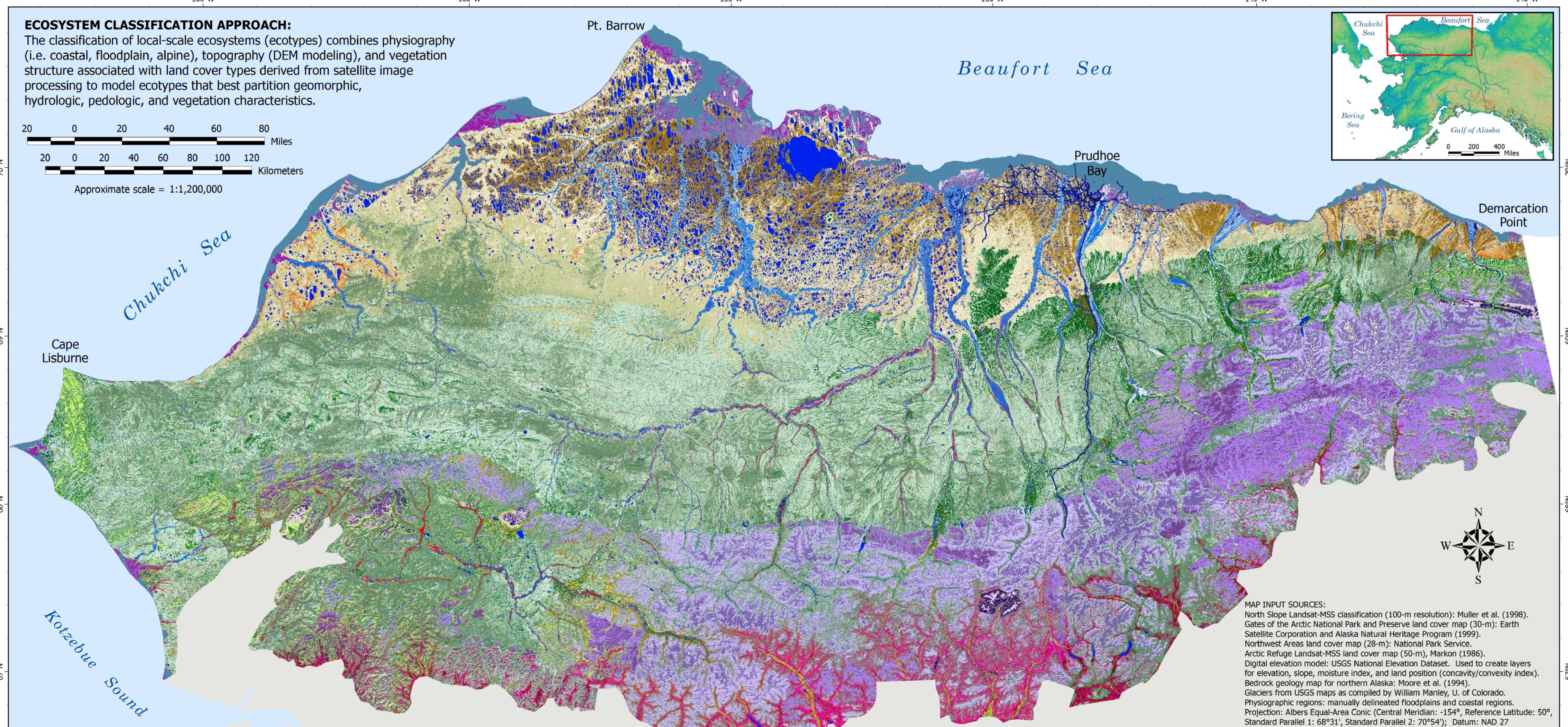
Ecosystems of Northern Alaska



ABSTRACT

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In response to a need for a unified ecological map for ecoregional planning in northern Alaska by the Nature Conservancy, we developed a map of local-scale ecosystems (ecotypes) that encompasses the Brooks Range, Brooks Foothills, and Beaufort Coastal Plain ecoregions. Our approach to ecological land classification and mapping combined vegetation structure associated with existing landcover maps derived from satellite image processing, with physiography (i.e., coastal, floodplain, alpine), topography (DEM modeling), and bedrock characteristics to model ecotypes that best partition geomorphic, hydrologic, pedologic, and vegetative characteristics. We developed a classification that included 7 alpine, 9 upland, 5 lowland, 10 riverine, 4 coastal, and 1 human-modified ecotypes that encompass a broad diversity of ecological characteristics ranging from boreal forests in the southern Brooks Range to brackish meadows along the Beaufort Sea coast. As input to map development, we used four existing landcover maps for the: North Slope by Muller et al. (1999), Gates of the Arctic National Park and Preserve by the Earth Satellite Corporation and Alaska Natural Heritage Program (1999), northwest Alaska parks by the National Park Service (1999), and the Arctic National Wildlife Refuge by Markon (1986). For physiography, we manually delineated floodplains and coastal areas at 1:100,000-scale on NASA Geocover satellite imagery, and differentiated alpine, upland and lowland areas by using a digital elevation model to characterize elevation, slope, moisture index, and land position (concavity/convexity index). Bedrock geology was adapted from Moore et al. (1994). Glacial extent was obtained from USGS maps, as compiled by Manley (pers. comm.). Rule-based models were developed to recode the map classes from the individual landcover maps into ecotypes. In the resulting map of the 306,4084km² area, 57% of the area has upland, 18% has alpine, 17% has lowland, 5% has riverine, 3% has coastal, and <0.1% has human-modified ecotypes. Each ecotype typically is associated with 2−4 geomorphic units, 2−4 closely related soil types, 1−3 plant associations, and differing permafrost conditions. For ecoregional planning, the map was used to identify rare ecosystems and high-value wildlife habitats deserving priority protection.

SAVING THE LAST GREAT PLACES ON EARTH

Produced 2004, Updated 2010

ECOTYPE DESCRIPTIONS

Alpine Glaciers: Perennially frozen snow and ice at high elevations, typically on north-facing slopes.

