National Park Service - Alaska Region
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ECOLOGICAL SUBSECTIONS OF KOBUK VALLEY NATIONAL PARK

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Contents

Introduction

There has been increasing interest in inventory and monitoring of natural resources in National Parks, Monuments, and Preserves in Alaska. However, the choice of where to sample is difficult due to the large area involved. One useful strategy is to stratify sampling by ecosystem regions, to ensure adequate coverage of all ecosystems and economical allocation of the sampling effort. The purpose of this ecological unit map is to aid sampling for inventory and monitoring studies in Kobuk Valley National Park, Alaska (Fig. 1).

The guiding principle in definition of ecosystem regions is that ecosystems consist of the sum of the biotic and abiotic environment, and meaningful boundaries can be drawn that separate zones of relatively uniform ecological conditions (Bailey, 1996; Rowe and Sheard, 1981). Because the various tiers of the ecosystem (geology, landforms, soils, vegetation, etc.) are linked, they tend to change together and can be used in concert to define and map ecosystem regions.

Ecosystem regions (or "ecological units") defined by the above approach can be delineated at various scales, from tiny microsites to global-scale regions. The system of units used here was developed for mapping by the U.S. Forest Service and consists of the numerous levels, intended for use at different scales (Table 1). As discussed below, the units in the present study are *Subsections*, subdivided further into finer units where possible.

Ecological units delineated at the scale of this study are complex mosaics with many different kinds of vegetation and soils. A particular kind of vegetation or soil may occur in more than one unit; for example, black spruce (*Picea mariana*) woodland on wet soils with permafrost occurs as a component of many of the ecological units recognized here. However, the exact set of components in an ecological unit, their relative area, and their location on the landscape is unique for each unit. In other words, each unit consists of a mosaic of vegetation, landforms, and soils that is consistent and different from all the other units.

Because this map and write-up are based entirely on remotely-sensed data interpreted during a few weeks in the winter of 2000-2001, they should be considered preliminary. Use of the map and its verification by fieldwork should lead to refinement of boundaries, subdivision or amalgamation of units, and more comprehensive map unit descriptions.

Methods

The ecological units were delineated following the basic principles outlined by Bailey (1996) and Wertz and Arnold (1972). Ecological units were recognized by qualitative interpretation and synthesis of the available data for the study area, using the author's knowledge of what is ecologically important. Quantitative methods (e.g., map overlay and statistical analysis) were not used directly to define the ecological units or draw boundaries, although these methods were used to produce descriptive tables for the ecological units. These ecological units are best thought of as hypotheses about what constitutes ecologically significant regions in the study area, hypotheses that can be tested against any data that may be collected there in the future (Rowe and Sheard, 1981).

According to Bailey (1996), ecological units delineated at the scale of the present study (1:250,000) generally coincide with geologic or geomorphologic features. While geologic and geomorphic features typically determine the boundaries between ecological units in this study, the purpose was not to produce a geologic or geomorphologic map. Instead, the scale of these features and their close linkage to biotic features make them the best basis for mapping ecological units.

Ecological units were delineated in ArcView 3.2a (Copyright 1992-2000, Environmental Systems Research Institute, Inc.) using as base maps satellite imagery (Thematic Mapper image 7 July 1985, path 78, row 13) and US Geological Survey Topographic Maps (a digital raster graphic mosaic of 1:250,000 and 1:63,360 scale maps). The on-screen scale used when locating polygon vertices by clicks with the mouse varied from about 1:50,000 to 1:100,000, with the purpose to produce boundaries that are accurate and smooth at 1:250,000 scale. Because of the scale of mapping, line placement is accurate to within about 250 m. Users should be careful when enlarging the map to scales larger than it was drawn (i.e. larger than 1:100,000). The two base maps (topographic and satellite image) were alternated frequently to check the location of boundaries against both topography and surface reflectance.

Boundaries were drawn by mentally synthesizing the basemap information with data from the following references:

- High-altitude color-infrared aerial photographs (1:60,000 scale, 1978-1980) viewed in stereo for landforms and vegetation;
- Geologic maps (1:250,000 scale) for major bedrock (Patton *et al.*, 1968, Patton and Miller, 1968; Mayfield and Tailleur, 1978; Karl *et al*., 1989) and surficial (Fernald, 1964; Hamilton, 1984a; Kuhry-Helmens *et al*., 1985; the latter has a scale of 1:63,360) geologic features; and
- Land cover maps (Markon and Wesser, 1998) from Thematic Mapper satellite imagery classified into 20 vegetation and other land cover classes.

In response to the needs of the expected users of the maps, ecological units were delineated as finely as the methods would allow. Ecological *Subsections* were delineated and named by conventions outlined in Cleland *et al*. (1997). Most of the subsections could be readily subdivided into more detailed units. However, not all of these more detailed units are fine enough to qualify as the next level down in the National Hierarchical Framework of Ecological Units, the *Landtype Association* (Table 2; Cleland *et al.*, 1997). Furthermore, field sampling would be needed to verify the composition of any landtype associations. Thus the finer units are here referred to simply as "detailed ecological units".

Ecologic units that occurred in the National Park were extended beyond the park boundary to their natural limits, and joined with a map of Noatak National Preserve by Torre Jorgenson of ABR Inc. Our placement of ecologic unit boundaries outside of National Park Service boundaries should be considered tentative.

After ecological unit boundaries were finalized, the ArcView polygon shapefile was converted into an ARC/INFO 8.0.2 coverage. The fields in the polygon attribute table of this coverage are:

AREA	polygon area in units of decimal degrees
PERIMETER	polygon perimeter decimal degrees
*#	ARC/INFO's internal polygon identification number (* depends on the coverage name)
*-ID	user-option polygon identification number (* depends on the coverage name)
PARK_CODE	four-character NPS abbreviation for the park unit or units where the polygon occurs
ECOREGION	from an unpublished map by G. Nowacki, P. Spencer, T. Brock, M. Fleming, and M. Torre Jorgenson, 6/2000
SECTION_NA	full name for the ecological section
SUBSECT_CO	symbol for the ecological subsection
SUBSECT_NA	full name of the ecological subsection
DETSUB_CO	symbol for detailed ecological unit
DETSUB_NA	full name of detailed ecological unit
PHYSIOGRAP	physiography (landform) descriptor
LITHOLOGY	lithology (rock or sediment) descriptor
MANUSCRIPT_LINK	name and section of html document, to be used as a hotlink field in ArcView.

Soil and permafrost information is somewhat speculative, based on aerial photograph interpretation of vegetation and landforms, and the author's experience in similar regions elsewhere in Alaska (Swanson, 1995, 1996a,b). Patterned ground is usually not visible on the aerial photographs used, but the types most likely to be present are given under "soils" in the ecological unit descriptions. For more information on arctic and subarctic patterned ground, see Washburn (1956, 1979), and Zoltai and Tarnocai (1981), and Williams and Smith (1989). Vegetation information in the map unit descriptions is based on the land cover classification of the study area by Markon and Wesser (1998) and interpretation of aerial photographs. Land cover information in the tables was computed by ArcView overlay of the ecological units onto the land cover map. The elevations in the map unit descriptions were computed by ArcView overlay of the ecological units onto the 90 m Digital Elevation Model of Alaska.

Ecological Unit Descriptions

The map legend for ecological units of Kobuk Valley National Park is given in Table 2. The criteria used to delineated the subsections are summarized in Table 3. For areas of the land cover classes composing the subsections and the total area of each subsection, see Table 4.. Mean climatic data for Kobuk, Alaska (about 60 km east-southeast of the southeastern tip of the study area, elevation 43 m, 150 ft.) are given in Table 5. For units that range outside of the National Park, the elevations in the descriptions below are for the portion of the that falls within the Park boundaries only.

A simplified map of subsections in Kobuk Valley National Park is given in Fig. 2. For locations of the detailed ecological units, see the ARC/INFO coverage that accompanies this report.

AFH Akiak Foothills Subsection

The Akiak Foothills Subsection. These low mountains are composed mostly of schist and have rounded summits. Low elevations are forested, while higher elevations have shrubs or sparse vegetation. July 10, 2001; roll 4, frame 2

Detailed ecological units in the Akiak Foothills Subsection:
AFH1 Akiak Foothills - 961 km^2
AFH2 Akiak Foothills Alluvial Fans - 92 km^2
AFH3 Akiak Foothills Floodplains - 35 km^2
(areas within the park boundaries)

AFH1 Akiak Foothills

Geology and Physiography: low mountains with rounded crests and no cirques. Composed of Paleozoic phyllite and schist.

Elevation: 33 to 836 m (108 to 2743 ft)

Soils: mostly rocky soils with a loamy matrix. Most are probably fairly well drained, with permafrost absent or below 1 m and a surface organic layer < 20 cm thick. Some more gentle slopes probably have wetter soils with permafrost within 1 m and a surface organic layer 10 to 30 cm thick. Sorted circles and nets, and mudboils are probably present on ridge crests.

Vegetation/land cover: ridges crests have sparse vegetation of dwarf shrubs. Slopes have low or tall shrubs, open or closed. At lower elevations an open spruce overstory is present.
Notes: the transition between the Akiak Foothills and Akiak Mountains is gradational and boundary placement somewhat arbitrary.

AFH2 Akiak Foothills Alluvial Fans

Geology and Physiography: coarse-grained alluvium and debris-flow sediment in fans in the larger valleys of the Akiak Mountains. In some places this unit includes the narrow floodplain of the river flowing down the axis of the valley.
Elevation: 35 to 249 m (115 to 817 ft)
Soils: generally coarse-grained, with rocks in a sandy-loamy matrix. Drier portions probably lack permafrost, but some more densely vegetated parts probably have permafrost.
Vegetation/land cover: mostly white spruce woodland with shrub or lichen understory, or deciduous shrubs (birch, willow, or alder).
Notes:

AFH3 Akiak Foothills Floodplains

Geology and Physiography: floodplains of small mountain rivers, with meandering, braided, and straight channel forms. Alluvium mostly coarse-grained.
Elevation: 58 to 236 m (190 to 774 ft)
Soils: probably mostly sandy and gravelly soils that lack permafrost and have a thin (< 20 cm) surface organic layer. Some wetter soils with permafrost on higher surfaces more distant from the channel. Along the Kalligurichеark and Kallarichuk Rivers, soils appear to be wetter, and may be permafrost-free in places due to groundwater discharge
Vegetation/land cover: along the larger streams (Salmon and Tutuksuk), vegetation ranges from unvegetated gravel bars, to willow, alder and balsam poplar on vegetated gravel bars, white spruce forest with alders on less frequently flooded areas, and some black spruce forest on the highest and least flooded surfaces. Along the smaller streams (the Kalligurichеark and Kallarichuk), mostly closed alder and willow shrubs, in some areas with an overstory of spruce.
Notes: the Kalligurichеark river in this map unit flow between alluvial fans that come from side valleys, and it looks like there is groundwater near the surface. Water probably infiltrates into the coarse-grained fans and then discharges at their margins into the floodplain.

AHW Ahnewetut Wetlands Subsection

The Ahnewetut Wetlands Subsection. Thermokarst lakes are separated by polygonal peat plateaus (note ice-wedge polygons). Vegetation is mostly low shrubs and sedges, with a few black spruce trees on drier sites. July 10, 2001; roll 1, frame 12

Detailed ecological units in the Ahnewetut Wetlands Subsection:
AHW1 Ahnewetut Creek Floodplain - 6 km^2
AHW2 Ahnewetut Wetlands - 142 km^2
AHW3 Niaktuvik Creek Floodplain - 6 km^2
(areas within the park boundaries)

AHW1 Ahnewetut Creek Floodplain

Geology and Physiography: floodplain of a small stream. The stream is fairly straight near the dunes, and meanders in its lower part.

Elevation: 11 to 20 m (36 to 66 ft)

Soils: fine-sandy and probably wet in most areas, with a surface organic layer present but probably < 20 cm thick. The permafrost distribution is uncertain, probably lacking in the southern part due to groundwater discharge but widespread in the northern part along the meadering portion of the stream.

Vegetation/land cover: mostly needleleaf woodland, presumably both black and white spruce with willow and alder understory. The vegetation in the southern part is uncertain, probably wet herbaceous and scrub.

Notes: Ahnewetut Creek is the only stream that crosses the Great Kobuk Sand Dunes. It maintains a narrow pass through the dunes (south of the AH1 ecological unit), in spite of large amounts of sand deposited on it in the winter while frozen (Dijkmans and Koster, 1990). This stream probably receives considerable groundwater discharge from the sandy aquifer that also feeds the Ahnewetut Wetlands. Thus it probably has open patches in the winter, has a more constant water level than most small streams in this region. The southern part of this unit appears to have icings (aufeis). For general information on icings, see Carey (1973).

AHW2 Ahnewetut Wetlands

Geology and Physiography: nearly level plain composed mostly of alluvial and eolian sand.

Elevation: 13 to 60 m (43 to 197 m)

Soils: mostly organic soils, soils with more than 40 cm of peat (organic soil material). Permafrost is probably absent in most wet fens (the sedge wetlands with numerous shallow ponds and

water table at or above the surface). Permafrost is probably present in the slightly drier tussock wetland areas.

