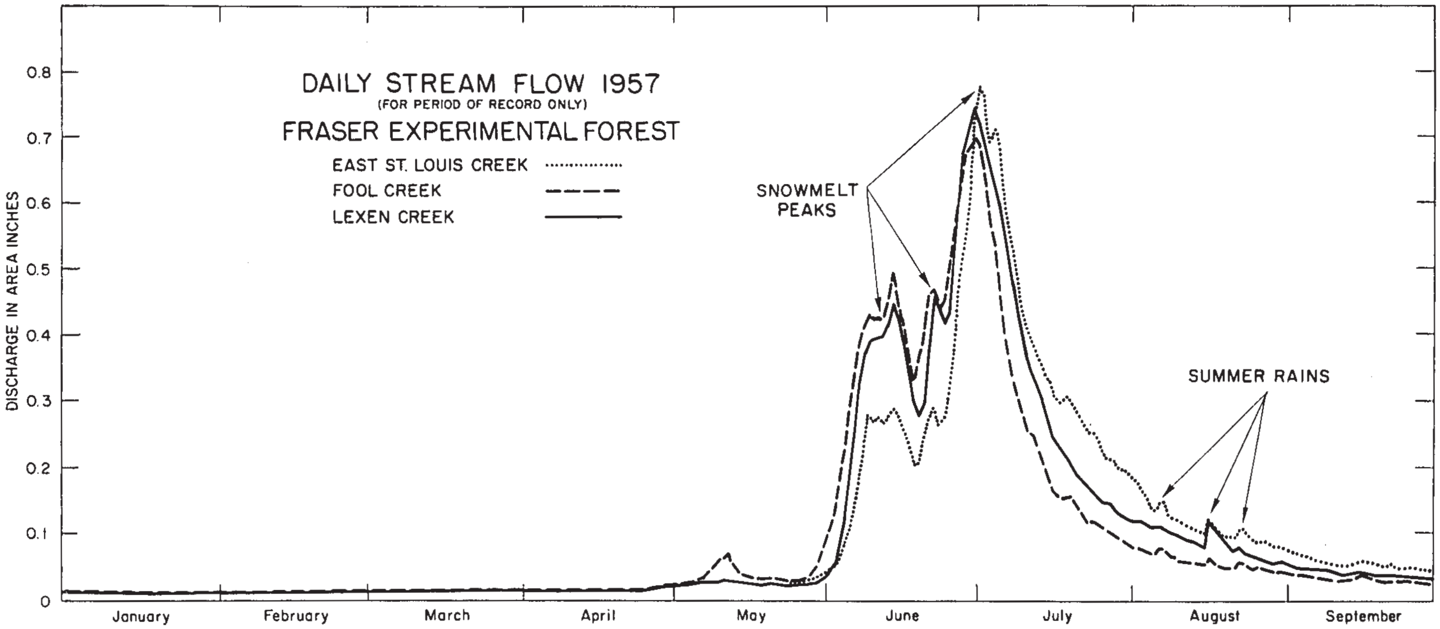


*Figure 17.*—**Hydrographs of three streams in the Fraser Experimental Forest that flow mainly on Darling nad Bobtail soils.**

little water. Usually they moisten the soil to a depth of a few inches, but most of this water is used by plants. Rather often, these soils are dry to the depth of root penetration, or 30 to 45 inches, when snow begins to fall. When this happens, they stay dry until the snow melts in spring.

*Hydrology of the subalpine soils.*—The soils in the subalpine part of this Area have physical properties that are hydrologically ideal under the present climate. The coarse textures, high percentage of large pores, and the large storage space in the regolith result in rapid infiltration and percolation, and consequently, in large storage of water. On the Darling and Leal soils, erosion does not occur under native timber stands, and only minimum erosion occurs on the Bobtail soils. There are no known soil-management practices that would increase the hydrologic effectiveness of these soils.

The hydrologic effect of roads on a watershed has been a question, since building of roads requires drainage of some bogs or the dissecting of some streams.

On the Fool Creek watershed, a system of roads was built that is much more extensive than ordinary logging operations might require. A total of 11.9 miles of road was built, of which 3.3 miles was main access road, and 8.6 miles was the total for 10 spur roads. The spur roads were built on the contour at intervals about 600 feet apart. In places these contour roads cut the stream system three or four times and interrupted and diverted the natural flow.

These roads gave access to 35 acres, or 5 percent of the total watershed. So far as could be determined, however, the roads did not affect stream hydrographs either by increasing water from the larger snowpack on the roads, or by causing ground water to drain out earlier through the numerous cuts through the water system. The effect of flow on the springs will need to be determined by a later field study.

