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Classification of Community Types, Successional Sequences, and Landscapes of the Copper River Delta, Alaska

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Abstract

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A classification of community types, successional sequences, and landscapes is presented for the piedmont of the Copper River Delta. The classification was based on a sampling of 471 sites. A total of 75 community types, 42 successional sequences, and 6 landscapes are described. The classification of community types reflects the existing vegetation communities on the landscape. The distribution, vegetation composition and structure, soils, and successional status of each community are discussed. The community types were placed within successional sequences reflecting their successional trends. Geomorphic and soil development were closely aligned with vegetation succession on the study area and, consequently, are described in detail. Each successional sequence was named after the oldest community type identified in the sequence and the landscape on which it occurs. Diagnostic keys, based on indicator species, are provided to aid in field identification of community types and successional sequences. The dominant landscapes, including outwash plain, tidal marsh, and floodplain, are described by using environmental processes, such as geomorphology, hydrology, and soil development, and by integrating communities and successional sequences into these processes.

Keywords: Alaska, Copper River Delta, classification, community type, succession, landscape, outwash, floodplain, delta, dune, barrier island.

Summary

A classification is presented to provide resource managers with an understanding of the vegetation communities, successional processes, and landscapes of the Copper River Delta. A classification integrating communities, succession, and landscapes is important because vegetation succession and communities can best be described and understood by first interpreting the landscapes on which they exist.

The study area is a discontinuous series of coastal deltas and alluvial piedmonts in south-central Alaska encompassing about 700,000 acres. Mountain range spurs interrupt the piedmont, and the largest glacial system in North America (Bering Glacier) borders the eastern side. Elevation on the study area ranges from 0 to 300 feet above sea level. Human-caused disturbance is limited primarily to timber harvesting on proximal outwash plains.

The vegetation on the Copper River Delta is dynamic and unstable because of tectonic uplift and geomorphic processes, such as erosion and deposition of sediments on tideflats and glacial river channels. Of special concern is the change in vegetation initiated by an earthquake in 1964 that uplifted the area 6 to 12 feet. Before 1964, the seaward portion of the piedmont was covered by tidal marshes dominated by sedges (*Carex* spp.) and mixed grass/forb communities. The earthquake lifted these marshes above the tidal influence, initiating massive changes in vegetation composition and structure. Some tidal marsh communities described as common in previous studies are now rare or absent. The uplifted tidal mudflats are presently developing tidal marshes. These vegetation changes in turn have strongly affected such management concerns as nesting habitat for the dusky Canada goose, staging ground for shorebirds, and the moose population of the delta.

This classification is divided into three sections: (1) landscape descriptions, (2) successional sequence descriptions, and (3) community type descriptions. Landscapes (analogous to landtype association from ECOMAP 1993) comprise the broadest level of the classification. Six landscapes were identified: (1) outwash plain, (2) floodplain, (3) linear dune, (4) uplifted marsh, (5) tidal marsh, and (6) barrier island-spit-coastal dune. Sediment deposition or erosion from fluvial and aeolian processes are the dominant driving successional forces on these landscapes. Landscape descriptions include landform, distribution, effect of the 1964 earthquake, and geomorphic processes. Each landscape adds greatly to the biological, habitat, and landform diversity of the Copper River Delta, often with community types, plant species, and successional sequences showing a high fidelity to specific landscapes.

The successional sequence classification level describes the full sequence of vegetation succession and landform-soil development. Community types are placed within successional sequences reflecting their successional trends and pathways. Geomorphic and soil development are closely aligned with vegetation succession on the study area and, consequently, are described in detail. A total of 42 successional sequences are identified, and each is named after the oldest community type identified in the sequence and the landscape on which it occurs. A diagnostic key, based on indicator species and landform, is provided to aid in field identification of the sequences. Each successional sequence exhibits high fidelity to specific landscapes.

Community types describe existing vegetation and are analogous to the plant association level of "The National Vegetation Classification Standard" (Bourgeron and Engelking 1994) and to types described at level V of "The Alaska Vegetation Classification" (Viereck and others 1992). Seventy-five communities (plus 35 undersampled communities) are described. Community type descriptions include other studies of the region, distribution of the community type, vegetation structure and composition, environmental factors such as soils and hydrology, and how each community type fits into succession. A diagnostic key, based on indicator species, is provided to aid in field identification of community types.

Contents

Introduction

The Copper River Delta presents a mosaic in vegetation structure, composition, and physical site characteristics. This classification has been prepared to provide resource managers with an understanding of the vegetation communities, succession, and ecosystems of the Copper River Delta. Natural classifications (Cooper and others 1991) such as those describing community types (Shephard 1995), plant associations (DeMeo and others 1992, Martin and others 1995), and habitat types (Cooper and others 1991, Daubenmire 1952, Daubenmire 1968, Hansen and others 1995, Pfister and others 1977) reflect ecological patterns. Consequently, they are useful at many management levels from describing the variability within individual communities to aggregating community types into hierarchical mapping units or ecosystems.

Wetland ecosystems dominate the Copper River Delta and are of prime importance to wildlife-fisheries habitat, water quality, water quantity, and species diversity. Coastal estuaries and riparian forests are among the most productive ecosystems on Earth, providing nutrients and solutes critical for the terrestrial and aquatic food webs. Fish species that support the commercial and sport fishing industries and wildlife species such as waterfowl, shorebirds, and moose are dependent on wetland habitats. In addition, wetlands filter pollutants and convert toxic solutes to an inert state, provide a slower release of flood waters, and reduce peak flows when floods occur. Despite their importance, these ecosystems are among the least studied and least understood areas in terms of structure, function, and management. Wetland ecosystems often have been overlooked, or considered a minor inclusion of the larger terrestrial or aquatic systems. Impacts from pollution, stream channeling, timber harvesting, mining, road construction, and agriculture often drastically affect these systems.

The vegetation on the Copper River Delta is highly dynamic because of a recent tectonic uplift of the region and active geomorphic processes such as erosion and deposition of sediments on estuaries, outwash plains, floodplains, and dunes. Of special concern is the change in vegetation initiated by an earthquake in 1964 that uplifted the area by 6 to 12 feet (Reimnitz 1966). Before1964, much of the delta was covered by brackish marshes dominated by sedges (*Carex* spp.)[1] and mixed grass/forb communities (Crow 1968, Potyondy and others 1975, Trainer 1959). The earthquake lifted these marshes above the tidal influence, initiating massive changes in vegetation composition and structure. Some tidal marsh communities described as common in previous studies (Crow 1968, Potyondy and others 1975) are now rare or absent on the landscape. Many pre-1964 tidal mudflats were elevated sufficiently that they are now developing brackish marshes. These vegetation changes in turn have strongly affected such management concerns as nesting habitat for the dusky Canada goose (*Branta canadensis*), staging ground for shorebirds, and the moose (*Alces alces*) population of the delta.

Natural resource managers and researchers on the Copper River Delta have developed several site- and vegetation-based classifications to meet their varied needs. Crow's (1968, 1971, 1976) vegetation work was limited in scope, specifically describing communities that were within the tidal marshes immediately after the 1964 earthquake. Davidson and Klinge's (1992) map unit work defined the soils of the delta,

[1] See appendix table 11 for a list of scientific names and authorities for all plant species mentioned.

described landforms, and provided baseline vegetation information but did not use vegetation as the base unit. Thilenius (1990) describes general vegetation changes initiated by the 1964 earthquake. Other studies were developed for specific applications such as mapping or describing wildlife habitat (Campbell 1990, Cornely and others 1985, Hagen and Meyer 1978, Potyondy and others 1975, Scheierl and Meyer 1977, Trainer 1959).

The objectives of this study were as follows:

1. Describe the geomorphic-based landscape units (landtype associations [ECOMAP 1993]) for the Copper River Delta.

2. Describe the major vegetation-site successional sequences.

3. Classify and describe vegetation-based community types.

4. Identify rare plant communities and landscapes.

A multilevel classification is important because vegetation succession and communities can best be described and understood by first interpreting the landscapes on which they exist. Because of the overriding importance of geomorphology and physiography, integrating both vegetation and landscapes is necessary to adequately describe vegetation distribution and dynamics (succession) on the Copper River Delta. This classification incorporates community information from the Copper River Delta into the ECOMAP (1993) classification and simultaneously attempts to improve the links among classification levels. The ECOMAP (1993) was partially developed to provide a geographic framework for logically grouping community types and forming successional pathways. The Copper River Delta classification is divided into three major levels: (1) landscape descriptions (comparable to landtype association [ECOMAP 1993]), (2) successional sequence descriptions, and (3) community type descriptions. Hereafter, the term successional sequence will be abbreviated as "s.s." and the term community type as "c.t." when used with a named successional sequence or community type.