Vegetation/land cover: mostly wet herbaceous vegetation (mostly sedges) with numerous small, shallow ponds in fens, and cottonsedge tussock wetland with low shrubs on slightly higher and drier surfaces. Also numerous small lakes. Some closed low and tall shrubs and open spruce forest along streams. The large areas of forest shown on the land cover map are doubtful; most is probably wet sedge and water.

Notes: this appears to be an area of abundant groundwater discharge. The most likely recharge area for the water is the sand dunes to the south and west, where lack of vegetation or permafrost prevent transpiration and runoff of precipitation and allow infiltration. Groundwater discharge apparently occurs through taliks (permafrost-free areas) in this area of discontinuous permafrost. It is likely that, as a result of groundwater discharge, some reaches of open water persist all winter on the creeks that cross this region. Northern ribbed fens and net fens are visible on air photos; palsa bogs and peat plateau bogs are likely also. For a general discussion of these wetland types, see Canada Committee on Ecological Land Classification (1988). Numerous lakes and ponds are present. The smallest and shallowest ponds (generally < 100 m wide but in some cases 200-300 m long) occur in fens. The larger water bodies (200 m to over 1 km across) appear to be of thermokarst origin, with groundwater discharge from the lake bottoms likely.

AHW3 Niaktuvik Creek Floodplain

Geology and Physiography: floodplain of a small meandering river.

Elevation: 19 to 60 m (62 to 197 ft)

Soils: probably sandy on point bars, with stratified sand and silt on older surfaces. Soil wetness and permafrost probably vary greatly over short distances. Soils on point bars and in vigorous spruce forest on young surfaces are probably mostly well drained, lack permafrost, and have an organic surface layer < 20 cm thick. Soils probably become wetter and have permafrost under more stunted forest and shrubs along the margins of the unit.

Vegetation/land cover: mostly spruce woodland, or spruce or mixed open forest with dense shrub understory. Trees become sparser and more stunted on wetter soils along the outer margin of this unit (away from the channel). Sparse vegetation is present on sandbars.

Notes: this stream originates in the Waring Mountains and flows by the Great Kobuk Sand Dunes, but most of it lies in the Ahnewetut Wetlands. Groundwater discharge in the latter area probably helps to maintain water levels during the winter and during droughts.

AKH Aklumayuak Foothills Subsection

Aklumayuak Foothills Subsection. These rounded hills are mostly covered by cottonsedge tundra, with a few bedrock exposures. They occur near and north of the drainage divide between the Noatak and Kobuk River, mostly in the Noatak National Preserve (a cloud shadow obscures the foreground). July 10, 2001; roll 3, frame 25.

Detailed ecological units in the Aklumayuak Foothills Subsection:
AKH Aklumayuak Foothills - 20 km^2
(area within the park boundaries)

AKH Aklumayuak Foothills

Geology and Physiography: rounded hills of slope deposits over bedrock composed mostly of phyllite, metasandstone, sandstone and shale. Bedrock exposures occur on some ridge crests. Much of this units is a high plateau strongly dissected into a network of rounded ridges by incision of Sapun and Nakolikurok Creeks and their tributaries. The portion that reaches the study area is a gentle solifluctions slope.

Elevation: 479 to 1068 m (1572 to 3504 ft)

Soils: probably stoney soils with a loamy matrix, with permafrost and an active layer of about 0.5 to 1 m. A surface organic layer is probably present in most areas but < 20 cm thick. Drier soils with a thicker active layer on some ridge crests. Sorted circles and nets, and mudboils are probably present

Vegetation/land cover: the portion that occurs in the study area is mostly open low shrub and tussock tundra, with some closed shrubs along drainages and open dwarf shrubs and rock exposures on ridgetops.

Notes: this unit occurs mostly in Noatak National Preserve. The portion in the study area straddles the drainage divide between the Noatak and Kobuk Rivers. Its gentle topography and arctic tundra vegetation make is most like the Noatak Valley landscapes to the north. The vegetation here has distinct stripes running up- and down-slope composed of more- and less-brushy areas. The brushy stripes are known as “water tracks” and are zones of concentrated runoff of water (Kane *et al*. 1991, Hinzman *et al*., 1993).

AKM Akiak Mountains Subsection

The Akiak Mountains Subsection. These rugged mountains composed of schist have sharp ridge crests. Vegetation at the high elevations pictured here sparse; dwarf or low shrubs occur on more stable slopes. July 10, 2001; roll 3, frame 14.

Detailed ecological units in the Akiak Mountains Subsection:
AKM1 Akiak Mountains - 1649 km^2
AKM2 Akiak Mountain Alluvial Fans - 30 km^2
AKM3 Upper Akillik River Floodplain - 8 km^2
AKM4 Upper Hunt-Akiak Floodplain - 22 km^2
AKM5 Upper Tutuksuk Floodplain - 8 km^2
(areas within the park boundaries)

AKM1 Akiak Mountains

Geology and Physiography: rugged mountains with cirques from Pleistocene glaciation and sharp ridge crests. Composed mostly of schist.

Elevation: 86 to 1233 m (282 to 4045 ft)

Soils: rubble and bedrock outcrops on ridge crests and upper slopes. Lower slopes probably have dry, rocky soils with a loamy matrix, a thin (< 20 cm) organic surface layer, and permafrost absent or below 1 m. Some lower slopes probably are wetter, have a thicker organic surface layer (10-30 cm), and have permafrost at 0.5 to 1m depth. Sorted circle and nets are probably common on stable sites.

Vegetation/land cover: barren or sparse vegetation of dwarf shrubs on upper slopes and ridge crests. Lower slopes have closed or open low shrubs, with an open spruce overstory at low elevations.

Notes: separation of the Akiak Mountains, Akiak Foothills, Tukpahlearik Mountains, and Kallarichuk Hills Subsections is tenative, based on minor differences in geology and ruggedness. Users may want to combine them for some purposes.

AKM2 Akiak Mountain Alluvial Fans

Geology and Physiography: coarse-grained alluvium and debris-flow sediment in fans in the larger valleys of the Akiak Mountains. In some places this unit includes the narrow floodplain of the river flowing down the axis of the valley.

Elevation: 50 to 283 m (164 to 928 ft)

Soils: generally coarse-grained, with rocks in a sandy-loamy matrix. Drier portions probably lack permafrost, but some more densely vegetated parts probably have permafrost.

Vegetation/land cover: mostly open and closed low shrubs; white spruce woodland occurs on favorable sites.

Notes:

AKM3 Upper Akillik River Floodplain

Geology and Physiography: braided floodplain of a small mountain river, and small alluvial fans of tributary streams.

Elevation: 78 to 233 m (256 to 764 ft)

Soils: probably mostly sandy and gravelly soils lacking permafrost and a surface organic layer. Some wet soils with permafrost on the alluvial fans.

Vegetation/land cover: mostly gravel bars with sparse vegetation of herbs and deciduous shrubs. On alluvial fans, some closed and open spruce forest, closed low shrubs, and low shrub-tussock tundra.

Notes: this section river is strongly affected by icing (aufeis). For general information on icings, see Carey (1973).

AKM4 Upper Hunt-Akiak Floodplain

Geology and Physiography: floodplains of small mountain rivers. Channel form is mostly straight or meandering, but braided in a few spots.

Elevation: 59 to 359 m (194 to 1178 ft)

Soils: probably consist of a thin layer of sandy and silty material over sand and gravel. Permafrost status is unknown.

Vegetation/land cover: mostly closed low shrub, with occasional groves of open white spruce forest.

Notes: this unit occurs above the zone where spruce forest forms a continuous band along the river. The scattered groves on these floodplains are at the altitudinal/elevation limit. The braided section of river near 67° 24’ 57” N and 158° 31’ 29” W is probably subject to icing. For general information on icings, see Carey (1973).

AKM5 Upper Tutuksuk Floodplain

Geology and Physiography: braided floodplain of a small mountain river

Elevation: 193 to 390 m (633 to 1280 ft)

Soils: probably mostly sandy and gravelly soils lacking permafrost and a surface organic layer.

Vegetation/land cover: closed low shrubs, gravel bars with sparse vegetation of herbs and deciduous shrubs, and some open spruce forest.

Notes: this section river is strongly affected by icing (aufeis). For general information on icings, see Carey (1973).

AKP Akillik Plain Subsection

The Akillik Plain Subsection. This nearly treeless region has numerous thermokarst lakes separated by polygonal peat plateaus with sedges, cottonsedge, and low shrubs. Some parts of the plain are gently sloping with few lakes. July 10, 2001; roll 2, frame 26

Detailed ecological units in the Akillik Plain Subsection:
AKP1 Akillik Bluffs - 8 km^2
AKP2 Akillik Tundra Flats - 191 km^2
AKP3 Akillik Wetlands - 181 km^2
AKP4 Jade Creek Floodplain - 3 km^2
(areas within the park boundaries)

AKP1 Akillik Bluffs

Geology and Physiography: steep slopes of small drainages incised into a high terrace north of the Kobuk River. Generally south-facing. Consists of sand and silt over old glacial till (Hamilton, 1984a).
Elevation: 12 to 74 m (39 to 243 ft)
Soils: on most steep slopes probably mostly rather dry, loamy soils with an organic surface layer less than 20 cm thick. Permafrost is probably absent on most of the steep slopes. On gentle footslopes and hill crests, soils are wetter, probably have permafrost, and the surface organic horizon is thicker.
Vegetation/land cover: mostly closed alder and willow shrubs. In small areas that have escaped recent fires, white spruce forest with alder understory.
Notes: this is the tallest bluff along the Kobuk River in the study area. According to geologic maps (Hamilton, 1984a) there is no bedrock exposed.

AKP2 Akillik Tundra Flats

Geology and Physiography: gently sloping plain, weakly dissected by small streams, probably composed of loess and possibly eolian fine sand.
Elevation: 15 to 175 m (49 to 574 ft)

Soils: probably mostly wet soils with permafrost and a rather thick (about 1 m) active layer and rather thin (about 10 to 20 cm) organic surface layer. Mudboils (unsorted circles) are probably common. Depressions probably have wetter soils with thicker organic mat and permafrost at about 0.5 m.

Vegetation/land cover: mostly tussock or low shrub tundra. Light colors on aerial photographs suggest significant lichen cover. On better drained and protected sites, spruce woodland or closed low shrubs, depending in the fire history. Closed low shrubs along drainageways and on steeper or south-facing slopes.

Notes: tundra vegetation is present in this region even though it is south of and altitudinally below treeline. The largely treesless condition is maintained here by a combination of high winds, wet soils, and fires. There are probably small patches of trees thoughout, and trees could rapidly colonize this unit if conditions became more favorable. The composition of the sediments in this region is poorly known; there appears to be sufficient silt to produce fairly cold and wet soils. For a general discussion of mudboils (probably common here) see Shilts (1978), and Zoltai and Tarnocai (1981).

AKP3 Akillik Wetlands

Geology and Physiography: gently sloping plain with numerous wetlands, small thermokarst ponds, and several larger thermokarst lakes. Sediments are probably loess and perhaps eolian find sand, with alluvium at depth.

Elevation: 11 to 132 m (36 to 433 ft)

Soils: mostly wet organic soils (> 40 cm of organic material) with permafrost at about 0.5 m depth. Some depressions probably have very wet organic soils without permafrost, while some higher areas probably have a thinner (20-40 cm) organic surface layer. Ice-wedge polygons are likely to be present.

Vegetation/land cover: mostly cottonsedge tussock wetland or low shrubs and cottonsedge, with wet sedge in depressions. The closed needleleaf forest on the landcover map is doubtful; most is probably mixed wet sedge and water.

Notes: wetland types visible on aerial photographs include net fens, northern ribbed fens and peat plateau bogs. For a general discussion of these wetland types, see Canada Committee on Ecological Land Classification (1988). There appears to be less groundwater discharge here than in the Ahnewetut Wetlands. Permafrost appears to be nearly continuous and water movement is lateral over frozen soil into depressions and seepage hollows.

AKP4 Jade Creek Floodplain

Geology and Physiography: floodplain of a small stream, meandering in its lower part and braided or straight in its upper part.

Elevation: 14 to 48 m (46 to 157 ft)

Soils: in lower part, probably a mixture of fine sand and silt, with permafrost probably present in less frequently flooded areas; an organic surface layer is probably present but generally <20 cm thick. In the upper part, silt, sand, and gravel are probably all present in soils.

Vegetation/land cover: mostly closed deciduous shrub, with an overstory of spruce trees in part.

Notes: Jade creek merges upstream with a system of alluvial fans originating in the Jade Mountains.

ATM Anaktok Mountains Subsection

The Anaktok Mountains Subsection. These rugged mountains are composed of marble and have little vegetation, except for shrubs on more stable sites. July 10, 2001; roll 3, frame 35.

Detailed ecological units in the Anaktok Mountains Subsection:
ATM1 Anaktok Mountains - 84 km^2
(area within the park boundaries)

ATM1 Anaktok Mountains

Geology and Physiography: steep mountains with sharp ridge crests, widespread bedrock exposures, and talus slopes. Composed mostly of Paleozoic marble.