*Hydrology of the alpine soils.*—The hydrologic function of the alpine soils is somewhat different from that of the subalpine. In the alpine, the precipitation comes mainly in the form of snow and is stored as snow and ice on the lee side of the numerous alpine rims (Alpine rimland), or in the soil as water and ice, or as ice in the extensive areas of Rock slides. The deep banks of ice and snow often do not melt until August or September, and in some years they do not completely melt.

Like the soils in the subalpine part of the Area, the soils in the alpine are coarse-textured and porous. The underlying regolith is shallower, however, and the percentage of large rocks is greater. Also, the dominant soils in the alpine, the Ptarmigan and Vasquez, have a herbaceous cover that can be destroyed by excessive grazing. Further, they are steeply sloping, and destructive erosion is therefore a problem in water management.

Deterioration of soils due to excessive grazing is at an advanced stage in many places. The soils of the alpine are normally very shallow, so loss of surface soil creates damage not practical to repair. Lost with the surface soil is the potential to produce vegetation, and vegetation is needed to hold water on the very steep slopes long enough to permit its entry into the soils.

The removal of the surface soil by wind on the exposed ridgetops also appears to have occurred because overgrazing by sheep has destroyed the willows and left trails where in some places erosion could start on Nystrom peat.

The management that might achieve the maximum hydrologic values from the soils of the alpine might well consist of (a) restoration of deteriorated bogs by mechanical means and by restricting use by livestock; (b) installing stone dams and checks in the gullies forming along driveways and in trails through passes, and then restricting use of such areas by livestock; and (c) eliminating all use by livestock on Alpine rimland and Alpine wind-eroded land. Mechancial practices for restoring the rimlands and wind-eroded land are not presently feasible.

HYDROLOGIC RATINGS: In table 12 are ratings showing the relative abilities of the soils of the Fraser Alpine Area to function hydrologically. The ratings do not take vegetation into account. They are based on three factors: (a) infiltration, or ability of the soils to permit passage of water through their immediate surface; (b) percolation, or the rate at which water moves down through the soil and fractured rock after it has moved through the immediate surface; and (c) storage, or space available to hold water that enters the soil. The space available in a soil (item c) depends largely on the thickness of the regolith and the size of the pores, for we are concerned primarily with downward movement of water by gravity and its emergence in springs. Table 12 also lists the hydrologic classes used by the Soil Conservation Service (*10*).

## Susceptibility of Soils to Erosion

To manage land efficiently, it is necessary to know how susceptible the soils are to erosion. Tendency to erode is inherent in the physical makeup of a soil, independent of the kind of vegetation that may be growing on it. This tendency can be neutralized by applying mechanical practices, by growing a vegetative cover, or by a combination of the two. Whatever the method, the intensity of the practices applied will be dictated by the degree to which the soil is susceptible to erosion.

In table 12 the inherent relative erodibility of the soils of the Fraser Alpine Area is indicated as *high*, *medium*. or *low*. Soils on which there is a high erodibility will, of course, require the most protection from running waters. In deriving these relative ratings the following factors were considered: (a) porosity and permeability of the soil, or its ability to absorb large quantities of water rapidly; (b) the water-storage capacity; (c) layers in the soil or regolith restricting passage of water; (d) texture, or size of the grains of soil, and the ease with which these would be transported in moving water; and (e) steepness of slope.

In the alpine part of this Area, few mechanical practices can be used successfully on the soils that have deteriorated. Also, revegetation is not a promising short-term solution, because the soils are inaccessible, shallow, stony, steep, and in a rigorous climate. The corrective practices that seem most feasible are to establish willows in some of the deteriorated bogs (Nystrom peat) and to hand-construct rock dams or barriers in gullies and trails. The most feasible corrective measure would be to prevent livestock use in the eroded areas and to reduce use on other areas to prevent future deterioration.

On subalpine soils—dominantly the Darling, Leal, and Bobtail soils—erosion control will be needed mostly where there is logging and road building. At this time, measures for control of erosion are largely preventative, rather than corrective. Normal precautions should be taken in harvesting timber. Reasonable manipulation of the vegetation for the purpose of increasing yield of water will have minimum detrimental effect on the soils.