Landscape is the highest level used in this classification and is based predominantly on geomorphology. Geomorphic processes are the dominant driving successional force on the delta. Six landscapes were identified on the Copper River Delta: outwash plain, floodplain, linear dune, uplifted marsh, tidal marsh, and barrier island-spit-coastal dune. Landscape descriptions include landform, distribution, and ecosystem processes. Each landscape adds greatly to the biological, habitat, and landform diversity of the Copper River Delta. Many community types and plant species show a high fidelity to specific landscapes.

The ECOMAP (1993) classification places the study area into two subsections: the Copper River Subsection and the Copper River Delta Subsection (fig. 1). The Copper River Subsection includes outwash plain and linear dune landscapes along the Copper River, and the Copper River Delta Subsection includes the remainder of the study area. The distinction between subsections is due to the influence that cold air drainage down the Copper River has on vegetation composition, succession, and phenology. The outwash plain landscape is the only landscape that occurs in both the Copper River Subsection and the Copper River Delta Subsection. Consequently, outwash plain successional sequences were divided into outwash plains occurring on either the Copper River Subsection or the Copper River Delta Subsection.

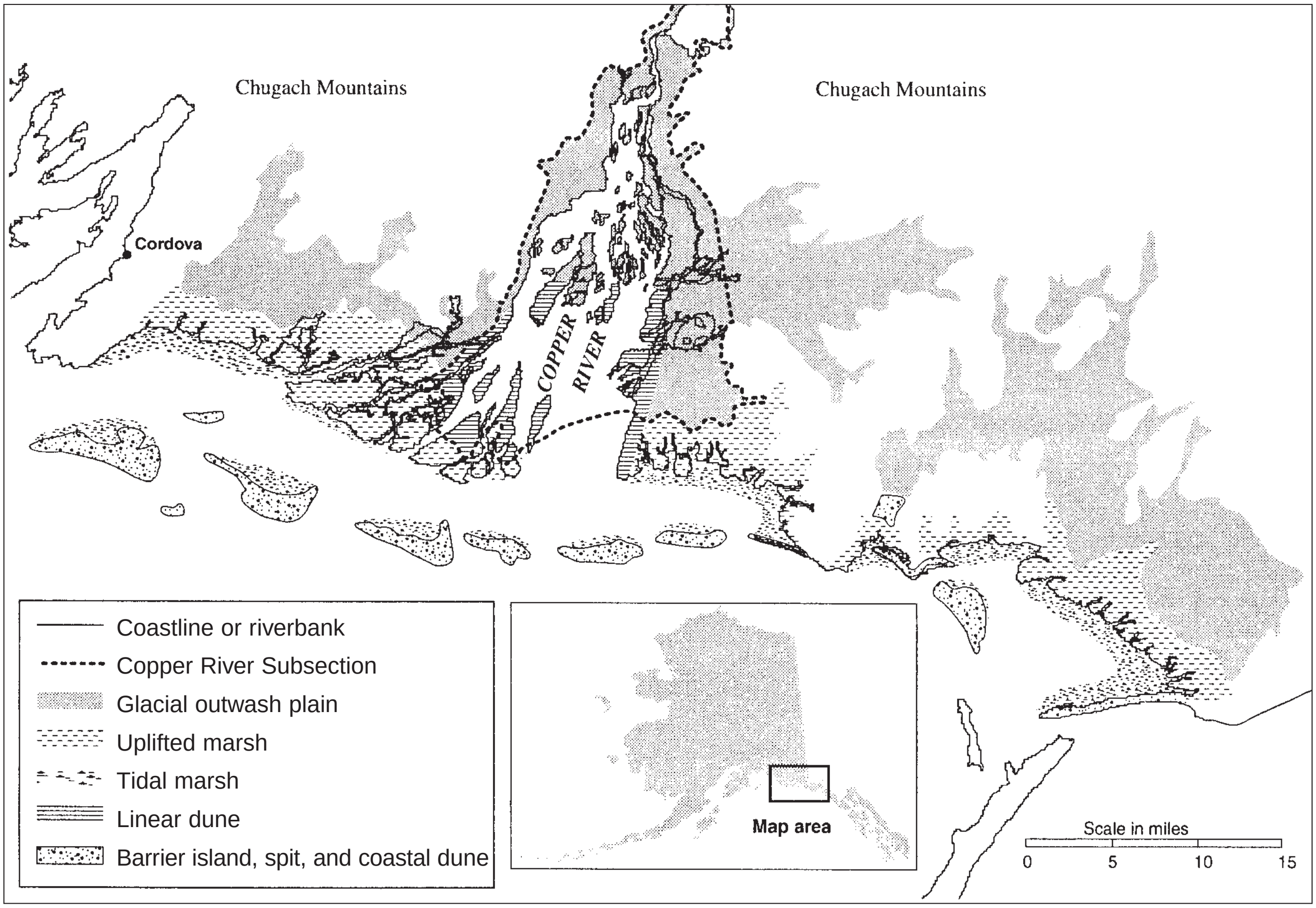

Figure 1—Topography and landscapes (landtype associations) of the Copper River Delta. The study area falls within two ECOMAP (1993) subsections: most of the Copper River is within the "Copper River Subsection," and the remainder of the piedmont falls within the "Copper River Delta Subsection."

Successional sequence is the next finer level and describes the full sequence of vegetation and site succession (Arno and others 1985). Each successional sequence is named after the oldest community type in the sequence and the landscape on which it occurs. Landscape was included in the successional sequence name because these aeolian- and fluvial-derived landscapes have an overriding influence on vegetation succession. Knowing the site conditions (i.e., landscape) under which a community develops can greatly enhance the understanding of successional pathways. Communities dominated by aquatic vegetation were not included as late-successional communities.

The successional sequences are inferred chronosequences; this method presents certain problems in accuracy. Studies have shown that a consistent stepwise progression in seral stages is not an accurate portrayal of succession on any given surface (Boggs and Weaver 1994, Fastie 1995). Multiple pathways occur and are likely a function of landscape characteristics and species life history. This classification does not attempt to describe absolute steps in community succession but rather presents general or multiple pathways.

Community type is the finest level of the classification and is analogous to level V from “The Alaska Vegetation Classification” (Viereck and others 1992). Community type descriptions include other studies of the region, distribution of the community type, vegetation structure and composition, environmental factors such as soils and hydrology, and successional status. The community types from the Copper River Delta have been placed into “The Alaska Vegetation Classification” (Viereck and others 1992) in appendix table 10.

Study Area and Climate

The study area is a discontinuous series of coastal wetlands in south-central Alaska (fig. 1). It stretches 75 miles parallel to the coastline (from latitude 60°38' N. to 60°00' N., and longitude 145°52' W. to 143°30' W.) with a maximum width of 37 miles. The study area is a broad low-gradient (< 7-percent) plain bordered by the Gulf of Alaska to the south, and coastal mountains (1,500 to 7,730 feet) to the north. Mountain range spurs interrupt the wetland plain, and the largest glacial system in North America (Bering Glacier) borders the eastern side. Elevation on the study area ranges from 0 to 300 feet above sea level. Human-caused disturbance has been minimal, except timber harvesting on a small percentage of the study area.

Landscapes on the plain include kettle-kame topography, moraines, outwash plains, floodplains, deltas, linear dunes, and dune-dominated landscapes fronting the ocean. The spatial distribution of the geomorphic landscapes is relatively consistent and proceeds, moving seaward, from kettle-kame topography, moraines, outwash plains or floodplains, deltaic deposits, to dune-dominated landscapes fronting the ocean. The temporal distribution of these landscapes ranges from new to relatively old. Full descriptions of the outwash plain, floodplain, delta (uplifted marsh and tidal marsh), linear dune, and dune landscapes are presented in the landscape section.

A marine climate dominates the Copper River Delta resulting in mild wet summers and cool wet winters. This climate is maintained by the Alaska Current, which delivers warm ocean currents to the area and frequent atmospheric low pressure systems in the Gulf of Alaska. The Chugach Mountains also play a significant role, greatly increasing precipitation while sheltering the coast from the continental-interior air masses.

The mild seasonal temperatures result from of the ocean being warmer than the air in the winter and cooler than the air in the summer (Searby 1969). The warm ocean water delivered by the Alaska Current originates as part of the Kurosiro Current off the south China coast. It becomes the North-Pacific Current as it moves east across the Pacific Ocean, and eventually reaches the coast of North America. There it splits, one branch turning south as the California Current, the other turning northward as the Alaska Current, eventually moving into the Gulf of Alaska. Although modified somewhat from southward cold flowing waters from the Bering Sea, the Alaska Current is relatively warm.