Elevation: 351 to 982 m (1152 to 3222 ft)

Soils: mostly dry, rocky soils with a thick active layer (> 1 m) and little or no surface organic layer. On some lower slopes soils probably have a loamy matrix with numerous rocks, a surface organic layer <20 cm thick, and active layers are probably thinner but still usually over 1 m. Sorted circles and nets are probably common on stable sites.

Vegetation/land cover: most slopes and ridge crests are barren or have sparse vegetation of dwarf shrubs and lichens. Lower slope positions have open or closed low or dwarf shrubs

Notes:

AYM Angayukaqsraq Mountains Subsection

The Angayukaksraq Mountains Subsection. These rugged mountains are composed of non-carbonate metamorphic rocks and are mostly exposed rock, talus, and scree. July 10, 2001; roll 3, frame 18.

Detailed ecological units in the Angayukaksraq Mountains Subsection:
AYM1 Angayukaqsraq Mountains - 170 km^2
(area within the park boundaries)

AYM1 Angayukaqsraq Mountains

Geology and Physiography: rugged mountains with sharp ridge crests and steep slopes with talus. Gentler and not as high in the southern part, and in the far north. Bedrock is mostly Proterozoic metamorphosed sedimentary and volcanic rocks (amphibolite, quartzite, and schist).

Elevation: 279 to 1417 m (915 to 4649 ft)

Soils: mostly bedrock outcrops or dry, rocky soils composed of talus and scree with a thick (> 1m) active layer and little or no organic surface layer. On lower slopes in the wider valleys, soils are probably rocky with a loamy matrix, rather dry but permafrost present (active layer perhaps about 1 m), and an organic surface horizon present but generally <30 cm thick. Sorted circles and nets are probably common on stable sites.

Vegetation/land cover: mostly bare rock and talus or scree on mountain slopes and crests. Some sparse vegetation of herbs and dwarf shrubs on upper slopes. On lower slopes, mostly open or closed low shrubs, with some tussock tundra and dry herbaceous vegetation.

Notes: the spruce forest mapped on north-facing slopes in this unit is probably not present.

JDM Jade Mountains Subsection

The Jade Mountains Subsection. These rugged mountains are composed of limestone and dolostone. Upper parts are sparsely vegetated talus and scree, while the lowest footslopes and valleys have spruce forest. July 10, 2001; roll 2 frame 31.

Detailed ecological units in the Jade Mountains Subsection:
JDM1 Jade Mountains - 26 km^2
(area within the park boundaries)

JDM1 Jade Mountains

Geology and Physiography: rugged mountains, glaciated during the Pleistocene, with much exposed bedrock and talus. Composed mostly of Mesozoic and Paleozoic mafic volcanic rocks; also some Paleozoic limestone and dolostone.

Elevation: 133 to 871 m (436 to 2858 ft)

Soils: bedrock outcrops and talus without soils cover most of the high ridges. Soils are present on lower slopes and probably consist of mostly of rocks with a loamy matrix, have surface organic layer up to about 20 cm thick, are fairly dry, and have a thick active layer (> 1 m). Sorted circles and nets are probably present on stable sites.

Vegetation/land cover: high ridges are barren or sparsely vegetated. Dry soils on lower slopes have dry herbaceous or dwarf shrub vegetation. Some concave low slope have low or tall shrubs, in some places with a spruce overstory.

Notes:

KLH Kallarichuk Hills Subsection

The Kallarichuk Hills Subsection. These mountains are composed of schist and are mostly rounded except in the highest parts. High ridges are unvegetated rock rubble, while the lowest slopes and valleys have spruce forest. July 10, 2001; roll 2, frame 11.

Detailed ecological units in the Kallarichuk Hills Subsection:
KLH1 Kallarichuk Hills - 334 km^2
(area within the park boundaries)

KLH1 Kallarichuk Hills

Geology and Physiography: low mountains with rounded ridge crests in the lower southern and peripheral parts, and sharp ridge crests with cirques in the highest central and northern region. Composed mostly of schist.

Elevation: 58 to 985 m (190 to 3232 ft)

Soils: bedrock outcrops and rubble on ridge crests. Steep, brushy slopes probably have rather dry, rocky soils with a loamy matrix, organic layer < 20 cm thick, and permafrost absent or below 1 m. Some gentler lower slopes probably have wetter, loamy soil with rocks, an organic surface layer 10-30 cm thick, and permafrost at a depth of 0.5 to 1 m. Sorted circles and nets are probably present on stable sites such as rounded ridge crests.

Vegetation/land cover: ridge crests and upper slopes are barren or sparsely vegetated with dwarf shrubs and lichens. Lower slopes have open or closed low shrubs or, at lower elevations, open spruce forest with shrub understory.

Notes: this unit is quite similar to the Akiak Mountains and Foothills, although more area is forested here. Separation of the Akiak Mountains, Akiak Foothills, Tukpahlearik Mountains, and Kallarichuk Hills Subsections is tenative, based on minor differences in geology and ruggedness. Users may want to combine them for some purposes.

KPP Kitlik Pediments and Plains Subsection

The Kitlik Pediments and Plains Subsection. Open black spruce forest and woodland cover these plains and very gentle hills. July 10, 2001; roll 2, frame 20.

Detailed ecological units in the Kitlik Pediments and Plains Subsection:
KPP1 Kallarichuk River Floodplain - 17 km^2
KPP2 Kitlik Pediment - 157 km^2
KPP3 Tutuksuk Plain - 261 km^2
(areas within the park boundaries)

KPP1 Kallarichuk River Floodplain

Geology and Physiography: floodplain of small meandering river.
Elevation: 11 to 118 m (36 to 387 ft)
Soils: Probably mostly loamy soils over sand and gravel, well drained and lacking permafrost in areas with early successional vegetation. In spruce forests drainage is probably poorer and permafrost present. Surface organic horizons probably mostly 0 to 20 cm thick, thickest in the older spruce forests.
Vegetation/land cover: mostly alder brush or white spruce forest with alder understory. Some less flooded areas probably have black spruce forest. Also sparsely vegetated sand and gravel bars.
Notes:

KPP2 Kitlik Pediment

Geology and Physiography: hills composed of conglomerate, melange, and phyllite, probably mantled by loess, colluvium, and old glacial till.
Elevation: 10 to 251 m (33 to 823 ft)
Soils: on convex hilltops, well-drained loamy soils with rocks, with a thin (< 20 cm) organic surface layer, and permafrost deep (> 1 m) or absent. Slopes probably have loamy soils with fewer rocks, with wetness and permafrost status dependent on the successional state of the vegetation. In burns soils probably have a thin (< 20 cm) organicd surface layer and permafrost is deep (> 1 m). Planar or concave slopes with late-successional vegetation

should have wetter soils, with a surface organic layer 10 to 30 cm thick and permafrost within 1.5 m of the surface.

Vegetation/land cover: spruce woodland with low shrub and lichen or tall shrub understory; or deciduous brush post-fire regeneration.

Notes: for a discussion of soils and fire-soil relationships on this kind of landscape, see Swanson (1996a, b).

KPP3 Tutuksuk Plain

Geology and Physiography: gently undulating plain, probably composed of old alluvial sediments or glacial till, covered by loess and possibly eolian sand.

Elevation: 14 to 235 m (46 to 771 ft)

Soils: silty, with other properties highly variable due to fire effects. In areas with mature black spruce forest, mostly wet soils with permafrost and a surface organic layer 10 to 30 cm thick. The thickness of the active layer probably ranges from 1-2 m on hill crests to about 0.5 m on footslopes. Earth hummocks are probably common. In burned areas the permafrost retreats to 2 m or more and soils become drier, except on some lower parts of slopes. Some flat areas have organic soils with permafrost, dotted with thermokarst depressions with very wet organic soils lacking permafrost.

Vegetation/land cover: on areas not recently burned, mostly black spruce woodland or open forest. In burned areas, mostly low shrubs. Drainageways have dense willow shrubs, and the occasional thermokarst depressions have moss and sedges.

Notes: this appears to be an old surface, but the composition of the sediments is unknown. Judging from the shallowness of the thermokarst depressions it appears that the sediments are not mainly ice-rich Pleistocene silt. Drainage is fair over most of the unit due to the gentle slopes, although in some large flat areas it is restricted and peat plateaus (Zoltai and Tarnocai, 1975) have formed. For a general discussion of the effects of fires on black spruce forests such as these, see Viereck (1983).

KRF Kobuk River Floodplain Subsection

The Kobuk River Floodplain Subsection. Migration of this meandering river has produced a pattern of spruce-forested ridges and elongate wet sedge depressions. The Kobuk River is visible in the background. July 10, 2001; roll 1, frame 10.

Detailed ecological units in the Kobuk River Floodplain Subsection:
KRF1 Kobuk River Floodplain - 227 km^2
KRF2 Kobuk River Scalloped Floodplain - 30 km^2
(areas within the park boundaries)

KRF1 Kobuk River Floodplain

Geology and Physiography: nearly level plain composed of sandy and silty alluvium over gravelly alluvium. Numerous long, gentle, curving ridges alternate with long shallow ponds. Includes the Kobuk River proper.

Elevation: 10 to 60 m (33 to 197 ft)

Soils: soils are highly variable as a function of flooding frequency, height of the surface above the river, and vegetation. Sparsely vegetated point bars and islands probably have dry, sandy or gravelly soils without permafrost. In less frequently flooded areas with deciduous trees or shrubs, mixed white spruce and deciduous trees, or large white spruce the soils are still well-drained and lack permafrost, but have a loamy surface layer and a thin organic surface layer. The thickness of the loamy surface layer is unknown but could occupy the entire soil profile. On higher surfaces with less frequent flooding and a thick loamy surface layer, permafrost is present, soils are wetter, and have an organic surface layer.

Vegetation/land cover: the most frequently flooded areas have sparse vegetation of herbs and willows. Flooded areas near the river have closed tall or low shrubs, or poplar forest, or white spruce forest. Higher and less frequently flooded areas have black spruce forest, in some places becoming quite sparse in favor of sedges and low shrubs. Wet herbaceous vegetation or low shrubs occur in depressions. Includes considerable open water – the Kobuk River.

Notes: the most recently deposited alluvium has a distinct pattern of curved narrow ridges separated by wetlands or ponds. With time and the action of thermokarst, the ponds become more amorphous in shape, eventually leading to the “scalloped” floodplain phase (Pewe,

1948, 1975), here treated as a separate unit. For a general discussion of plant succession and soils on interior Alaskan floodplains, see Viereck (1970) and Viereck *et al*. (1993). For information on the Kobuk River floodplain see Swanson (1995). There is a small are of active parabolic sand dunes on the south bank of the Kobuk River just west of the mouth of the Hunt River.

KRF2 Kobuk River Scalloped Floodplain

Geology and Physiography: nearly level plain composed of sandy and silty alluvium over gravelly alluvium. Numerous irregularly shaped ponds, in former channel depression greatly modified by thermokarst.

Elevation: 12 to 50 m (39 to 164 ft)

Soils: wet soils composed of silt and fine sand, with a thick (probably 20-40 cm) organic surface layer and permafrost at about 0.5 m depth.

Vegetation/land cover: mostly cottonsedge tussock wetland, low shrubs and tussocks, or closed shrubs.

Notes: this unit includes the oldest phase of floodplain development, the “scalloped” phase of Pewe (1948, 1975). The name refers to the form of ponds, which as a result of thermokarst have lost their originally long, gently curving shape.

KSD Kobuk Sand Dunes Subsection

The Kobuk Sand Dunes Subsection. (Upper photo) The Great Kobuk Sand Dunes are a large active dune field with ridges up to 50 m high spaced 200 to 300 m apart. The main dune-forming winds blow from right (east) to left (west). July 10, 2001; roll 1, frame 18.

(Lower photo) This view of the Little Kobuk Sand Dunes shows both active dunes (background) and stabilized dunes vegetated with spruce open forest and woodland (foreground). July 10, 2001; roll 1, frame 4.

Detailed ecological units in the Kobuk Sand Dunes Subsection:
KSD1 Great Kobuk Sand Dunes - 61 km^2
KSD2 Kobuk Dune Creeks - 8 km^2
KSD3 Kobuk Partly Stabilized Dunes - 28 km^2
KSD4 Kobuk Sand Sheets - 30 km^2
KSD5 Little Kobuk Sand Dunes - 8 km^2
KSD6 Little Kobuk Sand Dunes - 88 km^2
(areas within the park boundaries)

KSD1 Great Kobuk Sand Dunes

Geology and Physiography: active sand dunes. Dune forms are mostly transverse, with some parabolic near the eastern margins.
Elevation: 29 to 149 m (95 to 489 ft)
Soils: fine sandy soils, dry, with no horizon development in most areas, and lacking permafrost.
Vegetation/land cover: mostly unvegetated sand. Some sparse vegetation of herbs and shrubs.
Notes: these dunes are formed by dominantly east-southeasterly winter winds. For general information on dunes, see McKee (1979). For specifics on the Kobuk Sand Dunes, see Fernald (1964), Kuhry-Helmens *et al*. (1985), Hamilton *et al*. (1988), and Dijkmans and Koster (1990).