## The Area as a Wildlife Habitat

All parts of this Area are excellent summer habitat for deer, elk, and bear. None of it is suitable as a winter habitat for these animals. Probably the value of the Area as a summer habitat will increase as logging continues to open timbered areas and thus creates more fringe areas where there will be more food and a denser ground cover to provide protection. Any increase in big game, however, will depend more on the winter range, which lies at lower elevations outside of the Area. The summer range within the Area is now abundant for the big game population. Other animals in the Area are mentioned in Part I of this report.

Advances in fish management could make this Area very attractive to sportsmen, because there are many small lakes and streams in the watershed of St. Louis Creek and immediately below all of the alpine lands.

Ptarmigan and blue grouse live in the Area the year round. During winter they inhabit the wooded areas. The number of grouse is limited, but management based on increased knowledge of their requirements might increase their number.

## Opportunities for Recreation

Most of the Fraser Alpine Area is isolated, wild, and rugged. Except for the road system built to facilitate work in the Fraser Experimental Forest, and the road over Jones Pass, the area is accessible only by hiking or riding.

These alpine lands afford one of the grandest vistas in Colorado, but few people visit them. They will doubtless remain wild and free of developments for a long time. Consequently, there is an excellent opportunity to develop a system of trails for riding and hiking. Stops below timberline could be provided at places where water and fishing are available.

This Area could well be used by people wishing to avoid more congested recreation areas. It is close to Denver, and can be reached from Berthoud, Loveland, and Jones Passes. Limited opportunity for picnicking, camping, and fishing is now offered in the Fraser Experimental Forest. Expansion of these facilities will depend on whether they prove compatible with use of the watershed for experimental purposes. Two ski lifts are located near the survey area, and at these, winter use exceeds 100,000 visits.

## Suitability of Soils for Engineering

Practically all engineering in this Area is concerned with location, construction, and maintenance of roads.

The Nystrom and Lunch peats are the problem soils in road construction. If roads must cross these soils, there are serious difficulties in getting drainage and in stabilizing cut slopes. The problems are most severe in spring, when snow melts, because most of the total annual precipitation must be disposed of in a short period. A greater number of culverts are usually needed than first appraisals indicate.

Because slopes are steep, many of the cut banks are high. Banks in the vicinity of seeps do not stabilize for several years, and they require considerable maintenance.

Roads should be located carefully to avoid as many seep and peat areas as possible. Because these are of small size, they could not be delineated on the soil maps, but reference to figure 15 will show the problem.

Small areas of bedrock, though important in road construction, could not be shown on the soil map. Where it is difficult to determine whether an exposed rock is part of the bedrock, or merely a boulder, reference to the soil map may be of some value. In areas of the Ptarmigan, Darling, Bobtail, and Bottle soils, it is safest to assume that an exposed rock is bedrock. In areas of Vasquez, Leal, Mine, and Tabernash soils, and Alluvial land, an exposed rock is more likely a boulder.

In most places on the well-drained soils throughout this Area, road grades safely can be raised 10 or 12 percent for short distances where necessary. The lack of silts and clays makes the soils unusually stable against erosion in most places. This general lack of fines, however, may be a problem in obtaining a proper mixture of material for surfacing roads. This problem will be most acute on the Leal soils.

Roads will require relatively little maintenance if they are properly located and if adequate drainage is provided at the time of construction. In mountain areas, it would be difficult to find conditions for building and maintaining roads more satisfactory than those in the Fraser Alpine Area.

## Research Value of the Survey

This soil survey is detailed enough to be of value in general research. For example, if stream gaging stations are to be placed on similar watersheds for the purpose of comparing treated and untreated areas, the information in this survey is sufficient to locate the similar watersheds. The soil map and accompanying report are reliable sources of information on acreage of trees and grassland in each watershed, and also the acreages of rock, rock slides, eroded soils, and the like. The map and report are also adequate if the purpose is to select grazing units in the alpine; for example, grazing units that would have relatively the same acreages of Ptarmigan, Vasquez, and Nystrom soils.

In the study of water production, this soil survey can be of considerable value because it gives acreage, size, slope, and location of those land types in the alpine where snow accumulates and where erosion by water, wind, and gravity is prevalent.

The survey is adequate if the purpose is to select general locations for small plots on which intensive research is to be conducted. The final location of such plots, however, will require additional intensive investigation of the soils. By use of this survey, the researcher can save considerable part of the effort in assuring that plots for proposed research are on important, extensive soils, and that the plots are on the same kinds of soils.

If plots for intensive research already have been located and used, and the purpose is to discover the kind of soil they are on, this survey is not adequate. More intensive investigation of the soil at the site of these plots will be necessary.

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