High zones of precipitation occur along the coast because of the frequent atmospheric low pressure systems of the region in combination with the coastal mountain ranges. Orographic effects significantly increase precipitation along the base and within the Chugach Mountains. Most of the resultant precipitation flows to the delta as glaciers or streams, both of which influence the geomorphology of the Copper River Delta. In general, average yearly precipitation increases, moving landward, from 38 inches on open ocean, to 86 inches midway across the piedmont, to 180+ inches at the mountain bases (Searby 1969). Average annual snowfall midway across the piedmont is 128 inches. Heavy seasonal snow occurs at all weather stations, although above-freezing temperatures typically limit snow accumulation. The record precipitation for a 24-hour period is 7.9 inches (September 1951). As suggested by the heavy precipitation, the delta is cloudy, averaging 262 cloudy days per year and 52 clear days per year.

Mean monthly temperatures at sea level range from 25°F in January to 54°F in July (climate data from Cordova airport). The recorded extreme temperatures are 86°F in July and -30°F in January. The Soil Conservation Service estimates the growing season is 107 days between May 10 and September 30, based on the last and first 28°F frost. Mean temperature during the growing season is 50°F, and average monthly precipitation is 7.8 inches, and ranges from 5.1 inches in June to 12.9 inches in September. During the remainder of the year, temperatures are commonly below freezing, with an average of 30°F.

The coastal mountain ranges of Alaska form a barrier between continental and maritime air masses. Differences in climate between the interior and coast, separated by only 50 miles, are striking. Summers in the interior are typically hot and relatively dry, and winters are cold to extremely cold and dry. Continental air masses do move across the region of the Copper River Delta bringing warm or cold air, but their frequency and duration are typically short. The Copper River canyon breaching the Chugach Mountains serves as a corridor allowing continental air to flow down the canyon onto portions of the delta where it mixes with maritime air masses.

The prevailing winds on the Copper River Delta are easterly, and the average wind speed midway across the piedmont is 5 miles per hour. Surface friction over land and the protection of mountainous terrain often cause substantial reductions in wind speed. Although rugged terrain is common in the region of the Copper River Delta, sustained high winds are frequent and typically the result of two circumstances: (1) low or high pressure cells moving through the region and producing broad bands of wind that may persist for 3 or more days with little change (wind speed rarely exceeds 100 miles per hour [Thilenius 1990]); or (2) a narrow band of strong wind flowing down the Copper River canyon over the delta. A strong pressure gradient is formed between the high pressure systems of the interior and the low pressure of the Gulf of Alaska. In addition, gravity-induced fluid flow and venturin effects of deep narrow valleys enhance the high winds. These winds frequently exceed 60 miles per hour for several days or weeks (Thilenius 1990). The winds under extreme conditions will gust up to 120 miles per hour extending up to 30 miles out to sea. Ships report abrupt changes in wind entering and leaving the narrow band (Thilenius 1990).

The effect of the cool air mass flowing down the Copper River canyon is not felt equally across the delta. The canyon walls funnel the cold air out to sea, missing much of the delta east and west of the Copper River. A microclimate exists at the mouth of the Copper River of high winter winds, alternating cold and mild temperatures, heavy snow fall, late snow melts including snowdrifts that can persist all summer, and windblown loess. Striking changes in vegetation composition, phenology, and landform are evident in and out of the wind corridor. Sitka spruce is essentially absent in the wind corridor yet common on mesic landforms on the remainder of the delta. Vegetation phenology is typically 2 to 3 weeks behind that of adjacent lands not subjected to the cold airflows. At the mouth of the Copper River, the high winds form linear dunes; the linear dune landscape is absent from the rest of the delta.

Ecological Terms and Concepts

Community Types, Successional Sequences, and Landscapes

Classification is an attempt to divide vegetation and the environment into abstract natural units that are useful for management purposes. Management goals play a critical role in determining the type of classification to be developed. Community types, successional sequences, and landscapes of the Copper River Delta are described to further our understanding of the ecology of the region.

Community type—A community type is an aggregation of all sampled communities (sites) distinguished by floristic and structural similarities in both overstory and undergrowth layers (Hansen and others 1995, Youngblood and others 1985). Each community type represents a relatively narrow segment of the variation in vegetation. Sites making up a type at times are consistent in structure and composition, whereas other types are highly variable, each site appearing on a continuum. Community types are considered taxonomic in nature because they are repeatable across the landscape, much as soils are taxonomically based and repeatable across the landscape. Many classifications define the term plant association the same as community type.

Naming of the community type follows the frequently used system of a binomial with the dominant overstory species separated from the dominant or diagnostic indicator of the undergrowth by a slash (e.g., the *Myrica gale/Carex lyngbyaei* [sweetgale/ Lyngby's sedge] c.t.; Mueller-Dombois and Ellenberg 1974). In herbaceous communities, however, structure is sometimes limited to a single layer; we consider this the overstory and either ignore all references to additional layers (e.g., the *Carex lyngbyaei* [Lyngby's sedge] c.t.) or designate a codominant species with a dash (e.g., the *Carex lyngbyaei-Lathyrus palustris* [Lyngby's sedge-vetchling] c.t.).

Successional sequence—Succession is the replacement of one community (or population) by another over time. A successional sequence describes vegetation and site (soil and landform) succession, and sequentially links community types. This classification does not attempt to describe absolute steps in succession but rather presents general or multiple pathways. Two types of succession are generally recognized, primary and secondary. **Primary succession** is succession on newly created surfaces such as sediment filling in a lake, new alluvial bar deposits along rivers, tectonically uplifted tidal flats, or mineral soil exposed by glaciation or landslides. **Secondary succession** occurs after vegetation is destroyed or altered by a disturbance but the site characteristics, such as soil and hydrology, are left intact. Common disturbances leading to secondary succession are fire, disease, blowdown, insect infestation, and flooding.

For both primary and secondary succession, a series of changes is initiated leading from colonization or regeneration on the site by pioneer species, which in turn are replaced by secondary invaders, which in turn may be replaced by tertiary invaders and so on. Generally, ecologists and land managers have had to deal only with secondary succession when working with nonwetland or upland sites. In many wetland and dune ecosystems, however, primary succession is just as important as secondary succession in expressing the general landscape mosaic.

A successional sequence is named after the oldest community type found; this method of naming does not imply that the community type is the oldest community possible as conventionally used for the naming of plant associations, habitat types, and ecological site types (climax or potential native vegetation). This is because of the following conditions that exist within the successional sequences described:

- A community type may be late successional and relatively stable on one site, and temporary and successional on another site.
- Succession may be roughly cyclic or unidirectional.
- Site conditions are inherently unstable in some successional sequences.
- Species composition may be dependent on unstable rather than stable site conditions.

Landscape—This classification level is defined in ECOMAP (1993) as follows:

> At the Landscape scale, ecological units are defined by general topography, geomorphic process, surficial geology, soil and potential natural community patterns and local climate (Forman and Godron 1986). These factors affect biotic distributions, hydrologic function, natural disturbance regimes and general land use. Local landform patterns become apparent at this classification level, and differences among units are usually obvious to on-the-ground observers. At this level, terrestrial features and processes may also have a strong influence on ecological characteristics of aquatic habitats (Platts 1979). Landscape ecological units represent this scale in the hierarchy.

Landscapes (named landtype associations in the ECOMAP hierarchy) are groupings of land "based upon similarities in geomorphic process, geologic rock types, soil complexes, stream types, lakes, wetlands, and series, subseries, or plant association vegetation communities. Repeatable patterns of soil complexes and plant communities are useful in delineating map units at this level. Names of landtype associations are often derived from geomorphic history and vegetation community."

Other vegetation and site related ecological terms such as **habitat type, climax community, plant association,** and **ecological site type** are commonly used in this geographic region. Classifications based on these concepts have proven to be highly effective as management tools in the Western United States. Although this classification is not based on these concepts, they are in common enough use to warrant definition and discussion.

- **Habitat type—**As defined by Daubenmire (1968), habitat type refers to the land area (site) that supports, or has the potential of supporting, the same climax vegetation. Site conditions may change over time in a predictable manner. Although any given habitat type may support various successional communities, the ultimate end product of vegetation succession anywhere within that habitat type will be a similar plant community.

- **Climax community—**The climax community is the final or steady state plant community that is self-perpetuating and in dynamic equilibrium with its environment.

- **Plant association—**The plant association is named after the climax community (Daubenmire 1968).

- **Ecological site—**Ecological site (synonymous with **range site**) is a kind of land with a specific potential native vegetation and specific physical site characteristics, differing from other kinds of land in its ability to produce vegetation and to respond to management (USDA Soil Conservation Service 1983). Climate, soils, and vegetation are used to define the sites.