Alpine Non-carbonate Barrens: Barren (<5% plant cover) to partially vegetated (5–30%) areas on noncarbonate bedrock and talus slopes above treeline in the Brooks Range. Bedrock includes felsic intrusive (e.g., granite), noncarbonate metamorphic (e.g., schist), and noncarbonate sedimentary (e.g., sandstone, shale) rocks that generally have low calcium and sodium and high aluminum concentrations that lead to acidic soils. Soils are rocky, excessively drained, lacking in surface organic accumulations, and strongly acidic (pH < 5.5). At high elevations, common species include *Geum glaciale, Saxifraga bronchialis, S. flagellaris, S. nivalis, S. eschscholtzii*, and crustose and fruticose lichens.

Alpine Carbonate Barrens Barren (<5% plant cover) to partially vegetated (5–30%) areas on carbonate bedrock and talus slopes in the Brooks Range. Bedrock includes both sedimentary (limestone, dolostone) and metamorphic (marble) carbonate rocks. Soils are rocky, excessively drained, lacking in surface organics, and alkaline (pH > 7.3). Common pioneering plants include *Dryas integrifolia, D. octopetala, Saxifraga oppositifolia, Potentilla uniflora, Oxytropis nigrescens, O. arctica*, and *Carex rupestris*.

Alpine Mafic Barrens: Barren areas on intermediate, mafic, and ultramafic plutonic rocks above treeline that typically have dark-colored mineral assemblages with abundant iron and magnesium. Soils are rocky, excessively drained, lacking in surface organic accumulations, and are neutral to alkaline.

Alpine Non-carbonate Dryas Dwarf Shrub: Areas on noncarbonate and mixed noncarbonate-carbonate bedrock and talus slopes above treeline in the Brooks Range with dwarf shrub vegetation. Soils are rocky, excessively drained, strongly acidic, and have very thin surface organics. Vegetation is dominated by dwarf shrubs including *Dryas octopetala* (mostly south slopes), *Salix phlebophylla, S. arctica, Loiseleuria procumbens, Diapensia lapponica, Arctostaphylos alpina, Empetrum nigrum, Vaccinium uliginosum*, and *Cassiope tetragona* (north slopes). Other species include *Carex podocarpa, C. bigelowii, Hierochloe alpina, Cladina mitis,* and *C. rangiferina*.

Alpine Carbonate Dryas Dwarf Shrub: Areas on carbonate bedrock and talus slopes above treeline in the Brooks Range with dwarf shrub vegetation. Soils are rocky, excessively drained, rich in humus, and alkaline. Vegetation is dominated by dwarf shrubs including *Dryas integrifolia* (mostly south slopes), *D. octopetala, Cassiope tetragona* (north slopes), *Salix arctica*, and *Arctostaphylos alpina*. Other species include *Carex rupestris, C. bigelowii, Saxifraga oppositifolia, Potentilla uniflora, Oxytropis nigrescens, O. arctica, Nephroma arcticum, Rhytidium rugosum, Flavocetraria cucullata*, and *Thamnolia vermicularis*.