KSD2 Kobuk Dune Creeks

Geology and Physiography: valleys of creeks that flow through regions of stable or active sand dunes. Valleys are incised into the dunes and have rather broad, gently sloping bottoms that are not entirely occupied by the stream. Channel form is meandering or straight.
Elevation: 18 to 95 m (59 to 312 ft)
Soils: fine sandy soils, with unknown wetness and permafrost conditons. Possibly soils with permafrost but a rather thick active layer (1 m) and thin surface organic layer (10-20 cm).
Vegetation/land cover: mostly open or closed spruce forest. Some closed low shrub, especially near the creeks. Lacks unvegetated sandbars.
Notes: these creeks have small catchments and are probably fed mostly by groundwater that infiltrated in the dunes. Thus flow is relatively constant and unvegetated point bars are absent. Valleys were eroded by the stream but are probably filled by a mix of alluvium and sand brought in by wind or washed off the valley sides.

KSD3 Kobuk Partly Stabilized Dunes

Geology and Physiography: sand dunes, mostly vegetated, with small unvegetated active areas. Dune ridges are visible, and most dunes have parabolic form.
Elevation: 17 to 96 m (56 to 315 ft)
Soils: fine sandy soils, dry, with little horizon development in most areas, and mostly lacking permafrost except in some depressions.
Vegetation/land cover: mostly woodland of small spruce, birch, and/or aspen, with low shrubs and lichens. Some sparse vegetation of herbs and shrubs and patches of unvegetated sand.
Notes: these dunes are formed by dominantly east-southeasterly winter winds. The stabilized dunes occur mostly east of the active dunes. For general information on dunes, see McKee (1979). For specifics on the Kobuk Sand Dunes, see Fernald (1964), Kuhry-Helmens *et al*. (1985), Hamilton *et al*. (1988), and Dijkmans and Koster (1990).

KSD4 Kobuk Sand Sheets

Geology and Physiography: nearly level plain, locally dissected by small streams. Composed of fine, wind-deposited sand, possibly with loess layers. Dune ridges are indistinct or absent, and there are bare places with active sand transport.
Elevation: 14 to 101 m (46 to 331 ft)
Soils: fine sandy soils, rather dry, with a thin (probably < 10 cm) organic surface layer in most areas. Permafrost distribution is uncertain; soils probably lack permafrost in the sandiest areas and on higher places, and have permafrost in the gentle depressions.

Vegetation/land cover: mostly woodland of small spruce, birch, and/or aspen, with low shrubs and lichens. In burned areas, mostly low shrubs, with few lichens. Closed spruce forest near the Kobuk River west of Epiguruk Bluff.

Notes: for information sand sheets in Alaska, see Lea and Waythomas (1990). For information on the Kobuk Sand Dunes, see Fernald (1964), Kuhry-Helmens *et al*. (1985), Hamilton et al. (1988), and Dijkmans and Koster (1990).

KSD5 Little Kobuk Sand Dunes

Geology and Physiography: active sand dunes. Dune forms are transverse in the central portion and parabolic near the margins.

Elevation: 40 to 96 m (131 to 315 ft)

Soils: fine sandy soils, dry, with no horizon development in most areas, and lacking permafrost.

Vegetation/land cover: mostly unvegetated sand. Some sparse vegetation of herbs and shrubs.

Notes: these dunes are formed by dominantly east-southeasterly winter winds. For general information on dunes, see McKee (1979). For specifics on the Kobuk Sand Dunes, see Fernald (1964), Kuhry-Helmens *et al*. (1985), Hamilton *et al*. (1988), and Dijkmans and Koster (1990).

KSD6 Old Kobuk Sand Plain

Geology and Physiography: undulating plain, dissected by small streams. Lakes are common, expecially in the northeastern part; they may occupy former interdune depressions that have been modified by erosion and thermokarst. Composed of fine, wind-deposited sand, probably with some loess on the surface and possibly with loess layers. Dune ridges are mostly absent.

Elevation: 13 to 61 m (43 to 200 ft)

Soils: fine sandy soils, rather dry, with a thin (probably < 10 cm) organic surface layer in most areas. Permafrost distribution is uncertain; soils probably lack permafrost in the sandiest areas and on higher places, and have permafrost in the gentle depressions.

Vegetation/land cover: mostly woodland of small spruce, birch, and/or aspen, with low shrubs and lichens. In burned areas, mostly low shrubs, with few lichens. Bottoms of drainages have wet sedges and low shrubs.

Notes: this area was probably occupied by the Great Kobuk Sand Dunes in the past, but they long ago migrated further west, leaving sand deposits but dune morphology is modified beyond recognition. The water table not very far below the surface here, as shown by wetlands in bottoms of drainageways and the lakes. As the ground surface slopes down to the east, and the water table becomes nearer to the surface; eventually it is at the surface nearly everywhere in the adjacent Ahnewetut Wetlands Subsection.

KYM Kunyanak Mountains Subsection

The Kunyanak Mountains Subsection. These fairly rugged mountains are composed of limestone. Gentle slopes are covered by tussock or dwarf shrubs tundra, with rock rubble on steeper and higher slopes. July 10, 2001; roll 3, frame 23.

Detailed ecological units in the Kunyanak Mountains Subsection:
KYM1 Kunyanak High Ridges - 13 km^2
KYM2 Kunyanak Mountains - 108 km^2
KYM3 Tuktuksuk Ridge - 52 km^2
(areas within the park boundaries)

KYM1 Kunyanak High Ridges

Geology and Physiography: mountains composed of Paleozoic carbonate rocks (limestone and dolostone). Ridge crests generally rounded except in the western part.
Elevation: 467 to 1109 m (1532 to 3638 ft)
Soils: mostly dry, rocky soils with a thick (> 1 m) active layer and no organic surface layer. Bedrock outcrops are common. Moister soils, still very rocky but with a loamy matrix, and a thinner active layer (perhaps about 1 m) occur in the bottoms of some valleys. Sorted circles and nets are probably common on stable sites.
Vegetation/land cover: mostly barren rock or talus and scree with some sparse vegetation of dwarf shrubs. Open low shrub or tussock tundra in a few valleys on moister soils.
Notes:

KYM2 Kunyanak Mountains

Geology and Physiography: hills composed mostly of Paleozoic carbonate rocks (limestone and dolostone). Some ridge crests are rounded and some angular but not very high.
Elevation: 356 to 987 m (1168 to 3238 ft)
Soils: on convex hill slopes and crests soils are dry and rocky with a thick (> 1 m) active layer and no organic surface layer. Bedrock outcrops are common. On concave lower slopes soils are moister, probably rocky but with a loamy matrix, and have a thinner active layer (perhaps about 1 m). Sorted circles and nets, and mudboils are probably present.

Vegetation/land cover: convex hill slopes and crests are mostly barren rock or talus and scree, with some sparse vegtation of dwarf shrubs and lichens. Open low shrub or tussock tundra or moist to dry herbaceous vegetation on concave lower slopes. Some denser shrubs along drainages.
Notes:

KYM3 Tuktuksuk Ridge

Geology and Physiography: low mountains composed mostly of Paleozoic carbonate rocks (limestone and dolostone). Ridge crests are mostly angular.
Elevation: 242 to 988 m (794 to 3241 ft)
Soils: on convex hill slopes and crests soils are dry and rocky with a thick (> 1 m) active layer and no organic surface layer. Bedrock outcrops are common. On concave lower slopes soils are moister, probably rocky but with a loamy matrix, and have a thinner active layer (perhaps about 1 m). Sorted circles and nets, and mudboils are probably present.
Vegetation/land cover: convex hill slopes and crests are mostly barren rock or talus and scree, with some sparse vegtation of dwarf shrubs and lichens. Lower on slopes are open or closed low shrub, with white spruce woodland or open forest on some south-facing slopes.
Notes: most of this subsection is treeless, with the last few trees occurring on the lower part of Tuktuksuk Ridge.

NIP Nigeruk Plain Subsection

The Nigeruk Plain Subsection. This nearly level region has open black spruce forest or woodland where unburned as pictured here. Small thermokarst lakes such as the one in the foreground are present throughout, and they are quite abundant in some parts. July 10, 2001; roll 1, frame 36.

Detailed ecological units in the Nigeruk Plain Subsection:
NIP1 Nigeruk Plain - 561 km^2
NIP2 Nigeruk Plain Creeks - 13 km^2
NIP3 Nigeruk Plain, Lake-Rich - 99 km^2
(areas within the park boundaries)

NIP1 Nigeruk Plain

Geology and Physiography: undulating plain, probably composed of loess or loess and fine eolian sand, perhaps over sandy and silty alluvium at depth. Dissected by a dense network of small streams. Includes some thermokarst lakes.

Elevation: 11 to 228 m (36 to 748 ft)

Soils: silty, with other properties highly variable due to fire effects and position on the slope. In higher areas with mature black spruce forest, mostly moist soils with permafrost and a surface organic layer perhaps 10 to 20 cm thick. On lower slope positions the organic surface layer is probably 20 to 40 cm thick and the soils wetter. The thickness of the active layer probably ranges from 1-2 m on hill crests to about 0.5 m on footslopes. In burned areas the permafrost retreats to 2 m or more and soils become drier on higher slope positions. Earth hummocks are probably present.

Vegetation/land cover: mostly black spruce woodland or open forest, with low shrubs and mixed moss-lichen ground cover. More deciduous shrubs and few lichens in burned areas.

Notes: this appears to be an old surface that has been accumulating loess and ground ice for a long time. The composition of the sediments is unknown, but judging from the thermokarst, it appears to have significant silt content, and it may be very ice-rich like those discussed in Czudek and Demek (1970). Drainage is fairly good over most of the unit due to the gentle slopes, although in some flatter areas it is restricted and peat plateaus (Zoltai and Tarnocai, 1975) have formed. For a general discussion of the effects of fires on black spruce forests such as these, see Viereck (1983).

NIP2 Nigeruk Plain Creeks

Geology and Physiography: floodplains of creeks incised into the Nigeruk Plain. Channel forms are meandering.

Elevation: 13 to 57 m (43 to 187 ft)

Soils: probably stratified fine sand and silt, with variable wetness and permafrost conditions. The most prevalent is probably moist soils with permafrost but rather thick active layer (about 1 m) and thin surface organic layer (10-20 cm).

Vegetation/land cover: mostly needleleaf open forest or woodland, with dense understory of alder and willow shrubs, or closed alder/willow shrub.

Notes:

NIP3 Nigeruk Plain, Lake-Rich

Geology and Physiography: undulating plain, probably composed of loess or loess and fine eolian sand, perhaps over sandy and silty alluvium at depth. Includes numerous small thermokarst lakes.

Elevation: 15 to 117 m (49 to 384 ft)

Soils: silty, with other properties highly variable due to fire effects and position on the slope. In higher areas with mature black spruce forest, mostly wet soils with permafrost and a surface organic layer 10 to 30 cm thick. On lower slope positions the organic surface layer is probably 20 to 40 cm thick and the soils wetter. The thickness of the active layer probably ranges from 1-2 m on hill crests to about 0.5 m on footslopes. In burned areas the permafrost retreats to 2 m or more and soils become drier on higher slope positions. Earth hummocks are probably common. More level or depressional areas have organic soils with permafrost, dotted with thermokarst depressions with very wet organic soils lacking permafrost.

Vegetation/land cover: mostly black spruce woodland, with low shrubs and mixed moss-lichen ground cover. Fewer lichens and more deciduous shrubs in burned areas. Wet sedges and mosses in some thermokarst depressions.

Notes: this appears to be an old surface that has been accumulating loess and ground ice for a long time. The composition of the sediments is unknown, but judging from the thermokarst and general wetness of the landscape, it appears to have significant silt content. Sediments may be very ice-rich, like those discussed in Czudek and Demek (1970). Drainage is fair over most of the unit due to the gentle slopes, although in some flatter areas it is restricted and peat plateaus (Zoltai and Tarnocai, 1975) have formed. For a general discussion of the effects of fires on black spruce forests such as these, see Viereck (1983).

NTH Natmotirak Foothills Subsection

The Natmotirak Foothills Subsection. These hills are covered with low shrub and tussock tundra, with a few exposures of schist bedrock on hilltops. This subsection is mostly north of the Kobuk-Noatak divide. July 10, 2001; roll 3, frame 8.

Detailed ecological units in the Natmotirak Foothills Subsection:
NTH Natmotirak Foothills - 30 km^2
(area within the park boundaries)

NTH Natmotirak Foothills

Geology and Physiography: rounded hills with slope deposits over bedrock composed mostly of schist. Bedrock exposures occur on some ridge crests.

Elevation: 338 to 655 m (1109 to 1532 ft)

Soils: probably rocky soils with a loamy matrix, with permafrost present and an active layer of about 1 m. A surface organic layer is probably present in most areas but < 20 cm thick. Mudboils are probably common.

Vegetation/land cover: mostly open low shrub and tussock tundra, with some closed shrubs along drainages and open dwarf shrubs and rock exposures on ridgetops.

Notes: this Subsection occurs mostly in Noatak National Preserve. The part in the study area straddles the drainage divide between the Noatak and Kobuk Rivers. Its gentle topography and arctic tundra vegetation make is most like the Noatak Valley landscapes to the north.

NTM Natmotirak Mountains Subsection

The Natmotirak Mountains Subsection. These mountains occur near or just north of the Kobuk-Noatak divide and are composed of schist. High ridges have rock rubble or sparse vegetation, while gentler slopes have mostly dwarf or low shrubs. July 10, 2001; roll 3, frame 6.