Habitat type and plant association classifications were originally developed primarily for the management concerns of silviculturists who need accurate assessments of future timber availability (climax vegetation), timber productivity, species selection for regeneration and rehabilitation methods, and successional trends following disturbance. Within Alaska, Borchers and others (1989), DeMeo and others (1992), DeVelice and others (1994), and Martin and others (1995) have developed plant association classifications for the coastal rain forests.

Ecological site type classifications were developed for range and soil conservationists who need site productivity (for determining animal unit months) and soil erosion capability. An example in Alaska is the classification by Clark and Kautz (1993). Both community type and classifications based on climax communities (habitat type, plant association, and ecological site) reflect ecological conditions, and each has its limitations, the primary ones being (1) community types give no indication of succession, and (2) classifications based on climax do not describe the successional communities.

Historical arguments (Gleason 1917, 1927) against the concept of climax are continually updated (Sprugel 1990). The argument is that vegetation communities are continually adapting to a new and unique set of biotic and abiotic conditions over time. Consequently, stable communities do not exist in nature or are only a temporary phenomenon. These changing conditions include species migration, disease, climatic cycles, and long-term climate change. Other studies focusing on riparian-wetland and northern boreal ecosystems have cast doubt on the applicability of climax (Larsen 1980, Van Der Valk and Davis 1978, Youngblood and others 1985). Van Der Valk and Davis (1978) theorized that short-term climatic cycles have drastic effects on palustrine water levels leading to cyclical vegetation succession. Hansen and others (1995) present evidence of community types being both successional and climax. Site variables such as organic matter and siltation can change rapidly in late-successional riparian-wetland ecosystems contradicting one of the basic precepts of habitat types, that of relatively stable site conditions.

Habitat type classifications often use the term community type to represent only successional communities; the climax community is given the name plant association (Hansen and others 1995, Hoffman and Alexander 1976). This classification uses the term community type to describe all communities, with no indication of successional status and is consistent with usage by other authors (Padgett and others 1989, Youngblood and others 1985).

Additional terms commonly used within this report are ecosystem, landform, landscape, and geomorphology. An **ecosystem** is a community and its environment treated together as a functional system. The community, ranging in size from small ponds to entire forests, interacts with the climate and soil, transferring and circulating energy and matter (Whittaker 1975). **Landform** refers to the form of the land surface and associated ecosystems (Swanson and others 1988) at a smaller scale than associated with landscapes. Within this classification, it refers to levees, terraces, channels, sloughs, oxbows, ponds, dunes, and slacks. A larger land unit than landform is called **landscape**. This includes moraines, outwash plains, and deltas. **Geomorphic** process refers to the mechanical transport of organic and inorganic material such as mass movement, surface erosion, the transport of material (silt) by water, and biogenic soil movement by root throw and animals (Swanson and others 1988). Recognizable vegetation successional schemes driven by the abiotic and biotic factors are associated with these landforms and geomorphic processes.

Methods

Landscape types were determined from field observations, soil type maps (Davidson and Klinge 1992), and by contrasting drainage, topography, and vegetation patterns from aerial photographs. The landscapes include outwash plain, floodplain, linear dune, uplifted marsh, tidal marsh (estuary), and barrier island-spit-coastal dune. All are based primarily on geomorphology and are well defined by many authors (Carter 1988, ECOMAP 1993, Ritter 1986).

Successional sequences were determined by qualitative and quantitative field information and a literature review. Site characteristics tend to change rapidly on the region’s landscapes; consequently, site characteristics were measured and interpreted to reflect vegetation and landform succession. Examples are vegetation occurring on progressively older and higher alluvial deposits along rivers, filling of ponds with peat, paludification, or dunes that build in height and distance from the beach front. Changes in vegetation also were recorded when temporal gradients were observed. These include progressively older forest sites and, when possible, shrub sites. Similar successional sequences have been recorded in other regions and were helpful in interpreting vegetation and landform succession on the Copper River Delta. The site and vegetation data collection methods for succession are given in the field methods section (below) and were collected concurrently with community-type plot data.

Community types were defined from a database of 471 plots. Plots were sampled by sources shown in the following tabulation:

No. of plots	Year	Source of plot data
32	1989	Chugach National Forest
114	1992	Alaska Natural Heritage Program and Chugach National Forest
140	1993	Alaska Natural Heritage Program and Chugach National Forest
54	1993	USDA Copper River Delta Institute and Alaska Natural Heritage Program
131	1994	Alaska Natural Heritage Program and Chugach National Forest

Field Methods

Site selection was based on stratified random sampling methods (Mueller-Dombois and Ellenberg 1974, Steel and Torrie 1960) and involved (1) the broad stratification of the Copper River Delta into relatively even-sized strata (fig. 1), (2) randomly locating sampling points within these strata, and (3) sampling one site of each vegetation community found near the sampling point. The strengths of stratified random sampling are that stratification ensures sampling across the range of plant communities, and that locating the sampling points randomly within the strata allows a statistical error term to be assigned to any derived mean values (Mueller-Dombois and Ellenberg 1974, Steel and Torrie 1960). The use of total random placement of plots across the study area was precluded because of (1) the clumped distribution of vegetation that could lead to oversampling or undersampling of some communities and (2) the fact that rare communities could be overlooked.

Before field sampling, the Copper River Delta was stratified into nine relatively even-sized strata by using soils and vegetation. Soil divisions were based on the “general soils” described by Davidson and Klinge (1992) for the Copper River Delta area. These include the Saddlebag-Tiedeman, Ashman-Pete Dahl-Cryaquents, Softuk-Alaganik, Eyak, and Kokinhenik-Cryopsamments-Katalla associations, and the Kokinhenik and Deadwood consociations (see the “Soils” section in Davidson and Klinge [1992] for full soil descriptions). Further divisions of the strata were based on vegetation interpretation from infrared aerial photography. Strata were subdivided when they showed more than one distinct pattern of vegetation life form. In general, the strata corresponded to the defined landscapes (fig. 1).

Sixty sampling points were randomly located within the nine strata by using a grid and random numbers table. The number of sampling points for each stratum was weighted by total stratum area. The least number of sampling points was six, in what was later defined as the barrier island-spit-coastal dune landscape. Some sampling points were located because of ease of access and consequently do not constitute a random sample.

Each sample point was visited, and a list of vegetatively distinct sites (communities) was made during reconnaissance of the area. Each site was a homogeneous vegetation unit. One transect was then laid out and spanned as many sites as possible. The transect represented a moisture or soil gradient (catena), such as from emergent vegetation in ponds to shrub-dominated pond levees, or from newly colonized alluvial deposits along rivers to raised alluvial terraces dominated by old-growth spruce. The assumption was that at least part of the chronosequence was a successional sequence.

One example of each distinct site was sampled along the transect. Selection of sites to sample was similar to the approach termed "subjective sampling without preconceived bias" as described by Mueller-Dombois and Ellenberg (1974). Site selection was based on homogeneous vegetation. They were not chosen with regard to their position in any classification, extant or envisioned, or by applicability to specific management considerations (Cooper and others 1991, Hansen and others 1995, Pfister and others 1977, Youngblood and others 1985).

Along each transect, the following information was recorded between sites: changes in relative site elevation (measured at the soil surface), water level, depth to mineral soil, and depth of the histic layer. These measurements were recorded from a single soil pit per site and an abney level and measuring stick. Elevation of the soil surface relative to the low vegetation line (always on new alluvial deposits) was used adjacent to riverine systems.

One plot was located in each site. Circular 4,032-square-foot plots were used for forested communities, and rectangular 16- by 33-foot (538-square-foot) plots were used for the shrub and herbaceous communities. Within sites too narrow to enclose a plot, I used correspondingly narrow plots; in these cases, total plot area was maintained.

Vascular and nonvascular vegetation information within the plots was collected by using USDA Chugach National Forest vegetation plot methods (DeVelice and Hubbard 1993). Six-letter codes were used to abbreviate species names on the data sheets. The six-letter code for a species is the first three letters from both the genus and specific epithet. These codes follow the USDA Chugach National Forest vascular and nonvascular species list that is based on Hultén (1968). See DeVelice and Hubbard (1993) for a complete description of the methods and codes used.

Canopy cover was estimated visually (Brown 1954) for each species and was defined as the percentage of the ground in the plot covered by the gross outline of the foliage an of an individual plant (canopy), or the outline collectively covered by all individuals of a species or life form within the plot (Daubenmire 1959). Canopy cover classes were used for estimation and are given in table 1. Plant specimens not identified in the field were collected and identified in the office or at the University of Alaska Fairbanks Herbarium.