Alpine Mafic Dryas Dwarf Shrub: Areas on intermediate, mafic, and ultramafic plutonic rocks at high elevations with dwarf shrub vegetation. Rocks have dark-colored mineral assemblages with abundant iron and magnesium. Soils are rocky, excessively drained, lacking in surface organic accumulations, and are neutral to alkaline. Some areas have high levels of trace metals. Vegetation is poorly described for this type but it probably is similar to that described for Alpine Noncarbonate Dwarf Shrub Tundra.

Upland Spruce Forest: Upland areas on mid- to upper slopes on weathered bedrock, colluvium, and glacial till with needleleaf trees. Soils are loamy to rocky, well-drained, acidic, and have moderately thick organic horizons and may or may not have permafrost. This late-successional forest has an open to closed canopy of *Picea glauca*, but can include minor amounts of *Betula papyrifera* and *P. mariana*. The understory includes *Alnus crispa, Vaccinium vitis-idaea, Ledum groenlandicum, Empetrum nigrum, Rosa acicularis, Shepherdia canadensis, Spiraea beauverdiana, Linnaea borealis, Calamagrostis canadensis*, and feathermosses.

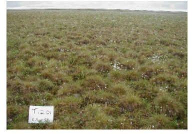
Upland Birch-Aspen-Spruce Forest: Upland areas on mid- to upper slopes on weathered bedrock, colluvium, and glacial till with vegetation co-dominated by broadleaf and needleleaf trees. Soils are well-drained, have thin organic horizons, are moderately acidic, and usually lack permafrost. This mid-successional mixed forest has an open to closed canopy of *Betula papyrifera, Populus tremuloides,* and *Picea glauca*. Understory plants include *Alnus crispa, Salix glauca, Vaccinium vitis-idaea, Ledum groenlandicum, Rosa acicularis, Cornus canadensis, Shepherdia canadensis, Linnaea borealis, Calamagrostis canadensis,* and feathermosses.

Upland Birch-Aspen Forest: Upland areas on mid- to upper slopes on weathered bedrock, colluvium, and glacial till with broadleaf deciduous trees. Soils are loamy to rocky, well-drained, have thin organic horizons, are acidic, and usually lack permafrost. The mid-successional forest is dominated by an open to closed canopy of *Betula papyrifera* and *Populus tremuloides*. Understory plants include *Alnus crispa, Salix glauca, Vaccinium vitis-idaea, Ledum groenlandicum, Rosa acicularis, Cornus canadensis, Shepherdia canadensis, Spiraea beauverdiana, Linnaea borealis, Calamagrostis canadensis*, and feathermosses.

Upland Tall Alder Shrub: Upland areas on mid- to upper slopes on weathered bedrock, colluvium, and glacial till with tall shrubs. Soils are loamy to rocky, well-drained, have thin organic horizons, are acidic, and usually lack permafrost. Vegetation is dominated by an open to closed canopy of *Alnus crispa*, although *Salix pulchra*, *Salix glauca*, and *Betula glandulosa* occasionally are abundant. Understory species include *Vaccinium uliginosum, Vaccinium vitis-idaea, Betula nana, B. glandulosa, Ledum groenlandicum, Empetrum nigrum, Equisetum arvense, Spiraea beauverdiana, Calamagrostis canadensis, Petasites frigidus, Sphagnum* spp., *Hylocomium splendens*, and *Dicranum* spp.

Upland Low Birch-Willow Shrub Tundra: Upland areas on mid- to upper slopes on weathered bedrock, colluvium, and glacial till with vegetation dominated by low shrubs. Soils are loamy to rocky, well-drained, have moderately thick organic horizons, are acidic, and usually have permafrost. Vegetation has an open to closed canopy *of Betula nana* and/or *Salix pulchra*. Other species include *S. glauca, Vaccinium uliginosum, V. vitis-idaea, Ledum decumbens, Empetrum nigrum, Arctostaphylos alpina, Dryas octopetala, D. integrifolia, Salix reticulata, Equisetum arvense, Carex bigelowii,* and the mosses and lichens *Hylocomium splendens, Tomentypnum nitens, Sphagnum* spp., *Cladina rangiferina,* and *Flavocetraria cucullata.*

Upland Shrubby Tussock Tundra: Gently sloping uplands and ridges on loess and colluvium (primarily>120 m elev.), with vegetation dominated by open low shrubs and tussock-forming sedges. Soils are somewhat poorly drained, loamy, acidic, have moderately thick surface organics, and are underlain by ice-rich permafrost. *Betula nana* and *Salix pulchra* overtop the *Eriophorum vaginatum* tussocks. Other plants include *E. angustifolium, Carex bigelowii, Ledum decumbens, Vaccinium vitis-idaea, V. uliginosum, Rubus chamaemorus, Hylocomium splendens, Sphagnum* spp., *Aulacomnium palustre, Cladina rangiferina,* and *Flavocetraria cucullata.*