Detailed ecological units in the Natmotirak Mountains Subsection:
NTM Natmotirak Mountains - 45 km^2
(area within the park boundaries)

NTM Natmotirak Mountains

Geology and Physiography: mountains generally north of the highest ridge between the Kobuk and Noatak drainages. Mostly rounded ridge crests, except for the highest ridges along the drainage divide. Composed of quartz-mica schist.

Elevation: 318 to 1229 m (1043 to 4032 ft)

Soils: probably mostly dry rocky soils with a loamy matrix and a deep active layer (> 1 m). An organic surface is thin or absent on dry ridge crests and up to 20 cm thick on shrubby lower slopes. Sorted circles and nets are probably common on stable sites.

Vegetation/land cover: ridges are sparsely vegetated or have open low or dwarf shrubs, with some closed low shrubs on lower slopes. The gentlest lower slopes have tussock tundra. The wet herbaceous vegetation shown on the land cover map is doubtful.

Notes: this unit is north of the highest ridges and north of tree line. It occurs mostly in the Noatak National Preserve.

SHF Salmon-Hunt Terraces and Floodplains Subsection

The Salmon-Hunt Terraces and Floodplains Subsection. (Upper photo) The Hunt River is one of several meandering streams that cross this subsection. Alder and willow cover much of this photo, with spruce on some higher surfaces. July 10, 2001; roll 2, frame 28. (Lower photo)

Much of this subsection is covered by a wet terrace with sedges, moss and low shrubs in low areas (light colored) and spruce on higher areas (dark colored). July 10, 2001; roll 2, frame 17.

Detailed ecological units in the Salmon-Hunt Terraces and Floodplains Subsection:
SHF1 Akiak Piedmont Dry Terraces - 18 km^2
SHF2 Hunt-Akillik Floodplain - 75 km^2
SHF3 Kaligurichеark River Floodplain - 25 km^2
SHF4 Salmon-Kitlik River Floodplain - 51 km^2
SHF5 Tutuksuk River Floodplain - 39 km^2
SHF6 Tutuksuk-Salmon Wet Terrace - 144 km^2
(areas within the park boundaries)

SHF1 Akiak Piedmont Dry Terraces

Geology and Physiography: nearly level plain composed of sand and gravel. A mantle of find sand and silt is present but generally quite thin (probably < 25 cm) except locally in some elongate zones following former stream courses.

Elevation: 28 to 121 m (92 to 397 ft)

Soils: mostly dry gravelly soils with a thin (probably < 25 cm) loamy surface layer and thin (probably < 15 cm) organic surface horizon. Soils locally moister and possibly with permafrost in belts with thicker loamy surface layer.

Vegetation/land cover: mostly open spruce forest or spruce woodland, with low shrubs, lichens, and mosses. Locally denser trees and shrubs in areas with moister soils.

Notes: lichen woodlands on dry terrace soils are more widespread in Canada than Alaska and have been studied extensively there (Moore, 1980; Rowe, 1984).

SHF2 Hunt-Akillik Floodplain

Geology and Physiography: floodplain of meandering rivers.

Elevation: 12 to 134 m (39 to 440 ft)

Soils: Soils are highly variable depending on the age of the surface and the vegetation. Most probably consist of a loamy layer over sand and gravel, with the loamy layer thickest on higher and older surfaces. Permafrost is probably absent from sparsely vegetated gravel bars and most deciduous shrub and forest areas. Mature stands of white and black spruce probably have permafrost, with a thicker surface organic layer and thinner active layer in the latter. Soils probably become moister and finer grained in the lower part of this floodplain, near and below the confluence of the Akillik and Hunt Rivers.

Vegetation/land cover: dominantly closed shrubs and spruce forest ranging from woodland to closed. Frequently flooded sand and gravel bars are sparsely vegetated. Deciduous shrubs (willows and alders) and balsam poplar forest tend to occur near the river channel, with white and black spruce forests occurring on higher surfaces that are often further from the river. Some wet herbaceous and emergent vegetation probvably occurs in oxbow lakes in the lower part of this floodplain, near and below the confluence of the Akillik and Hunt Rivers.

Notes: soils and vegetation of this floodplain probably generally resemble those of the Chena River (Viereck, 1970).

SHF3 Kaligurichеark River Floodplain

Geology and Physiography: floodplain of small meandering river, slightly incised into a broad plain.

Elevation: 13 to 114 m (43 to 374 ft)

Soils: Probably mostly loamy soils over sand and gravel. Soils with early successional vegetation are well drained and lack permafrost. In spruce forests drainage is probably poorer and permafrost present. Surface organic horizons are probably mostly 0 to 20 cm thick, thickest in the older spruce forests..

Vegetation/land cover: mostly willow and alder brush or white spruce forest with alder understory. Some less flooded areas probably have black spruce forest. Also sparsely vegetated sand and gravel bars.

Notes:

SHF4 Salmon-Kitlik River Floodplain

Geology and Physiography: floodplain of small meandering rivers. Alluvium is probably coarse-grained with a silty surface layer.

Elevation: 11 to 113 m (36 to 384 ft)

Soils: loamy surface layer of varying thickness over sand and gravel. The loamy layer is probably generally thinnest on younger point bars and in the upper (northern) half of the floodplain. In mature spruce forests with a thick loamy cap, there is probably an organic surface horizon 10-20 cm thick, permafrost is probably present (active layer 0.5 to 1.5 m), and soils are rather wet. Elsewhere soils are probably dry, lack permafrost, and have a thin (< 10 cm) surface organic layer.

Vegetation/land cover: frequently flooded gravel bars are sparsely vegetated. Near-channel areas have willow or alder brush, or balsam poplar forest. Less flooded areas have mostly white spruce forest with alder understory, with some areas of black spruce forest.

Notes: soils and vegetation of this floodplain probably resemble that of the Chena River (Viereck, 1970).

SHF5 Tutuksuk River Floodplain

Geology and Physiography: floodplain of a small river. Meandering in the lower half. Upper half combines meandering, braided, and straight channel forms. Alluvium coarse-grained in upper half, probably with a silty surface layer in lower half.

Elevation: 12 to 159 m (39 to 522 ft)

Soils: loamy surface layer of varying thickness over sand and gravel. The loamy layer is probably generally thinnest on younger point bars and in the upper (northern) half of the floodplain. In mature spruce forests with a thick loamy cap, permafrost is probably present and soils rather wet. Elsewhere soils are probably dry and lack permafrost. In the southermost several kilometers near the Kobuk River, soils appear to be wet even near the river channel.

Vegetation/land cover: frequently flooded gravel bars are sparsely vegetated. Near-channel areas have willow or alder brush, or balsam poplar forest. Less flooded areas have mostly white spruce forest with alder understory, with some areas of black spruce forest. The southernmost several kilometers are dense deciduous brush (alder and willow).

Notes: soils and vegetation of the lower part of this floodplain probably resemble that of the Chena River (Viereck, 1970). In the southernmost part, the regional water table is probably near the surface.

SHF6 Tutuksuk-Salmon Wet Terrace

Geology and Physiography: nearly level plain composed of alluvium, with loess or peat mantle in some parts. The central and southeastern portions have numerous channel scars and are probably Holocene in age with little loess. Marginal areas on the western, northern, and eastern sides are older sediments with more peat and loess cover. Alluvium is probably sandy and gravelly at depth but with a loamy surface layer that could be more than 1 m thick in places.

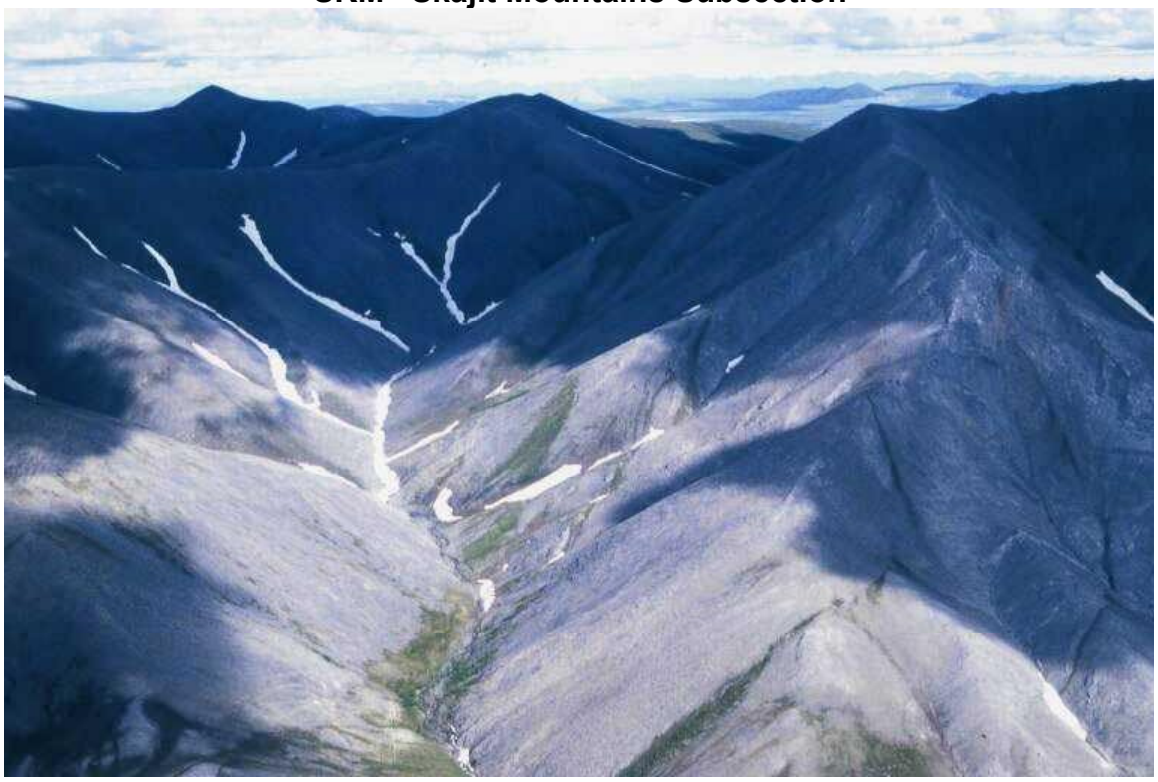
Elevation: 11 to 113 m (36 to 371 ft)

Soils: in the central and southeastern parts, higher areas probably have wet soils with permafrost but a relatively thin (< 30 cm) organic surface layer). Depressions in this area probably have organic soils, both with and without permafrost. In the marginal areas on the western, northern, and eastern sides, mostly frozen organic soils, with permafrost-free organic soils in thermokarst depressions.

Vegetation/land cover: open black spruce forest or woodland, with low shrubs, moss, and lichen understory; and depressions with shrubs or wet herbaceous vegetation. Dwarf shrub post-fire regeneration in the burn in the far northeast.

Notes: central portion appears to be a terrace with regional groundwater table near the surface. Depressions in this region follow former river channels and may lack permafrost due to the warming effect of the groundwater; the higher areas here probably have permafrost, but do not have a large amount of ground ice. The western, northern, and eastern parts are mostly peat plateaus (for information on these features see Zoltai and Tarnocai, 1975), with numerous small, sedge-moss thermokarst depressions indicating greater age and ground ice content. In the far northeastern part, northeast of the Tuktuksuk River, there is a net fen and the terraces have few thermokarst depressions, probably indicating younger age and less ground ice.

SKM Skajit Mountains Subsection



The Skajit Mountains Subsection. These rugged mountains are largely unvegetated and composed of light-colored limestone (cloud shadows darken the higher ridges here). July 10, 2001; roll 3 frame 2.

Detailed ecological units in the Skajit Mountains Subsection:
SKM Skajit Mountains - 22 km^2
(area within the park boundaries)

SKM Skajit Mountains

Geology and Physiography: rugged mountains with sharp ridge crests and steep slopes of talus and scree. Composed of Paleozoic limestone and dolostone.

Elevation: 239 to 983 m (784 to 3225 ft)

Soils: mostly bedrock outcrops and rubble with little soil. Lower slopes have dry, rocky soils with little or no surface organic layer and a thick active layer (> 1 m). Some sorted circles and nets probably occur on stable sites.

Vegetation/land cover: mostly barren or sparsely vegetated. Some lower slopes have dwarf or low shrubs. The closed needleleaf forest shown on the landcover map is doubtful.

Notes:

SRH Salmon River Hills Subsection

The Salmon River Hills Subsection. These rounded hills with some fairly steep slopes are incised by the Salmon River (meandering in the center background) and its tributaries. Vegetation is mostly dwarf shrub and low shrub tundra, and persistent snowdrifts occur in the less of ridgetops. (The higher mountains in the background are in other subsections). July 10, 2001; roll 3, frame 29.

Detailed ecological units in the Salmon River Hills Subsection:
SRH1 Salmon River Hills - 327 km^2
(area within the park boundaries)

SRH1 Salmon River Hills

Geology and Physiography: fairly steep hills formed by the incision of the Salmon River and its tributaries. Hill crests rounded with bedrock exposures common at the summits. Bedrock is Paleozoic shale, sandstone, conglomerate, and quartz-mica schist.