Canopy height was measured for all species. A measuring tape and abney level were used to measure plants over 10 feet tall. Shorter plants were measured with a tape measure or were estimated.

Table 1—Canopy cover classes and their range of percentage of cover values

Class	Range of class
	Percent
1	0 to < 1
3	1 to < 5
10	5 to < 15
20	15 to < 25
30	25 to < 35
40	35 to < 45
50	45 to < 55
60	55 to < 65
70	65 to < 75
80	75 to < 85
90	85 to < 95
98	95 to < 100

Table 2—Tree size group categories and their range of values by using diameter at breast height (d.b.h.), tree height, or percentage of dead canopy

Age group	Range for age group
Seedling	< 1 inch d.b.h. or < 4.5 foot height
Sapling	1 to < 5 inches d.b.h. or > 4.5 foot height
Pole	5 to < 9 inches d.b.h.
Mature	9 to < 14 inches d.b.h.
Mature plus	> 14 inches d.b.h.
Dead	100 percent of the canopy is dead

The canopy of tree species was divided into size groups to evaluate regeneration and structure of the trees within each plot. Two separate measures were made, tree height and diameter at breast height (d.b.h.). Tree height ranges are < 8 inches tall, 8 inches to < 10 feet, 10 to < 50 feet, and > 50 feet; diameter at breast height ranges are given in table 2. Each size group was assigned a canopy cover reflecting its relative share (of 100 percent) of the species canopy cover. The size group categories totaled 100 percent within each species.

Similarly, each shrub species was divided into age groups to evaluate regeneration and structure of the shrubs within each plot. The structural layers were based on relative maturity of the plants as defined in table 3.

Vertical structure was further described by recording cover values by structural layer. The canopy cover for each of the plant life forms (tree, shrub, graminoid, forb, fern-allies, moss, and lichen) in various structural layers were recorded. The tree structural layers were based on tree height, and their ranges are < 8 inches tall, 8 inches to < 10 feet, 10 to < 50 feet, and > 50 feet. The shrub, graminoid, and forb layers were based on height and are < 8 inches, 8 inches to < 5 feet, and > 5 feet. Summing of the cover values within each structural layer may total greater than 100 percent. This showed that the vegetation was layered and overlapping.

Table 3—Shrub age group category definitions

Age group	Range for age groups
Young	Typically with < 2 years woody growth aboveground; growth may be vegetative (including buried stems) or from seed
Mature	1. Typically with > 2 years woody growth aboveground 2. Less than 30 percent of the canopy is dead 3. Reproductive ability; evident flowers, seeds, or other reproductive structures
Decadent	Greater than 30 percent of the canopy is dead
Dead	100 percent of the canopy is dead

Table 4—Ground cover categories and definitions

Category	Description
Bare soil	Less than 1/16-inch diameter soil particles and ash
Gravel	1/16 to < 3 inches diameter
Rock	Greater than 3 inches diameter
Litter and duff	Litter includes leaves, needles, twigs, fecal material, bark, and fruits; duff is the fermentation and humus sections of the organic layer
Wood	Downed wood fragments > 1/4-inch diameter
Cryptograms	All bryophytes, club mosses, and lichens
Basal vegetation	The soil surface taken up by the live basal or root crown portion of plants
Water	That portion of the area of the plot covered by water at the time of sampling

Tree age was estimated by counting the rings of one average-sized tree less than 50 feet tall, and from one tree greater than 50 feet tall from each plot. Seedlings and saplings trees were cut and aged at the base. Pole and mature trees were cored and aged at breast height. Diameter at breast height, tree height, and the number of rings from the outer 1 inch of wood (increment) also were recorded for each tree that was aged. Shrub age was estimated by counting the rings at the plant base of an average-sized shrub from each plot.

Basal area of live trees and the number of dead trees were recorded for each plot. Dead trees were recorded in four d.b.h. categories (5 to < 9 inches, 9 to < 21 inches, 21 to < 33 inches, and > 33 inches), and their average height was recorded within each plot.

Ground cover information was collected for each plot. The categories are presented in table 4. The percentages for the ground cover categories typically summed to about 100 percent, though the sum ranged from 90 to 110 percent. Downed coarse wood was omitted from the above categories because it was invariably covered by moss, masking the actual cover of dead wood. Consequently, a separate downed wood category was created. The percentage of the surface within the plot that was covered by woody debris greater than 5 inches in diameter was recorded. The average diameter of the downed coarse wood also was recorded.

The following site variables were recorded within each plot: surficial deposit, landform, plot position, vertical slope shape, horizontal slope shape, aspect, slope, elevation, horizontal angle, other comments, and successional comments. Other recorded variables included plot number, date, other forms, observers, general location, United States Geological Survey (USGS) quadrangle, airphoto number, community size, and location (township, range, section, ¼ section, and ¼ ¼ section). A photographic record was taken for each site.

One complete soil pedon was sampled per plot, when time allowed. Soil characteristics included soil horizons, horizon depth, color, texture, size and shape of coarse fragments, depth and size of plant roots, and water table depth (Davidson and Klinge 1992). When a complete soil pedon was not sampled, a 20-inch soil core was used. A minimum of the following information was recorded: horizon depth, texture, size of coarse fragments, and water table depth.

Data Analysis

The following methods were used to define the community types of the Copper River Delta. The scientific name and corresponding canopy cover values were entered into Paradox[2] (Borland International 1993), a database program. The Paradox files were then ported to ECOAID, a computer data analysis system (Smith 1990) capable of summarizing large quantities of vegetation and environmental data. SYNTAX, a computer multivariate data analysis program for ecology and systematics (Podani 1993), was used to group the plots into community types.

To improve data analysis, the following species were combined before analysis: all mosses except *Sphagnum* (peat moss), all *Sphagnum* (peat moss) species, all lichen species, *Puccinellia nutkaensis* (Pacific alkaligrass) and *Puccinellia pumila* (dwarf alkaligrass), *Deschampsia caespitosa* (tufted hairgrass) and *Deschampsia beringensis* (Bering hairgrass), and *Vaccinium ovalifolium* (tall blueberry) and *V. alaskensis* (Alaska blueberry). Scientific names of plants are from Hultén (1968).

A stepwise procedure of successive approximations was used to classify the community types (Pfister and Arno 1980). Association tables of the preliminary dominance-type groupings were created by using the species and cover data. Two-way indicator species analysis (Hill 1979), detrended correspondence analysis (Hill and Gauch 1980), and hierarchical clustering (Ludwig and Reynolds 1988) by using average links, percentage difference, and dissimilarity were used for further approximations of groups.

Percentage of canopy cover breaks by life form play a critical role in community groupings. The artificial canopy cover breaks of 10 percent, 25 percent, and 60 percent have been widely used in the literature to separate forest, shrub, and herbaceous communities (Hansen and others 1995, Pfister and others 1977, Viereck and others 1992, Youngblood and others 1985). I attempted to justify these canopy cover breaks by life form (tree, shrub, and herbaceous) by using ordination and hierarchical clustering data analysis techniques. The results suggested that using a single cover break (such as 25 percent) to separate all tree communities from all shrub communities was

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[2] The use of trade or firm names in this publication is for reader information and does not imply endorsement by the U.S. Department of Agriculture of any product or service.

not reliable. Community types, however, often could be statistically separated by using canopy cover breaks. Consequently, the most statistically relevant cover breaks are those using a single species or group of species, and not a generic life form break. For example, 50 percent *Alnus crispa* subsp. *sinuata* (Sitka alder) combined with 30 percent *Equisetum arvense* (meadow horsetail) are statistically supportable cover breaks for defining the *Alnus crispa/Equisetum arvense* (Sitka alder/meadow horsetail) community type. Unfortunately, the generic 25-percent-cover break to define shrub types would necessitate the inclusion of all stands with alder cover between 26 and 49 percent in this community type.

Although the 10- and 25-percent breaks are artificial, these standard cover breaks were used within this classification. This is because of their wide use throughout the classification literature and to fit this classification in with already established classifications for the region. I feel that future classifications should not necessarily hold to these artificial life form cover breaks and, in addition, use other vegetative components, such as community structure (mature stand versus old-growth stand), to separate communities.

A dichotomous key was developed during the process of successive approximations. Typically, the presence or absence of the dominant species representing each community type was used as the indicator species within the key.

A community type description was prepared for each type. The descriptions were based on species lists, canopy cover, structure, and site information. Constancy-coverage tables (appendix tables 12-19) were created for each defined community type.

Three classifications based on forested plant associations (DeMeo and others 1992, Martin and others 1995, Pawuk and Kissinger 1989) and two based on community types (DeVelice and others 1994, Shephard 1995) for the coastal zones of southeast and south-central Alaska are in common use. I attempted to adopt their defined plant associations and community types; however, some types were designated by using different criteria and thus are not equivalent. Consequently, I selected the plant associations from these classifications that best fit the forested vegetation found on the Copper River Delta.