Upland Tussock Tundra: Gently sloping uplands on loess, colluvium, and coastal plain deposits (primarily <120 m elev.) with tussock-forming sedges. Soils are moist, somewhat poorly drained, loamy, circumneutral to acidic, and have moderately thick surface organics underlain by ice-rich permafrost. Vegetation is dominated by *Eriophorum vaginatum.* On circumneutral soils, *Carex bigelowii, Dryas integrifolia, Salix pulchra, Cassiope tetragona, S. reticulata*, and *Tomentypnum nitens* are common. On acidic soils, plants include *Betula nana, S. pulchra, Ledum decumbens, Vaccinium vitis-idaea, Rubus chamaemorus, E. angustifolium, Hylocomium splendens, Sphagnum* spp., and *Cladina rangiferina.*

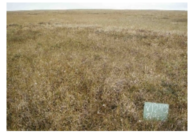
Upland Dryas Dwarf Shrub Tundra: Upland windswept ridges and upper slopes on weathered bedrock, colluvium, inactive sand dunes, and coastal plain deposits with dwarf shrubs vegetation. Soils are well-drained, loamy to rocky, have thin organic horizons, and are circumneutral to acidic. Dwarf shrubs include *Dryas octopetala* (mostly south slopes), *D. integrifolia*, *Salix phlebophylla, S. arctica, S. reticulata, Loiseleuria procumbens, Diapensia lapponica, Arctostaphylos alpina, Empetrum nigrum, Vaccinium uliginosum, Ledum decumbens*, and *Cassiope tetragona* (north slopes). Also common are *Carex bigelowii, C. scirpoidea, Arctagrostis latifolia, Equisetum variegatum*, and lichens.

Upland Moist Sedge-Shrub Tundra: Upland ridges and upper slopes on weathered bedrock, loess-mantled bedrock, colluvium, and glacial till, with vegetation co-dominated by sedges and low and dwarf shrubs. Soils are loamy to rocky, somewhat poorly drained, have moderately thick surface organics, and are alkaline to acidic depending on substratum. On acidic soils, plants include *Betula nana, Salix pulchra, Carex aquatilis, Eriophorum angustifolium*, and *Sphagnum* spp. On circumneutral to alkaline soils, plants include *Salix lanata, Dryas integrifolia, S. reticulata, Rhododendron lapponicum, Equisetum arvense, Carex bigelowii, Tomentypnum nitens*, and *Thamnolia vermicularis*.

Lowland Spruce Forest: Low-lying flats and gentle slopes on colluvium and abandoned floodplains with needleleaf forests. Soils are wet, somewhat poorly drained, have moderately thick surface organics, are acidic, and usually are underlain by permafrost. The open tree canopy (usually 5–10 m high) is dominated by *Picea mariana*, although *P. glauca, Larix laricina*, and *Betula papyrifera* occasionally are present. In the wettest areas the trees can be very stunted. Common understory plants include *Salix pulchra, Betula nana, Vaccinium uliginosum, Ledum groenlandicum, Potentilla fruticosa, Rubus chamaemorus, Equisetum arvense, Carex bigelowii, Sphagnum* spp., *Hylocomium splendens, Pleurozium schreberi, Cladonia* spp., and *Peltigera* spp.

Lowland Low Birch-Willow Shrub Tundra: Flats and lower slopes on drained-lake basins, abandoned floodplains, colluvium, and coastal plain deposits with vegetation dominated by low shrubs. Soils are poorly drained, loamy, acidic, have moderately thick surface organics, and are underlain by permafrost. The open to closed low shrub canopy has *Salix pulchra* and *Betula nana*. Acidic soils support *Ledum decumbens, Vaccinium uliginosum, Petasites frigidus, Rubus chamaemorus, Eriophorum angustifolium, Carex aquatilis, Calamagrostis canadensis,* and *Sphagnum* spp. Circumneutral to alkaline soils have *Salix lanata, S. reticulata, Dryas integrifolia, Arctostaphylos rubra, Equisetum arvense, E. angustifolium*, and *C. aquatilis*.