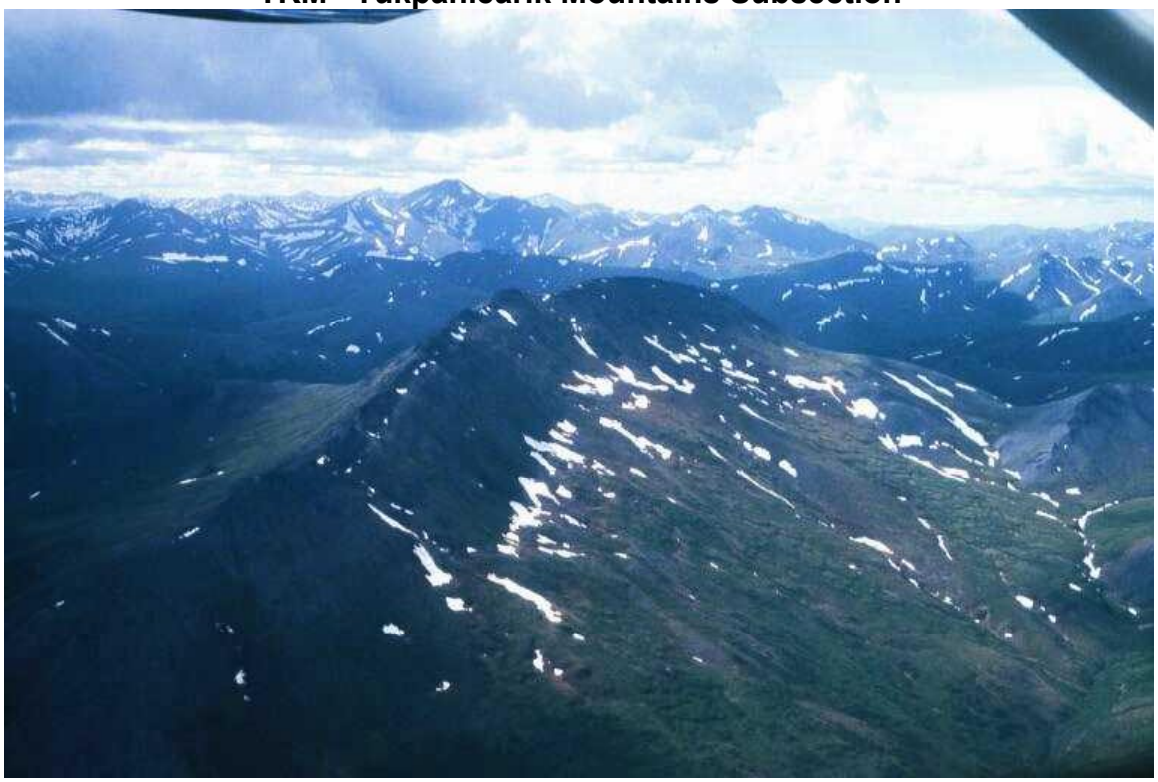
Elevation: 126 to 783 m (413 to 2569 ft)

Soils: probably mostly loamy soils with rocks present, somewhat wet with an active layer of perhaps 1 m and a surface organic layer 10 to 30 cm thick. On ridge crests, dry rocky soils with a thick (> 1 m) active layer and a thin surface organic layer. Sorted circles and nets are probably common on more stable sites such as gentle ridge crests.

Vegetation/land cover: mostly open dwarf and low shrub tundra, with some closed low shrubs on lower slopes and in drainageways. Convex ridge crests have dry herbaceous or sparse vegetation of dwarf shrubs and lichens. Spruce woodland is shown on some north-facing by the land cover map, which seems doubtful. Spruce is present on floodplains and south-facing slopes just to the south of this unit.

Notes: cornice snowbeds are common on this unit. They are oriented mostly east-west just north of ridge crests, i.e. are deposited by south winds.

TKM Tukpahlearik Mountains Subsection



The Tukpahlearik Mountains Subsection. These mountains are composed mostly of schist and have some sharp ridge crests but relatively little talus and scree. Note the solifluction lobes on the mostly vegetated slope on the right. July 10, 2001; roll 3, frame 31.

Detailed ecological units in the Tukpahlearik Mountains Subsection:
TKM1 Tukpahlearik Mountains - 229 km^2
(area within the park boundaries)

TKM1 Tukpahlearik Mountains

Geology and Physiography: low mountains with both rounded and sharp ridge crests, widespread bedrock exposures, but few talus or scree slopes. Composed mostly of Paleozoic schist, with some quartzite and marble.

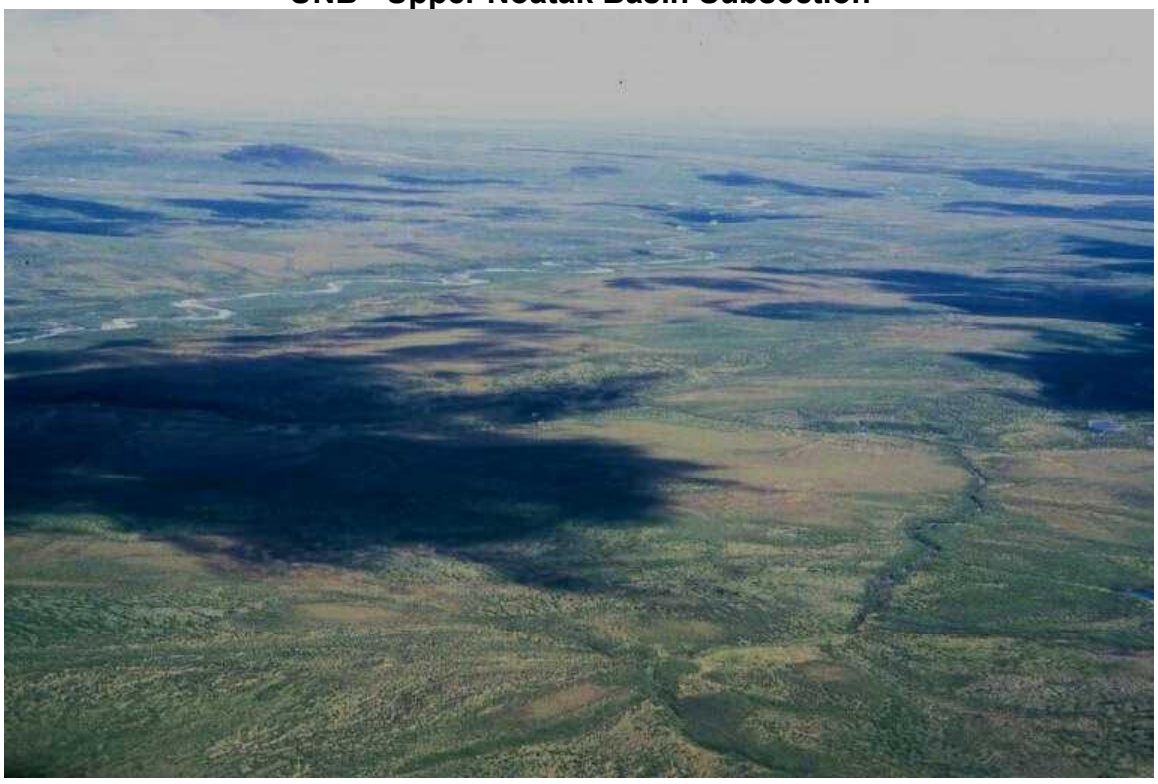
Elevation: 221 to 959 m (725 to 3146 ft)

Soils: on convex ridges mostly dry, rocky soils with a thick active layer (> 1 m) and little or no surface organic layer. On concave lower slopes soils probably have a loamy matrix with rocks, a surface organic layer <20 cm thick, and active layers perhaps about 1 m, locally to 0.5 m. Sorted circles and nets are probably common on stable sites.

Vegetation/land cover: convex ridge crests and shoulders are barren or have sparse vegetation of dwarf shrubs and lichens. Lower slope positions have open or closed low or dwarf shrubs, with tussock tundra on the most gentle slopes. Some valley bottoms, especially in the far south, have open spruce forest or spruce woodland.

Notes: separation of the Akiak Mountains, Akiak Foothills, Tukpahlearik Mountains, and Kallarichuk Hills Subsections is tenative, based on minor differences in geology and ruggedness. Users may want to combine them for some purposes.

UNB Upper Noatak Basin Subsection



The Upper Noatak Basin Subsection. This lowland is an ancient lake plain and occurs mostly in Noatak National Preserve. Vegetation is mostly tussock and low-shrub tundra. July 10, 2001; roll 3, frame 9.

Detailed ecological units in the Upper Noatak Basin Subsection:
UNB Upper Noatak Basin - 2 km^2
(area within the park boundaries)

UNB Noatak Lake Plain

Geology and Physiography: gently sloping topography dissected slightly by modern streams, composed of Pleistocene lacustrine and glaciolacustrine sediment.

Elevation: 364 to 470 m (1194 to 1542 ft)

Soils: mostly wet, silty soils with few stones, a thin (< 1 m) active layer, and an organic surface layer. Mudboils are probably present.

Vegetation/land cover: mostly tussock and open low shrub tundra. Denser shrubs occur along drainages.

Notes: this unit is extensive in Noatak National Preserve but only reaches Kobuk Valley National Park in one small area. These lacustrine deposits have been mapped by Hamilton (1984a,b), but the history of this large former lake has not been studied in detail.

WRM Waring Mountains Subsection

The Waring Mountains Subsection. These rounded mountains are largely forested with spruce where not recently burned. Higher ridge crests have low or dwarf shrubs, lichens, and some exposed rock. July 10, 2001; roll 1, frame 31.

Detailed ecological units in the Waring Mountains Subsection:
WRM1 South Waring Valleys - 2 km^2
WRM2 Waring Hills - 89 km^2
WRM3 Waring Mountains - 249 km^2
(areas within the park boundaries)

WRM1 South Waring Valleys

Geology and Physiography: gently sloping lower slopes and valley bottoms, composed of colluvium, loess, and alluvium.
Elevation: 116 to 178 m (381 to 584 ft)
Soils: mostly loamy wet soils with permafrost, a thin active layer (probably about 0.5 m) and a thick organic surface layer (probably 20 to over 40 cm).
Vegetation/land cover: mostly black spruce woodland. Also tussock and low shrub wetland, and, in thermokarst depressions, wet sedge and moss.
Notes: this unit occur mostly south of the study area. The flattest valley bottoms have peat plateau wetlands (see Zoltai and Tarnocai, 1975)

WRM2 Waring Hills

Geology and Physiography: gently sloping hills composed of Cretaceous conglomerate, sandstone, and mudstone
Elevation: 53 to 266 m (174 to 873 ft)
Soils: probably mostly composed of loess or loess and eolian sand, but coarser-grained material derived from bedrock, loess, and possibly old glacial till is present on hilltops. Soils in the fine-grained sediments vary greatly as a function of post-fire succession; they are generally wet and have permafrost within 1 m of the surface under old (>100 years) vegetation and drier

with permafrost receded to > 1 m in burns. Soils on coarser sediments of hilltops are probably loamy with rocks, dry, and permafrost is below 1 m or absent.

Vegetation/land cover: mostly post-fire successional open low shrubs. Unburned areas are mostly open black spruce forest. Closed low and tall shrubs along drainageways.

Notes: for a discussion of soils and fire-soil relationships on this kind of landscape, see Swanson (1996a, b)

WRM3 Waring Mountains

Geology and Physiography: low, rounded mountains composed of Cretaceous graywacke and mudstone derived from volcanic rocks.

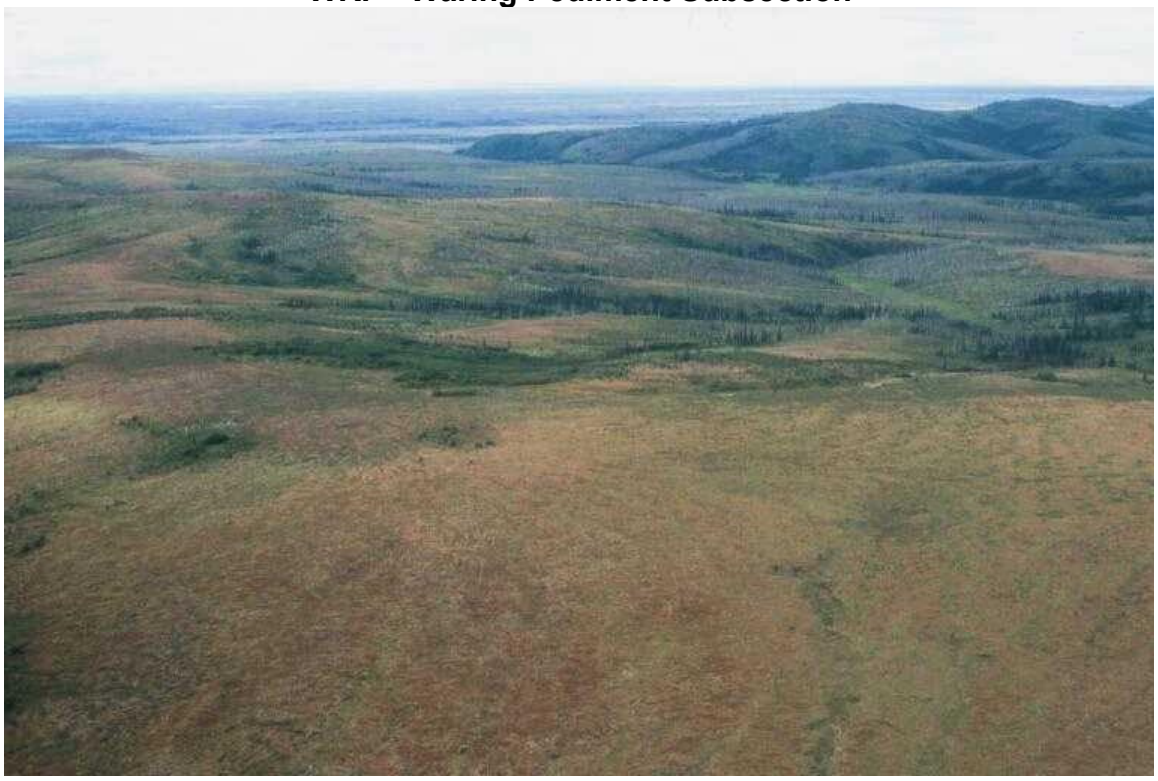
Elevation: 21 to 560 m (69 to 1837 ft)

Soils: ridge crests have dry, rocky soils with permafrost deep or absent and a thin (probably usually < 10 cm) organic surface layer. Slopes probably have loamy soils with rocks, mostly dry and with permafrost absent or below 1.5 m, with an organic surface layer up to 20 cm thick. Permafrost is probably present within 1 m of the surface on some lower slopes and north aspects, and soils here are wetter and have an thicker organic surface layer.