Rarity Status of Landscapes and Community Types

Landscapes

The rarity status of all landscapes described for the Copper River Delta is presented below. The status of each landscape is given for both Alaska and the Copper River Delta. Rarity determinations of landscapes were based on ground observations and topographic maps. When the ECOMAP (1993) project is completed at the landscape level for Alaska, more accurate analyses can be made concerning rarity of ecosystems.

Outwash plains are common on the Copper River Delta and throughout south-central and southeast Alaska.

Floodplains are uncommon on the Copper River Delta but are common in southeast Alaska.

Uplifted marshes of the Copper River Delta are significant because of the extensive area of tidal marsh that was affected. Because of the high frequency of tectonic activity found throughout coastal Alaska, the uplifted marsh landscape is not necessarily uncommon. However, tidal marshes uplifted to a comparable height and of a similar age, are likely rare.

Linear dunes are uncommon on the Copper River Delta. Their distribution is poorly known throughout Alaska but appears to be rare. Further regional studies are necessary to quantify their importance and distribution. A rare combination of environmental factors helps make this ecosystem unique. The Copper River is one of the four rivers (Copper, Alsek, Taku, and Stikine) that dissect the coastal mountain ranges of south-central and southeast Alaska and allow direct contacts between the interior and coastal air masses. The Copper River valley acts as an air corridor between the interior and coast resulting in high sustained winter winds as the cold interior air masses move to the coast. There they meet the warmer coastal air mass to create a microclimate of high winter winds, alternating cold and moderate temperatures, high snow fall, late snow melts including some snowbanks that may persist through summer, and wind-blown loess.

Tidal marshes comprise only a minor percentage of the Copper River Delta. They are widely distributed throughout south-central and southeast Alaska, but their total area is small. Many community types and plant species have a high fidelity to this type and rarely occur on other landscapes. Other tidal marshes of south-central and southeast Alaska contain communities and successional pathways that are similar to those of the Copper River Delta. Because of the infrequency of this landscape throughout south-central and southeast Alaska, this landscape and some of its community types may be considered rare.

The barrier island-spit-coastal dune landscape is common on the seaward edge of the Copper River Delta. Barrier islands are different from coastal dunes and spits in that they are separated from the mainland by channels and an estuary. This separation from the mainland provides habitat for marine mammal haul out grounds, huge bird colonies including the highest nesting density for dusky Canada geese, and as a stopover feeding ground for millions of migrating shorebirds. Coastal dunes and spits are relatively common along the north Pacific coast of North America and along other coasts of the world. The barrier island portion of this landscape, however, is extremely rare within the Humid Temperate domain of North America (northern California through Kodiak Island). Barrier islands are relatively common along the Bering Sea and Arctic Ocean coasts of Alaska and occur on 13 percent of the world's coasts (King 1972). Consequently, on a regional basis, the barrier island portion of the barrier island-spit-coastal dune landscape is rare.

Community Types

The rare community type section is presented in two categories: (1) communities that are rare statewide and (2) communities that are rare only within the region of the Copper River Delta. The conservation global ranking (G1, G2, etc.) and state ranking (S1, S2, etc.) status of each community type are given (DeLapp 1991). Global ranks are defined as G1 = critically imperiled globally, G2 = imperiled globally, G3 = either very rare and local throughout its range or found locally in a restricted range, and G? = rarity status unknown. Rarity determinations of community types were based on ground observations and a literature review. Summaries presented in tables 5 and 6.

Table 5—List of statewide rare community types on various landscapes

Community type	Landscape
Carex lyngbyaei-Lathyrus palustris (Lyngby's sedge-vetchling)	Uplifted marsh
Myrica gale/Carex lyngbyaei (sweetgale/Lyngby's sedge)	Uplifted marsh/tidal marsh
Myrica gale/Epilobium angustifolium (sweetgale/fireweed)	Uplifted marsh/slack-coastal dune
Poa macrantha (seashore bluegrass)	Coastal dune
Salix arctica/Carex lyngbyaei (arctic willow/Lyngby's sedge)	Uplifted marsh
Zannichellia palustris (horned pondweed)	Tidal marsh/uplifted marsh

Table 6—List of communities, and associated landscapes, that are rare only within the region of the Copper River Delta

Community type	Landscape
Carex chordorrhiza (creeping sedge)	Uplifted marsh
Carex rostrata (beaked sedge)	Outwash plain of Copper River
Hierochloe odorata (vanilla grass)	Distal outwash plain
Hippuris tetraphylla (four-leaf marestail)	Tidal marsh
Poa macrantha (seashore bluegrass)	Coastal dune
Salix alaxensis (feltleaf willow)	Linear dune
Tsuga heterophylla/Vaccinium ovalifolium/Lysichiton americanum (western hemlock/tall blueberry/yellow-skunk cabbage)	Distal-proximal outwash plain
Zannichellia palustris (horned pondweed)	Tidal marsh/uplifted marsh

Statewide Rare Communities

The *Carex lyngbyaei-Lathyrus palustris* (Lyngby's sedge-vetchling) c.t. (G2; S2) is a major type of the Copper River Delta but rare in the remainder of Alaska. It is found on root mats or mineral soils on uplifted marshes with semipermanent standing water.

The *Myrica gale/Carex lyngbyaei* (sweetgale/Lyngby's sedge) c.t. (G?; S2) is a major type on the Copper River Delta but rare in the rest of Alaska. It is found on saturated peat between levees and ponds, wet levees, and raised peat on uplifted marshes and on tidal marshes.

The *Myrica gale/Epilobium angustifolium* (sweetgale/fireweed) c.t. (G?; S2) is found on poorly drained levees of uplifted marshes and slacks of coastal dunes.

The *Poa macrantha* (seashore bluegrass) c.t. (G?; S1) is found on the barrier island-spit-coastal dune landscape. It is more common (at least at the species level) in Washington, Oregon, and California.

The *Salix arctica/Carex lyngbyaei* (arctic willow/Lyngby's sedge) c.t. (G?; S1) has not been previously described in the literature. It is found on the uplifted marshes at the mouth of the Copper River on moist levees or pond edges.

The *Zannichellia palustris* (horned pondweed) c.t. (G?; S2) is found in freshwater ponds and, possibly, brackish water ponds along much of coastal Alaska (Crow 1979).

Copper River Delta rare communities—The *Carex chordorrhiza* (creeping sedge) c.t. (not ranked) is limited to ponds of the uplifted marsh on the Copper River Delta. Similar *Carex chordorrhiza* (creeping sedge) c.t.'s are found throughout south-central and southwest Alaska.

The *Carex rostrata* (beaked sedge) c.t. (G5; S5) is limited to ponds on terraces of the Copper River but is a common emergent sedge community of interior Alaska.

The *Hierochloe odorata* (vanilla grass) c.t. (not ranked) is limited to pond edges along the distal outwash of the Copper River Delta. This community has not been previously described in Alaska. It likely occurs, however, in other regions of Alaska.

The *Hippuris tetraphylla* (four-leaf marestail) c.t. (not ranked) is rare on the Copper River Delta but is widely distributed in brackish marshes along much of coastal Alaska.

The *Poa macrantha* (seashore bluegrass) c.t. (G?; S1) is rare in Alaska and the Copper River Delta. It is found only on the barrier island-spit-coastal dune landscape.

The *Salix alaxensis* (feltleaf willow) c.t. (not ranked) occurs on the linear dune landscape and has a limited distribution. Many *Salix alaxensis* (feltleaf willow) community types have been defined throughout Alaska.

The *Tsuga heterophylla/Vaccinium ovalifolium/Lysichiton americanum* (western hemlock/tall blueberry/yellow skunk cabbage) c.t. (G5; S5) occurs on both proximal and distal outwash deposits of the Copper River Delta, and on the boundary of the uplifted marsh and distal outwash. This community is common in the adjacent valleys, mountains, and throughout south-central and southeast Alaska.

The *Zannichellia palustris* (horned pondweed) c.t. (G?; S2) is rare in Alaska and on the Copper River Delta (Crow 1979). It is found in freshwater ponds and, possibly, brackish water ponds.

Landscape Descriptions

This section provides an overview of the major processes that have led to the formation of the Copper River Delta, followed by descriptions of landscapes (landtype associations [ECOMAP 1993]). Geomorphology is the primary environmental factor controlling succession at the landscape level for the Copper River Delta. Interactions between the basic geomorphic processes of hydrology, sedimentation, and wind strongly influence the landforms, disturbance regimes, soils, nutrient cycles, and vegetation. Consequently, the study area was divided into the following six geomorphic based landscapes: outwash plain, floodplain, linear dune, uplifted marsh, tidal marsh, and barrier island-spit-coastal dune (fig. 2). These landscape delineations are similar to those used by Davidson and Klinge (1992) and Thilenius (1990) for the Copper River Delta.