Lowland Moist Sedge-Shrub Tundra: Low-lying flats and gentle slopes on drained lake basins, abandoned floodplains, colluvium, and coastal plain deposits, particularly on the Beaufort Coastal Plain, with vegetation co-dominated by sedges and low or dwarf shrubs. Soils are saturated at intermediate depths (>15 cm), loamy with moderately thick surface organics, are circumneutral to alkaline, and are underlain by ice-rich permafrost. Sites generally are free of surface water during summer. Vegetation is dominated by *Carex aquatilis, C. bigelowii, Eriophorum angustifolium*, and *Dryas integrifolia*. Other species include *Salix lanata richardsonii, S. pulchra, S. reticulata, Tomentypnum nitens,* and *Hylocomium splendens*. Acidic vegetation could not be adequately differentiated from non-acidic vegetation on the Beaufort Coastal Plain.



Lowland Wet Sedge Tundra: Low-lying flats and drainages on drained-lake basins, abandoned floodplains, colluvium, and coastal plain deposits with vegetation dominated by sedges. Soils are poorly drained, usually circumneutral, and have moderately thick to thick (10–50 cm) surface organics over silt loam underlain by ice-rich permafrost. Ice-wedge development in older landscapes creates distinctive low-centered polygons. The surface generally is flooded (depth <0.3 m) during early summer and soils remain saturated throughout the growing season. Vegetation is dominated by *Carex aquatilis* and *Eriophorum angustifolium*, while the willows *Salix lanata richardsonii* and *S. pulchra*, often are present but usually not co-dominant. Other common species include *Dryas integrifolia, S. reticulata, C. bigelowii,* and *Equisetum scirpoides* on higher microsites and polygon rims.

Lowland Water: Shallow (<1.5 m) ponds and deep (≥1.5 m) lakes resulting from thawing of ice-rich permafrost, primarily on the coastal plain and distal portions of abandoned floodplains. In shallow ponds water freezes to the bottom during winter, thaws by early to mid-June, and is warmer than water in deep lakes. In deep lakes, water does not freeze to the bottom during winter in deeper portions of the lake. Sediments are loamy to sandy. These lakes lack riverine influences (flooding).

Lacustrine Barrens (not mapped): Barren or partially vegetated areas on newly exposed sediments in recently drained-lake basins. The surface usually is nonpatterned due to the lack of ice-wedge development. Soils are saturated to well-drained, sandy to loamy, lack surface organics, and are alkaline. Colonizers include *Arctophila fulva, Carex aquatilis, Dupontia fisheri, Scorpidium scorpioides*, and *Calliergon* sp. on wet sites and *Poa alpigena, Senecio congestus, Salix ovalifolia*, and *S. arctica* on drier sites.

Lacustrine Marsh (not mapped): Shallow (depth <1 m), permanent waterbodies with emergent aquatic sedges and grasses. Water and bottom sediments freeze completely during winter, but the ice melts in early June. The sediments range from sands to organics (10–50 cm deep) overlying silt loam. In deeper water (30–100 cm), *Arctophila fulva* can form sparse to dense stands and is the predominant vegetation. In shallower (<30 cm) water, *Carex aquatilis* and *Eriophorum angustifolium* are dominant, and *Utricularia vulgaris* is common. This ecosystem type is important to waterbirds but could not be mapped separately.

Riverine Spruce Forest: Flat areas on inactive floodplains subject to infrequent flooding with needleleaf trees. The late-successional forest has an open to closed tree canopy dominated by *Picea glauca*. Soils are well-drained, loamy to gravelly, have moderately thick surface organics, and are acidic. The understory is dominated by *Alnus crispa, Vaccinium uliginosum, V. vitis-idaea, Arctostaphylos rubra, Cornus canadensis, Viburnum edule, Rosa acicularis, Mertensia paniculata*, and feathermosses (*Hylocomium splendens, Rhytidiadelphus triquetrus*, and *Pleurozium schreberi*).

Riverine Spruce-Balsam Poplar Forest: Flat areas on inactive floodplains subject to infrequent flooding with mixed forests of needleleaf and broadleaf trees. The mid-successional forests have an open to closed tree canopy dominated by *Picea glauca* and *Populus balsamifera*. Soils are well-drained, loamy to gravelly, have moderately thick surface organics, and are circumneutral to acidic. The understory is dominated by *Alnus crispa, Vaccinium uliginosum, V. vitis-idaea, Arctostaphylos rubra, Cornus canadensis, Viburnum edule, Rosa acicularis, Equisetum arvense, Epilobium angustifolium, Calamagrostis canadensis,* and feathermosses (*Hylocomium splendens, Rhytidiadelphus triquetrus*, and *Pleurozium schreberi*).