Vegetation/land cover: ridge crests have low shrubs and, where not recently burned, lichens. Slopes are mostly shrub or birch-aspen post-fire regeneration, with open spruce over shrubs where not recently burned.

Notes: normally features of this height are called “hills” not “mountains”, but here mountains is the established name.

WRP Waring Pediment Subsection



The Waring Pediment Subsection. These gentle hills extend south from the Waring Mountains (visible in the right background). This region had spruce woodland with a luxuriant lichen cover until a recent fire; it now has mostly low shrubs and herbs. July 10, 2001; roll 1 frame 25.

Detailed ecological units in the Waring Pediment Subsection:

WRP1 Waring Pediment - 6 km^2
(area within the park boundaries)

WRP1 Waring Pediment

Geology and Physiography: rounded hills consisting of graywacke and mudstone. Slopes dominently convex, and probably are covered in most places with a thin layer of colluvium.

Elevation: 61 to 222 m (200 to 728 ft)

Soils: on ridge crests, probably rocky soils with a loamy with a loamy matrix, thin (<20 cm) organic surface layer, dry, and lacking permafrost. Lower slopes probably have wetter soils with fewer rocks, permafrost at a depth of 0.5 to 1.5 m, and a surface organic layer 10-30 cm thick.

Vegetation/land cover: prior to a recent fire, the ridges had black and white spruce woodland with lichen ground cover. Lower slopes had open or closed shrubs (alder and willow) with spruce overstory.

Notes: this area has burned since production around 1980 of aerial photographs and satellite images used in this report. Previously the ground cover of *Cladina* lichens was so luxuriant on the ridges that the ground appears nearly white on aerial photographs, and numerous caribou trails suggests these lichens were used frequently as forage. Due to the fire this area appears to now be mostly herbaceous vegetation and low shrubs. It will be many decades before a dense lichen mat reforms here (Scotter, 1964; Black and Bliss, 1978; Johnson, 1981; Swanson, 1996c). For a general discussion of pediments in the subarctic, see French and Harry (1992).

References

Bailey, R. G. 1996. Ecosystem geography. Springer-Verlag, New York, 204 pp.

Black, R.A., and Bliss, L.C. 1978. Recovery sequence of *Picea mariana-Vaccinium uliginosum* forests after burning near Inuvik, Northwest Territories, Canada. Canadian Journal of Botany 56:2020-2030.

Canada Committee on Ecological (Biophysical) Land Classification, National Wetlands Working Group. 1988. Wetland of Canada. Polyscience, Montreal, 452 pp.

Carey, K.L. 1973. Icings developed from surface water and ground water. US Army CRREL, Cold Regions Science and Engineering, Monograph III-D3.

Cleland, D.T., Avers, P.E., McNab, W.H., Jensen, M.E., Bailey, R.G., King, T., Russell, W.E. 1997. National hierarchical framework of ecological units. Pp. 181-200 in: Ecosystem management (ed. M. S. Boyce and A. Haney). Yale University, New Haven, CT, 361 pp.

Czudek, T., Demek, J. 1970. Thermokarst in Siberia and its influence on the development of lowland relief. Quaternary Research 1:103-120.

Dijkmans, J.W.A., and Koster, E.A. 1990. Morphological development of dunes in a subarctic environment, central Kobuk Valley, northwestern Alaska. Geografiska Annaler 72A:93-109.

Fernald, A.T. 1964. Surficial geology of the central Kobuk River valley, northwestern Alaska. US Geological Survey Bulletin 1181-K, 29 pp.

French, H.M., Harry, D.G. 1992. Pediments and cold-climate conditons, Barn Mountains, unglaciated northern Yukon, Canada. Geografiska Annaler 74A:145-157.

Hamilton, T.D. 1984a. Surficial geologic map of the Ambler River quadrangle, Alaska. US Geological Survey Miscellaneous Field Studies Map MF-1678, scale 1:250,000.

Hamilton, T.D. 1984b. Surficial geologic map of the Howard River quadrangle, Alaska. US Geological Survey Miscellaneous Field Studies Map MF-1677, scale 1:250,000.

Hamilton, T.D, Galloway, J.P., and Koster, E.A.. 1988. Late Wisconsin eolian activity and related alluviation, central Kobuk River valley. US Geological Survey Circular 1016:39-43.

Hinzman, L.D., Kane, D.L., and Everett, K.R. 1993. Hillslope hydrology in an arctic setting. Permafrost, Sixth International Conference, July 5-9, 1993. South University of Technology Press, Beijing, China, pp. 267-271.

Johnson, E.A. 1981. Vegetation organization and dynamics of lichen woodland communities in the Northwest Territories, Canada. Ecology 62:200-215.

Kane, D.L., Hinzman, L.D., Benson, C.S., and Liston G.E. 1991. Snow hydrology of a headwater arctic basin 1. Physical measurements and process studies. Water Resources Research 27(6):1099-1109.

Karl, S.M., Dumoulin, J.A., Ellercieck, I, Harris, A.G., and Schmidt, J.M. 1989. Preliminary geologic map of the Baird Mountains and part of the Selawik quadrangles, Alaska. US Geological Survey Open File Report 89-551, scale 1:250,000.

Kuhry-Helmens, K.F., Koster, E.A., and Galloway, J.P. 1985. Photo-interpretation map of surficial deposits and landforms of the Kobuk Sand Dunes and part of the Kobuk Lowland, Alaska. US Geological Survey Open File Report 85-242. Scale 1:63,360.

Lea, P.D., Waythomas, C.F. 1990. Late-Pleistocene eolian sand sheets in Alaska. Quaternary Research 34:269-281.

Leslie, L.D. 1989. Alaska climate summaries, 2nd edition. Alaska Climate Center Technical Note No. 5, Arctic Environmental Information and Data Center, Univeristy of Alaska, Anchorage.

Markon, C. J. and S. D. Wesser. 1998. The Northwest Alaskan Parks Land Cover Map. Open File Report. U.S. Geological Survey.

Mayfield, C.F., and Tailleur, I.L. 1978. Bedrock geology of the Ambler River Quadrangle, Alaska. US Geological Survey Open File Map 78-120A, scale 1:250,000.

McKee, E.D (ed.). 1979. A study of global sand seas. US Geological Survey Professional Paper 1052.

Moore, T.R. 1980. The nutrient status of subarctic woodland soils. Arctic and Alpine Research 12(2):147-160.

Patton, W.W., Miller, T.P. 1968. Regional geologic map of the Selawik and southeastern Baird Mountains quadrangles, Alaska. US Geological Survey Miscellaneous Geologic Investigations Map I-530, scale 1:250,000

Patton, W.W., Miller T.P., and Tailleur, I.L. 1968. Regional geologic map of the Shungnak and southern part of the Ambler River quadrangles, Alaska. US Geological Survey Miscellaneous Geologic Investigations Map I-554, scale 1:250,000.

Pewe, T.L. 1948. Terrain and permafrost of the Galena Air Base, Galena, Alaska. U.S. Geological Survey Permafrost Program Progress Report 7, 52 pp.

Pewe, T.L. 1975. Quaternary geology of Alaska. U.S. Geological Survey Professional Paper 835, 145 pp.

Rowe, J.S. 1984. Lichen woodland in northern Canada. Pp. 225-237 in: Northern ecology and resource management: memorial essays honoring Don Gill (R. Olson, R. Hastings, and F Geddes, eds.). University of Alberta, Edmonton.

Rowe, J. S. and J. W. Sheard. 1981. Ecological land classification: a survey approach. Environmental Management 5:451-464.

Scotter, G.W. 1964. Effects of forest fires on the winter range of barren-ground caribou in northern Saskatchewan. Canadian Wildlife Service, Wildlife Management Bulletin, series 1, No. 18.

Shilts, W. W. 1978. Nature and Genesis of mudboils, central Keewatin, Canada. Canadian Journal of Earth Sciences 15(7): 1053-1068.

Swanson, D.K. 1995. Landscape ecosystems of the Kobuk Preserve Unit, Gates of the Arctic National Park. US Department of Interior, National Park Service, Technical Report NPS/ARRNR/NRTR-95/22.

Swanson, D.K. 1996a. Soil geomorphology on bedrock and colluvial terrain with permafrost in central Alaska, USA. Geoderma 71:157-172.

Swanson, D.K. 1996b. Susceptibility of permafrost soils to deep thaw after forest fires in interior Alaska, U.S.A., and some ecologic implications. Arctic and Alpine Research 28(2):217-227.

Swanson, D.K. 1996c. Fruticose lichen distribution in the Kobuk Preserve Unit, Gates of the Arctic National Park, Alaska. Technical Report NPS/AFA RNR/NRTR-96-28. US Department of Interior, National Park Service, Alaska Fiedl Area, Anchorage, Alaska, 22 pp.

Viereck, L.A. 1970. Forest succession and soil development adjacent to the Chena River in interior Alaska. Arctic and Alpine Research 2(1):1-26.

Viereck, L.A. 1983. The effects of fire in black spruce ecosystems of Alaska and northern Canada. Pp. 201-220 in Wein, R.W. and Maclean, D.A. (eds.), The role of fires in northern circumpolar ecosystems. Wiley, New York.

Viereck, L.A., C.T. Dyrness, and M.J. Foote. 1993. An overview of the vegetation and soils of the floodplain ecosystems of the Tanana River, interior Alaska. Canadian Journal of Forest Research 23:889-898.

Washburn, A.L. 1956. Classification of patterned ground and review of suggested origins. Geological Society of America Bulletin 67:823-865.

Washburn, A.L. 1979. Geocryology. Edward Arnold, London, 406 pp.

Wertz, W. A. and J. F. Arnold, 1972. Land systems inventory. U.S. Department of Agriculture, Forest Service, Intermountain Region, Ogden, Utah, 12 pp.

Williams, P.J., Smith, M.W. 1989. The frozen earth: fundamentals of geocryology. Cambridge University Press, Cambridge, UK, 306 pp.

Zoltai, S.C., Tarnocai, C. 1975. Perennially frozen peatlands in the western arctic and subarctic of Canada. Canadian Journal of Earth Sciences 12:28-43.

Zoltai, S.C., Tarnocai, C. 1981. Some nonsorted patterned ground types in northern Canada. Arctic and Alpine Research 13(2):139-151.