Overview of Processes Forming the Copper River Delta

The environmental factors that formed the contiguous outwash plains and deltas of the Copper River Delta region function on different temporal and spatial scales, which are not limited by the boundaries of landscapes or communities. The dominating environmental factors are hydrology, sediment supply, changes in sea level, nearshore ocean currents, and glacial advance and retreat. A broad-scale understanding of these factors and how they interact is critical to understanding vegetation succession and geomorphology of the region.

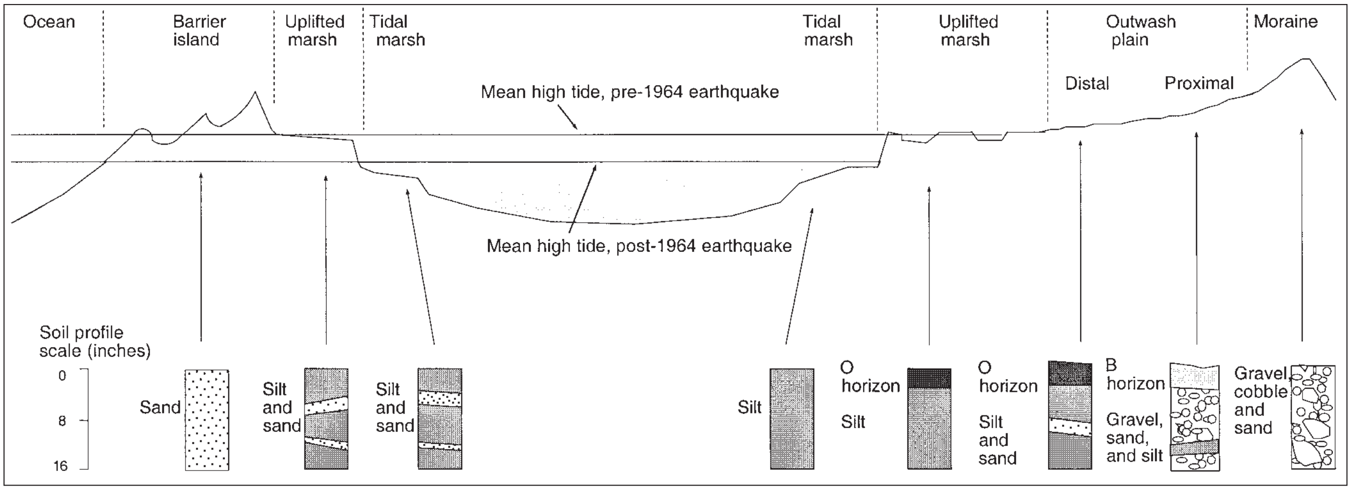

Figure 2—Idealized cross section of the major landscapes and soil characteristics on the Copper River Delta.

The primary environmental factor in the formation of the delta of the Copper River is the tremendous sediment load delivered to the coast by the Copper River, at the rate of 97,000,000 metric tons per year (Hampton and others 1987). Without this continual delivery of sediment, the delta would not have formed or maintained itself. When the river enters the calmer waters of the ocean, water velocity decreases, thereby resulting in rapid deposition of the sediment load in the river. Progradation of the delta front occurs if sedimentation on a delta exceeds erosion, whereas vertical expansion of the delta surface (elevation) is limited by the maximum water height of the tide.

Erosion of the delta front, channels, and tideflats is dependent on the hydrologic energy of the tide, waves, and nearshore and offshore currents (Alaska Current). Their hydrologic energy is high on the Copper River Delta, thereby suggesting that it should rapidly erode, but the tremendous sediment load delivered by the Copper River seems to compensate for the high water energy. The uplifted marsh, tidal marsh, subtidal and, to a large degree, barrier island and spit landscapes were all formed from these deltaic deposits. They likely underlie all other landforms of the Copper River Delta.

Sea level changes caused by tectonic uplift and subsidence have a significant influence on the size of the delta. The repeated tectonic uplift of the region (about every 600 years) lifts portions of the tideflats and tidal marshes out of the ocean and expand the delta front seaward. However, this is more than compensated for by regional subsidence that, in time, lowers the original uplifted marsh and tideflat surfaces below sea level. As the tidal water invades the uplifted surfaces, marine deltaic sediments are deposited. Sedimentation rates seem to equal subsidence rates, thereby allowing for maintenance of the intertidal land. The net effects of tectonic uplift, subsidence and sedimentation, are expansions of the delta front seaward and expansion of the tidal and uplifted marshes. This cycle has been relatively stable over the last 5,000 years, which marks the end of the post-Pleistocene rapid increase in sea level (Plafker and others 1990).

On the delta front, barrier islands and spits form the seaward edge of the estuary (figs. 1 and 2). The islands and spits are maintained by silt and sand that are transported by near-shore currents, waves, and wind parallel to shore. The sediment is eventually stabilized by vegetation or deposited in a zone of slack water; consequently, the islands and spits migrate parallel to the direction of transport. The islands and spits shelter the estuary from ocean currents and waves. The resultant low hydrologic energy and surplus of fine sediment provide excellent conditions for marsh development on the edges of the estuary.

Glacial outwash plains are found on top of or layered into the marine deltaic deposits. They are formed when streams from glacial meltwater distribute sediment downward along the valley as a massive plain. These plains are often highly dynamic because of high rates of erosion, deposition, and vegetation establishment. Glacial cycles of retreat and advance will strongly affect the deposits, with glacial advance physically covering the landscape, and glacial retreat uncovering land forming glacial lakes, kettle-kame topography, and outwash plains. Streamflow and sedimentation rates are also significantly altered because of glacial cycles, and affects channel pattern, channel location, and the general dynamics of outwash plains.

In summary, the Copper River supplies the primary sediment load necessary for the development of the delta (figs. 1 and 2). Nearshore transport of sediment on the edge of the delta maintains the barrier islands and spits that form the seaward border of the estuary. The estuary is sheltered from offshore ocean currents and waves by the barrier islands and spits, which enables tidal marshes to form on the edges of the estuary. The glaciers flowing from drainages feeding the Copper River Delta advance and retreat over time, destroying and creating new landscapes. Glacial streams deposit sediment across the delta as massive outwash plains.

Outwash Plain Landscape

Landform—An outwash plain is a broad fluvial plain consisting of braided and meandering active streams, abandoned channels, forest or shrub-dominated alluvial terraces or levees of varying levels, and ponds (fig. 3). On the proximal outwash deposits (closer to the glacier), the terrain is rough, often with incised stream channels and abrupt terraces. In contrast, the distal outwash deposits (further from the glacier) are relatively smooth with less elevation change between the channels and levees or terraces. Ponds are rare on the proximal outwash, and more common on the distal sections. Late successional vegetation on the proximal outwash is forest dominated by Sitka spruce and western hemlock, whereas late successional vegetation on the distal outwash is dominated by peatlands with stringers of shrub and forest that have formed on levees.

Distribution—Outwash plains, along with uplifted marshes, are the dominant landscapes on the Copper River Delta (figs. 1 and 2). Examples of outwash plains include the terraces of the Copper River, and the lands below the major glaciers such as the Scott, Sheridan, Sherman, Saddlebag, Miles, Martin, Kushtaka, and Bering. These lands form nearly all the area between the mountain-glacier bases and the uplifted marsh.