Riverine Balsam Poplar Forest: Flat areas on inactive floodplains subject to infrequent flooding and that have vegetation dominated by broadleaf forests. Soils are well-drained, loamy to gravelly, have thin surface organics, and are circumneutral. The mid-successional forest has an open to closed canopy dominated by *Populus balsamifera,* or occasionally *Betula papyrifera*. The understory has *Alnus crispa, Rosa acicularis, Equisetum arvense, Epilobium angustifolium, Hedysarum alpinum, Calamagrostis canadensis, Galium boreale*, and *Rhytidiadelphus triquetrus*.

Riverine Tall Alder-Willow Shrub: Flat areas on active floodplains subject to frequent flooding that have vegetation dominated by tall shrubs in the boreal region. Soils are well-drained, loamy to gravelly, have very thin surface organics, and are circumneutral. The early succession community has an open to closed tall shrub canopy dominated by *Salix alaxensis, S. arbusculoides, S. monticola,* and *Alnus crispa*. The understory is dominated by *Vaccinium uliginosum, Artemisia tilesii, Calamagrostis canadensis, Petasites frigidus*, and *Equisetum arvense*. Mosses and lichens are not abundant.

Riverine Low Willow Shrub Tundra: Flat to gently sloping areas on active and inactive floodplains in tundra regions subject to variable flooding frequency and that have vegetation dominated by tall and low shrubs. On the narrow zone close to the river, soils are frequently flooded, well-drained, lack organic accumulations, and have vegetation dominated by open tall (>1.5 m) *Salix alaxensis, S. arbusculoides*, and *S. glauca*. *Alnus crispa* is uncommon. In the understory *Equisetum arvense, Astragalus alpinus, Aster sibericus*, and *Festuca rubra* are common. On inactive floodplains, where soils have interbedded organic layers and are seasonally saturated, *Salix lanata richardsonii* and *S. pulchra* are dominant. Common understory species include *Salix reticulata, Arctostaphylos rubra, Dryas integrifolia, Arctagrostis latifolia, Equisetum* sp., legumes, *Tomentypnum nitens*, and other mosses.

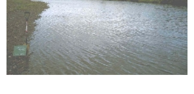
Riverine Dryas Dwarf Shrub Tundra: Flat areas on inactive floodplains subject to infrequent flooding and that have vegetation dominated by dwarf shrubs. Soils are well-drained, alkaline, sandy to rocky, and have thin surface organics underlain by ice-poor permafrost. The dwarf shrub *Dryas integrifolia* is dominant and *Salix reticulata, S. lanata richardsonii, Carex bigelowii, Arctagrostis latifolia, Astragalus* spp., *Oxytropis deflexa*, and *Equisetum scirpoides* are common. *Tomentypnum nitens* and *Distichium capillaceum* are common mosses.

Riverine Moist Sedge-Shrub Tundra: Flat areas on inactive floodplains subject to infrequent flooding and that have vegetation co-dominated by sedges and low and/or dwarf shrubs. Soils are moderately well-drained, loamy, have moderately thick surface organics, are circumneutral and underlain by ice-rich permafrost. Vegetation is dominated by *Carex aquatilis* and *Eriophorum angustifolium* with *Dryas integrifolia, Salix lanata richardsonii, S. reticulata,* and *Carex bigelowii*, *Equisetum* spp., *Tomenthypnum nitens* and *Campylium stellatum* as common associates

Riverine Wet Sedge Tundra: Flat areas on active and inactive floodplains subject to frequent or infrequent flooding and that have vegetation dominated by sedges. Soils are poorly drained, loamy with moderately thick to thick surface organics, are circumneutral to alkaline, and are underlain by ice-rich permafrost. Surface forms vary from nonpatterned to low-relief, low-centered polygons, the latter are indicative of ice-wedge development. Vegetation is dominated by *Carex aquatilis* and *Eriophorum angustifolium*, although occasionally the willow *Salix lanata richardsonii* is a co-dominant. Other species include *Dupontia fisheri, Equisetum variegatum,* and *Pedicularis sudetica, Campylium stellatum, Scorpidium scorpioides*, and *Limprichtia revolvens*.

Riverine Marsh (not mapped): Shallow waterbodies (0.1–1.0 m) on active and inactive floodplains subject with emergent aquatic grasses and sedge vegetation. Due to shallow water depths the water freezes to the bottom in the winter and the ice melts by early June. *Arctophila fulva* is found in deeper water, while *Carex aquatilis* is found in very shallow water. *Hippuris vulgaris* occasionally is present.

Riverine Barrens: Barren or partially vegetated (<30% cover) areas on active river channel deposits associated with meandering or braided rivers. Frequent sedimentation and scouring restricts establishment and growth of vegetation. Soils are poorly to excessively drained, sandy to gravelly, lack surface organics, are alkaline, and usually have ice-poor permafrost in arctic regions and lack permafrost is boreal regions. Typical pioneer plants include *Salix alaxensis, Deschampsia caespitosa, Chrysanthemum bipinnatum, Epilobium latifolium, Artemisia arctica, Festuca rubra, Arctagrostis latifolia,* and *Trisetum spicatum*.