Table 1. National Hierarchical Framework of Ecological Units*

Ecoregion (<1:5,000,000)
Subregion
  Section (1:7,500,000 to 1:3,500,000)
  Subsection (1:3,500,000 to 1:250,000)
Landscape
  Landtype association (1:250,000 to 1:60,000)
Land unit
  Landtype (1:60,000 to 1:24,000)
  Landtype phase (>1:24,000)
*from Cleland *et al.*, 1997; typical mapping scales for each level are given in parentheses

Table 2: Index to the Ecological Units of Kobuk Valley National Park

Subsection		**Detailed Ecological Unit**	
Symbol	***Name***	***Symbol***	***Name***
AFH	Akiak Foothills	AFH1	Akiak Foothills
		AFH2	Akiak Foothills Alluvial Fans
		AFH3	Akiak Foothills Floodplains
AHW	Ahnewetut Wetlands	AHW1	Ahnewetut Creek Floodplain
		AHW2	Ahnewetut Wetlands
		AHW3	Niaktuvik Creek Floodplain
AKH	Aklumayuak Foothills	AKH	Aklumayuak Foothills
AKM	Akiak Mountains	AKM1	Akiak Mountains
		AKM2	Akiak Mountains Alluvial Fans
		AKM3	Upper Akillik River Floodplain
		AKM4	Upper Hunt-Akiak Floodplain
		AKM5	Upper Tutuksuk Floodplain
AKP	Akillik Plain	AKP1	Akillik Bluffs
		AKP2	Akillik Tundra Flats
		AKP3	Akillik Wetlands
		AKP4	Jade Creek Floodplain
ATM	Anaktok Mountains	ATM1	Anaktok Mountains
AYM	Angayukaqsraq Mountains	AYM1	Angayukaqsraq Mountains
JDM	Jade Mountains	JDM1	Jade Mountains
KLH	Kallarichuk Hills	KLH1	Kallarichuk Hills
KPP	Kitlik Pediments and Plains	KPP1	Kallarichuk River Floodplain
		KPP2	Kitlik Pediment
		KPP3	Tutuksuk Plain
KRF	Kobuk River Floodplain	KRF1	Kobuk River Floodplain
		KRF2	Kobuk River Scalloped Floodplain
KSD	Kobuk Sand Dunes	KSD1	Great Kobuk Sand Dunes
		KSD2	Kobuk Dune Creeks
		KSD3	Kobuk Partly Stabilized Dunes
		KSD4	Kobuk Sand Sheets
		KSD5	Little Kobuk Sand Dunes
		KSD6	Old Kobuk Sand Plain
KYM	Kunyanak Mountains	KYM1	Kunyanak High Ridges
		KYM2	Kunyanak Mountains
		KYM3	Tuktuksuk Ridge
NIP	Nigeruk Plain	NIP1	Nigeruk Plain
		NIP2	Nigeruk Plain Creeks
		NIP3	Nigeruk Plain, Lake-Rich

NTH	Natmotirak Foothills	NTH	Natmotirak Foothills
NTM	Natmotirak Mountains	NTM	Natmotirak Mountains
SHF	Salmon-Hunt Terraces and Floodplains	SHF1	Akiak Piedmont Dry Terraces
		SHF2	Hunt-Akillik Floodplain
		SHF3	Kaligurichеark River Floodplain
		SHF4	Salmon-Kitlik River Floodplain
		SHF5	Tutuksuk River Floodplain
		SHF6	Tutuksuk-Salmon Wet Terrace
SKM	Skajit Mountains	SKM	Skajit Mountains
SRH	Salmon River Hills	SRH1	Salmon River Hills
TKM	Tukpahlearik Mountains	TKM1	Tukpahlearik Mountains
UNB	Upper Noatak Basin	UNB	Upper Noatak Basin
WRM	Waring Mountains	WRM1	South Waring Valleys
		WRM2	Waring Hills
		WRM3	Waring Mountains
WRP	Waring Pediment	WRP1	Waring Pediment

Table 3. Summary of Criteria Used to Delineate Subsections in Kobuk Valley National Park

Subsection	Summary of Delineation Criteria
AFH – Akiak Foothills	Rounded low mountains on the south slope of the Brooks Range. Topography is gentler than the Akiak Mountains and cirques are absent.
AH – Ahnewetut Wetlands	Plain covered with wetlands and lakes northeast of the Kobuk Sand Dunes, probably fed by groundwater that originally infiltrated in the dunes.
AKH - Aklumayuak Foothills	Rounded hills composed of slope deposits over bedrock composed of phyllite, metasandstone, sandstone, and shale. Located mostly north of the Noatak-Kobuk divide and north of tree line. Western part is a plateau deeply incised by small streams. The line separating this unit from the Salmon River Hills was placed just south of the Kobuk-Notaka drainage divide where the shrubby vegetation of the Salmon River Hills gives way to herbaceous tundra.
AKM – Akiak Mountains	Rugged mountains with cirques and sharp ridge crests, composed mostly of schist, on the south slope of the Brooks Range. Differentiated from other rugged mountain subsections to the north by the composition of the bedrock and the presence here of forest in the valley bottoms.
AKP – Akillik Plain	Gently sloping plain, located above present-day streams and probably composed of Pleistocene loess and fine sand. The surface is covered mostly by wetlands and ecotonal tundra that exists below regional tree line due to wind, fires, and wet soils.
ATM – Anaktok Mountains	Rugged mountains composed of marble, located mostly along the Noatak-Kobuk drainage divide.
AYM - Angayukaqsraq Mountains	Rugged mountains with cirques, north of treeline and composed of a mixture of metavolcanic and metasedimentary rocks.
JDM – Jade Mountains	Rugged mountains with cirques composed of limestone and dolostone, forming the southernmost extension of the Brooks Range in this area.
KLH – Kallarichuk Hills	Low mountains, fairly rugged in the northern part, composed mostly of schist. Located on the south slope of the Brooks Range. Similar to the Akiak Mountains, Akiak Foothills, and Tukpahlearik Mountains, but form a rather distinctive southward extension of the Brooks Range. Valleys are fairly heavily forested on the east side, but the west side (which is more exposed to the ocean) is mostly tundra.
KPP – Kitlik Pediments and Plains	Gentle hills and undulating plains below the Brooks Range in the Kitlik River region. Includes both gentle bedrock-cored hills (pediments) and undulating plains composed of Quaternary sediments. Drier and more forested than the Akillik Plain and less deeply thermokarsted than the Nigeruk Plain. Surface is higher and older than the Salmon-Hunt Terraces and Floodplains.
KRF - Kobuk River Floodplain	Areas on the alluvial plain of the Kobuk River that are still subject to flooding and/or erosion by meander migration of the Kobuk River
KSD – Kobuk Sand Dunes	Active sand dunes, vegetated sand dunes, vegetated sand sheets, older sand areas modified by erosion and thermokarst, and small streams passing through the dunes
KYM – Kunyanak Mountains	Rounded and angular mountains composed of carbonate rocks (limestone and dolostone). Located near the Noatak-Kobuk drainage divide and almost completely above treeline. Isolated by about 30 km from the fairly similar Skajit Mountains unit.
NIP - Nigeruk Plain	Undulating plain, probably composed of Pleistocene loess and fine sand. The surface is well above present-day streams, and deep thermokarst depressions suggest a large amount of Pleistocene ground ice. Drier and more forested than the Akillik Plain.
NTH – Natmotirak Foothills	Rounded hills composed of slope deposits over bedrock, sloping down toward into the Noatak River basin north of the Noatak-Kobuk Divide.
NTM –	Rugged portion of the Baird Mountains that lies north of the highest ridges

Natmotirak Mountains	between the Kobuk and Noatak drainages, and completely north of tree line.
SHF – Salmon-Hunt Terraces and Floodplains	Floodplains and alluvial terraces of various tributaries to the Kobuk River that flow in from the north. Surfaces are probably mostly Holocene in age; they are generally lower, and have less loess and ground ice than the nearby Kitlik Pediments and Plains, Nigeruk Plain, and Akillik Plain, resulting in flatter topography and fewer lakes.
SKM - Skajit Mountains	Rugged mountains on the Noatak-Kobuk divide and north of tree line, composed of limestone. Isolated by 30 km from the fairly similar Kuyanak Mountains unit.
SRH – Salmon River Hills	A north-south trending band of relatively gently topography that extends through this part of the Brooks Range; located south of the Noatak-Kobuk divide but mostly above tree line.
TKM – Tukpahlearik Mountains	Rounded mountains composed of schist, located south of the Noatak-Kobuk divide. Intermediate in ruggedness between the Akiak Mountains and Akiak Foothills, but resembles both and could be combined with either for many purposes. Also resembles the Kallarichuk Hills (see above) and could be combined with it.
UNB – Upper Noatak	Gently sloping area of fine-grained sediments that was occupied by a large lake in the Pleistocene.
WRM – Waring Mountains	Rounded mountains and hills composed of clastic sedimentary rocks and located south of the Kobuk River. Includes a small region of low hills on the north side of the main ridge but not the larger gently sloping surface on the south side (the Waring Pediment)
WRP – Waring Pediment	Rounded hills sloping southward from the south side of the Waring Mountains. Probably consist of a thin layer of colluvium over graywacke and mudstone bedrock.

Table 4. Land Cover Composition and Area of the Ecological Subsections, Kobuk Valley National Park*

Ecological Subsection Symbol (see Table 2)	Area occupied by each land cover class, in % of the ecological unit																				Ecological Unit Area as % of Study	Area of Ecological Unit, km^2
	Closed needleleaf forest	Open needleleaf forest	Needleleaf woodland	Tall open and closed alder/willow	Closed low shrub - alder/willow	Closed low shrub - birch/ericaceous	Open low shrub - alder/willow	Open low shrub – birch/ericaceous	Open low and dwarf shrub tussock tundra	Dwarf shrub tundra/dwarf shrub	Open dwarf shrub - talus/lichen	Moist or dry herbaceous	Wet herbaceous	Sparsely vegetated	Barren	Snow/Ice/Cloud	Clear water	Turbid water	Shadow		
AFH	3	14	11	5	15	3	7	10	17	8	1	1	-	1	1	-	1	-	2	15	1087
AHW	16	24	5	-	6	-	-	5	23	1	-	-	-	-	1	-	19	-	-	2	154
AKH	-	-	-	1	-	1	9	24	31	7	4	14	-	3	4	-	-	-	-	-	20
AKM	3	9	3	1	9	5	4	23	15	7	2	1	-	6	5	-	1	-	5	24	1717
AKP	12	11	3	-	12	3	-	16	39	1	-	-	-	-	-	-	4	-	-	5	384
ATM	-	1	-	3	4	2	11	14	8	17	9	9	-	9	11	-	-	-	1	1	84
AYM	-	1	-	1	3	1	5	10	5	9	15	10	-	10	30	-	-	-	1	2	170
JDM	9	17	9	-	6	5	-	10	14	3	-	-	-	8	6	-	5	-	9	-	26
KLH	-	7	13	9	5	1	8	19	5	15	4	5	-	2	4	-	1	-	2	5	334
KPP	1	21	39	3	9	1	9	2	13	1	-	1	-	-	-	-	1	-	-	6	435
KRF	4	12	24	3	13	-	2	-	6	-	-	-	-	-	2	-	34	-	-	4	257
KSD	11	14	15	0	2	0	0	2	19	5	0	0	0	1	30	0	3	0	0	3	222
KYM	-	2	-	1	5	-	10	13	8	7	5	10	-	11	27	-	-	-	1	2	173
NIP	5	20	26	1	8	0	0	3	32	1	0	0	0	0	0	0	4	0	0	9	673
NTH	-	-	-	-	6	-	43	28	14	1	-	3	-	1	1	-	-	-	-	-	30
NTM	-	-	-	-	8	-	11	29	11	5	3	6	2	7	9	-	-	-	6	1	45
SHF	4	25	27	2	13	-	3	1	12	1	-	-	-	-	3	-	8	-	-	5	351
SKM	7	4	1	-	1	2	-	9	4	2	-	-	-	11	53	-	-	1	3	-	22
SRH	-	3	1	7	9	6	26	21	10	10	1	3	-	-	1	-	-	-	2	5	327
TKM	-	2	1	6	9	3	18	18	9	15	5	6	-	2	3	-	-	-	2	3	229
UNB	-	-	-	-	3	-	37	40	14	1	-	4	-	-	1	-	-	1	-	-	2
WRM	6	22	23	2	14	1	-	2	25	3	-	-	-	-	-	-	2	-	-	5	347
All	4	12	12	3	10	3	6	12	17	6	2	2	-	3	5	-	3	-	2	100	7089

*Dash indicates less than 0.5%. Land cover is based on a map by Markon and Wesser (1998). For Subsections that extend outside of the Park, only the part within the Park boundaries is analyzed here.

Table 5. Monthly Temperature and Precipitation at Kobuk, Alaska*

Month	Mean Temperature, °C	Mean Precipitation, cm
Jan	-23	1.6
Feb	-23	1.0
Mar	-18	1.7
Apr	-8	1.5
May	4	2.0
Jun	12	4.5
Jul	14	8.2
Aug	12	8.7
Sep	6	7.0
Oct	-7	2.1
Nov	-16	2.4
Dec	-23	1.7
Annual	-6	42.1

*From Leslie (1989) for years 1953-54 and 1964-79.

Fig. 1. Location of Kobuk Valley National Park

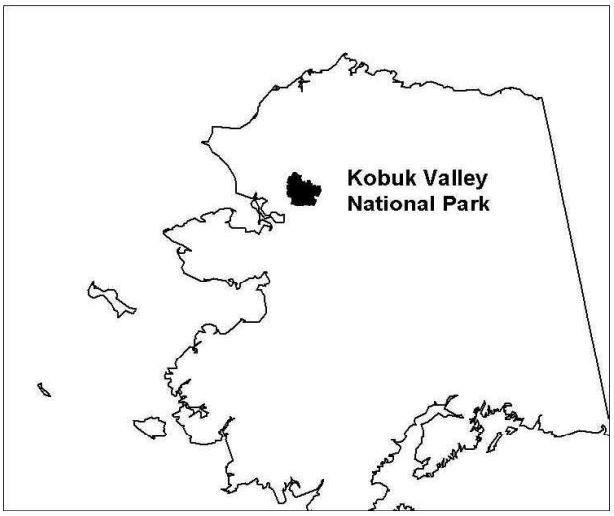


Fig. 2. Map of Ecological Subsections of Kobuk Valley National Park. Full names for the symbols in the legend and a brief description are given in Table 3. Lines within subsections delineate the detailed ecological units.