Riverine Waters: Permanently flooded channels of freshwater rivers and streams, and lakes on inactive floodplains that are subject to occasional flooding. Some stream water flows throughout the year. Peak flooding generally occurs during spring breakup and the lowest water levels occur during mid-summer.

MODELING APPROACH

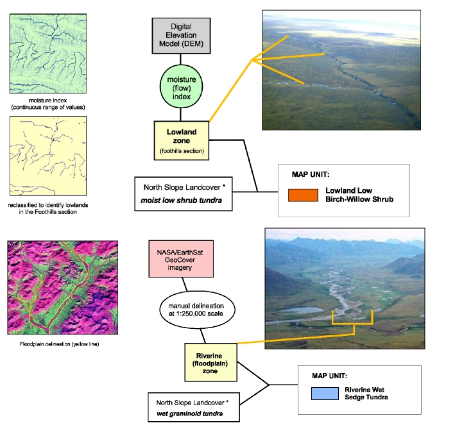


Table 1. Areal extent of ecotypes in northern Alaska.

	Beaufort Coastal Plain (%)	Brooks Foothills Area (%)	Brooks Range Area (%)	Total Area km²	%
Alpine Glaciers			0.2	234	0.1
Alpine Noncarbonate Barrens		0.0	9.0	11294	3.7
Alpine Carbonate Barrens		0.0	4.5	5772	1.9
Alpine Mafic Barrens			0.4	799	0.3
Alpine Noncarbonate Dryas Dwarf Shr.		0.3	18.9	24081	7.9
Alpine Carbonate Dryas Dwarf Shrub		0.0	9.4	11640	3.8
Alpine Mafic Dryas Dwarf Shrub		0.0	0.6	675	0.2
Upland Spruce Forest			4.9	6252	2.0
Upland Birch-Aspen-Spruce Forest			0.2	216	0.1
Upland Birch-Aspen Forest				232	0.1
Upland Tall Alder Scrub		0.1	3.0	3925	1.3
Upland Low Birch-Willow Shrub	0.0	28.3	22.8	61549	20.1
Upland Shrubby Tussock Tundra	0.3	40.6	8.5	57647	18.8
Upland Tussock Tundra	12.2	8.0	0.0	17164	5.6
Upland Dwarf Dryas Scrub Tundra	1.5	1.0	4.3	7478	2.4
Upland Moist Sedge-Shrub Tundra	0.5	10.1	6.3	20050	6.5
Lowland Spruce Forest			1.4	1781	0.6
Lowland Low Birch-Willow Shrub	1.9	0.8	0.8	3195	1.0
Lowland Moist Sedge-Shrub Tundra	25.0	3.0	0.0	19596	6.4
Lowland Wet Sedge Tundra	20.1	2.1	0.3	15879	5.2
Lowland Water	14.1	0.6	0.5	10492	3.4
Riverine Spruce Forest			0.4	521	0.2
Riverine Spruce-Balsam Poplar Forest			0.0	29	0.0
Riverine Balsam Poplar Forest			0.0	29	0.0
Riverine Tall Alder-Willow Scrub			0.1	109	0.0
Riverine Low Willow Scrub Tundra	0.3	0.9	0.3	1573	0.5
Riverine Dry Dryas Dwarf Scrub		0.0	0.5	630	0.2
Riverine Moist Sedge-Shrub Tundra	3.7	2.0	0.8	5687	1.9
Riverine Wet Sedge Tundra	2.2	0.5	0.1	2084	0.7
Riverine Barrens	1.3	0.7	0.3	1969	0.6
Riverine Waters	1.4	0.3	0.2	1546	0.5
Coastal Water	10.8	0.3		7307	2.4
Coastal Grass & Dwarf Shrub Tundra	2.1	0.2		1534	0.5
Coastal Wet Sedge Tundra	2.0	0.0		1340	0.4
Coastal Barrens	0.8	0.0		541	0.2
Clouds, Ice, Shadows	0.0	0.2	1.1	1554	0.5
Total (less Coastal Water & Clouds, km²)	64683	115407	126316	306405	

Coastal Grass and Dwarf Shrub Tundra: Low-lying, salt-affected areas along the coast with vegetation dominated by either grasses or dwarf shrubs. Soils are well-drained, slightly saline, and alkaline. On active dunes and beaches, vegetation includes *Elymus arenarius*, *Chrysanthemum bipinnatum*, *Puccinellia* spp., *Artemisia tilesii*, and *Salix ovalifolia*. Well-drained inactive tidal flats dominated by dwarf shrub vegetation have *S. ovalifolia, Stellaria humifusa, E. arenarius, Deschampsia caespitosa, Dupontia fisheri, Carex subspathacea*, and *A. tilesii*. Inactive dunes with slightly saline sandy soils have dwarf shrub vegetation dominated by *Empetrum nigrum, S. ovalifolia, E. arenarius, Lathyrus maritimus, C. bipinnatum*, and lichens. Substantial areas of this class include Lowland Moist Sedge-Shrub Tundra,

Coastal Wet Sedge Tundra: Low-lying, salt-affected areas on tidal flats, deltas, and muddy beaches along the coast that are frequently flooded and have vegetation dominated by sedges. The surface is nonpatterned. Soils are poorly drained, clayey to loamy, usually lack surface organics, and are brackish and alkaline. The soils are underlain by ice-poor permafrost. Vegetation is dominated by *Carex subspathacea*, *Carex ursina,* and *Puccinellia phryganodes*, with *Dupontia fisheri, Puccinellia andersonii, Cochlearia officinalis*, and *Stellaria humifusa* also common. Non-vascular plants usually are absent. Substantial areas of Lowland Wet Sedge Tundra are included in these mapped areas but could not be adequately differentiated.

Coastal Barrens: Barren or partially vegetated, salt-affected areas on tidal flats, deltas, and muddy beaches along the coast that are frequently flooded. Soils are poorly drained, clayey to loamy, usually lack surface organics, brackish, acidic to alkaline, and are underlain by ice-poor permafrost. Common colonizing plants include *Deschampsia caespitosa, Elymus arenarius, Salix ovalifolia*, *Stellaria humifusa,* and *Cochlearia officinalis* in well-drained areas, and *Puccinellia phryganodes, Dupontia fisheri*, and *Carex subspathacea* in wet areas. This class includes tundra that has been killed by saltwater intrusions from storm surges and partly colonized by salt-tolerant plants.

Coastal Water: Shallow (~<2 m) estuaries, lagoons, embayments, and tidal ponds along the coast of the Beaufort and Chukchi Seas. Winds, tides, river discharge, and icing create dynamic changes in physical and chemical characteristics. Salinity ranges widely from nearly fresh near rivers to saline in unprotected areas. Tidal ranges normally are small (<0.2 m) along the Beaufort and moderate (0.5–1 m) along the Chukchi Seas, but storm surges produced by winds may raise sea level as much as 2–3 m. The ice-free period extends from July until October.

Marine Water (not mapped): Deep (~>2 m) marine waters of the Beaufort and Chukchi Seas outside of lagoons and barrier islands. Ice coverage is highly variable from permanent pack ice to seasonally ice free areas. Small areas of Marine Water included in Coastal Water for mapping purposes.

Human Modified: Barren or partially vegetated areas resulting from human disturbance. As mapped, the areas are predominantly roads, pads, and mine pits and overburden.

Cloud, Snow and Ice: Areas with clouds, snow, and ice. The Clouds and Ice Class was combined with the Shadow classes for the final map. Most of the original shadow classes in the Brooks Range were recoded to alpine classes based on modeling. Remaining shadow areas are mostly due to clouds. Aufeis on rivers was classified as Riverine Barrens.

References

Earth Satellite Corporation. 1999. Gates of the Arctic National Park and Preserve Landcover Map and User's Guide. Final Report prepared for National Park Service, Anchorage, AK, by Earth Satellite Corporation and Alaska Natural Heritage Program.

Markon, C. 1986. Arctic National Wildlife Refuge landcover mapping project users guide. Unpubl. Rep. by U.S. Geological Survey, Anchorage, AK. 14 pp.

Manley, W., pers. comm. University of Colorado.

Moore, T. E., W. K. Wallace, K. J. Bird, S. M. Karl, C. G. Mull, and J. T. Dillon. 1994. Geology of northern Alaska. Pages 49-140 in G. Plafker, and H. C. Berg, eds., The Geology of Alaska. The Geological Society of America, Denver, CO. The Geology of North America, Vol. G-1.

Muller, S. V., A. E. Racoviteanu, and D. A. Walker. 1999. Landsat MSS-derived land-cover map of northern Alaska: extrapolation methods and a comparison with photo-interpreted and AVHRR-derived maps. Int. J. Remote Sensing 20:2921-2946.

National Park Service. 1999. Northwest Areas Landcover Map. Alaska Support Office, Anchorage, AK.