Processes—Outwash plains are formed by glacial streams that spread sediment across wide areas as a massive plain. A stream or a series of streams from the glacial meltwater breaches the terminal moraine to distribute material downward along the valley in more or less distinctly stratified deposits. To a degree, outwash plains are analogous to alluvial fans, except that outwash stream hydrology is controlled by rapid and drastic changes in discharge rates. The outwash plains on the study area are highly

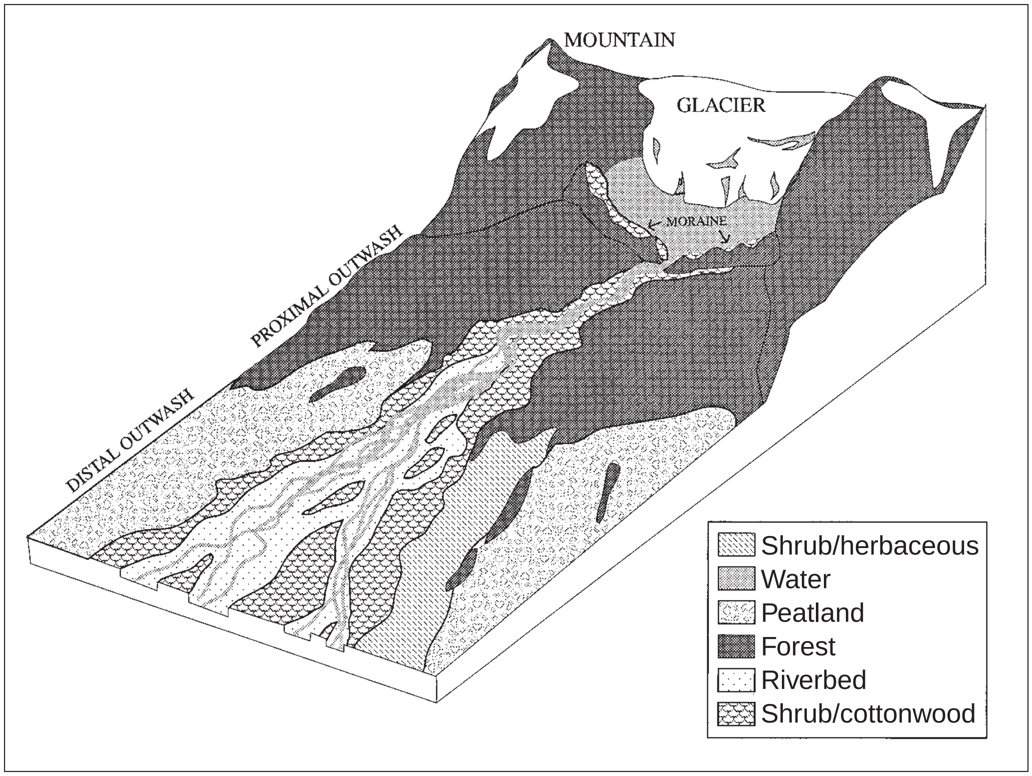

Figure 3—Oblique view of an idealized glacial outwash plain.

active and disturbance prone ecosystems. Floodplains occupy one end in the continuum of change as a glacially fed system converts to a nonglacially fed system; the fluvial reworking of the outwash deposits are considered floodplains. The floodplain landscape is described in the next section.

Two primary factors create and sustain the outwash plains: (1) during summer, there are rapid and drastic changes in water discharge rates, and (2) a large sediment supply from morainal deposits and new debris is deposited on the plain. The rapid changes in discharge rate are because of the release of water dammed behind or under the ice, ice-snow melt, and rain. The most extreme change in discharge rate is because of glacial lake discharges or the outburst of water impounded beneath glaciers. Glacial lake discharges are caused by the sudden release of glacial lake water when ice dams suddenly lift. The subsequent glacial flood inundates and scours substantial sections of the plain, often causing drastic shifts in the drainage pattern. The exact frequency of glacial lake discharges or outbursts is difficult to determine because of a lack of consistent data; some plains, however, have flooding events that occur every 10 years or less.

The volume of fluvially delivered outwash sediment influences deposition, erosion, and progradation on the outwash plain (Boothroyd and Ashley 1975). Horizontal deposition and progradation of the outwash front will occur during depositional periods, established by the balance between water volume and sediment load. The surface also may be at semiequilibrium or an erosional state. Channel downcutting also occurs and leads to channel entrenchment and the formation of high, and often well-drained, terraces. The portion of the outwash plain disturbed annually differs greatly. Below the Scott Glacier, virtually the entire outwash plain is flooded and disturbed annually. Consequently, the vegetation is either absent or in an early successional stage. In contrast, the Martin River floods a smaller portion of its outwash plain. It has vegetation ranging from early to late successional stages. Proximal outwash plains of the Copper River Delta tend to be steeper than the distal outwash, the average slope being 41.3 feet per mile and abruptly decreasing to 8.8 feet per mile on the distal outwash (Thilenius 1990).

The available vegetation literature on outwash plains (Scott 1974, Shephard 1995, Thilenius 1990, Viereck 1966) concentrates on soil-vegetation-landform interactions but also speculates on the response of vegetation to stabilization of the substrate and vegetation as glaciers retreat. This classification and Shephard (1995) link temporal and spatial changes in the dominant vegetation to changes in substrate and hydrology. As they move down-slope on an outwash plain, substrate deposits fine out, progressing from cobble, gravel, sand, and silt to clays. Water drainage also changes with distance from the glacier terminus. Terraces on the proximal outwash typically are well drained, whereas the distal portions are poorly drained with water tables often at the soil surface. This is because of the fine-textured substrate of the distal outwash perching the water table.

Succession of entire outwash plain ecosystems can be observed in the study area because of various recessional glacial sequences, with glacier positions ranging from near tidewater (Bering Glacier), to midvalley, to grounded on uplands. The response of a glacier's terminus to climatic variations of relatively low magnitude is often rapid (Porter 1986). For small low- and mid-latitude glaciers, the lag in dynamic response of the terminus to climatic changes is generally rapid, often a decade or less. For example, a glacial spur in Glacier Bay, Alaska, retreated 5.4 miles in the last 20 years (Fastie 1995). Consequently, for management purposes, it is not only necessary to understand vegetation and landform dynamics on outwash plains with relatively stable glaciers, but it is also important to understand these dynamics as glaciers advance or retreat.

The 1964-uplift of the delta seems to have had no effect on outwash plains. They were never tidally influenced, and the land gradient was not significantly altered.

Channel pattern—The movement of a glacial river across its plain determines the river channel pattern: straight, meandering, or braided. Each pattern can be found on outwash plains, often near each other, although straight channels are typically rare, with braided and meandering channels dominating the system. Rivers on outwash plains are similar to nonglacial rivers except that because of the rapid changes in discharge, channel movement and deposition-erosion also may be rapid. The following paragraphs describe glacial river channel patterns, erosion and deposition of sediment, and the response of vegetation.

Braided rivers have multiple, wide, shallow channels characterized by rapid erosion, deposition, and channel shifts (fig. 3). Vegetation ranges from sparse to well vegetated (often with *Populus trichocarpa* [black cottonwood] or *Picea sitchensis* [Sitka spruce]) depending on the rate of channel migration. Because of differential sedimentation rates, the active main channels often aggrade to a higher elevation than the smaller channels. The levees and terraces constraining the main channels frequently breach, which leads to rapid changes in the location of the river, leaving a maze of abandoned channels and terraces, often with a relief of 3 to 6 feet. This relief is reduced in the distal outwash plain where channels may become so shallow that the rivers merge into a single sheet of water during high flow. They may eventually grade into a well-defined floodplain, or a marsh and delta.

Meandering glacial rivers have one or two main channels that migrate like a whip or snake across its outwash plain. As water moves downstream, it erodes the outside curves of banks that are covered with riparian vegetation in different stages of succession, and deposits fresh alluvial materials on the point bars of inside curves. Vegetation stabilizes these new deposits. Alluvium also is deposited on the soil surface during flooding, further raising the soil surface height, but because surface height is a function of floodwater height, it eventually stabilizes (Leopold and others 1964). This channel pattern is associated with rivers having headwaters emerging from lakes formed by terminal moraines, as opposed to the braided channel system that typically does not have headwater lakes.

Terraces—For each of the stream channel patterns (straight, braided, and meandering), the lateral movement of rivers or abandonment of channels initiate a dynamic series of vegetation events. Vegetation colonizes and stabilizes each new deposit of alluvium or abandoned channel. Consequently, each deposit supports relatively even-aged vegetation.

Water availability plays a major role in community structure and composition on the terraces. Water inputs are from overbank flow (flooding), groundwater, and precipitation. Deposits with high permeability become progressively drier as they are vertically and horizontally removed from the active channels. This is because of decreased soil water recharge from channel seepage. Vegetation responds to these gradients in soil moisture with changes in composition and structure.

Ponds—Ponds, including meander scrolls and oxbows, on outwash plains are rare on the proximal outwash, but more common on the distal deposits. A meander scroll is formed on the convex side of river bends by alluvial deposition. As alluvium is deposited, it forms point bars and further inland an undulating topography of levees and depression. The meander scroll depressions often are filled with standing water or act as overflow channels during high flows. Oxbows are formed when a river abruptly changes course, cutting off a stream segment. Typically, the oxbow will partially fill with water.

In time, accretion or peat buildup will fill the ponds. Sedimentation rates will differ widely between ponds; some ponds may last for centuries, whereas others will fill in a matter of decades. Ponds closer to the river will fill first because during flooding, more silt is deposited closer to the water source.

Vegetation succession in ponds is highly variable and depends primarily on whether sediment or peat fills the depressions, nutrient availability, and the depth of the water table. Ponds that fill with sediment will progress from aquatic and emergent vegetation

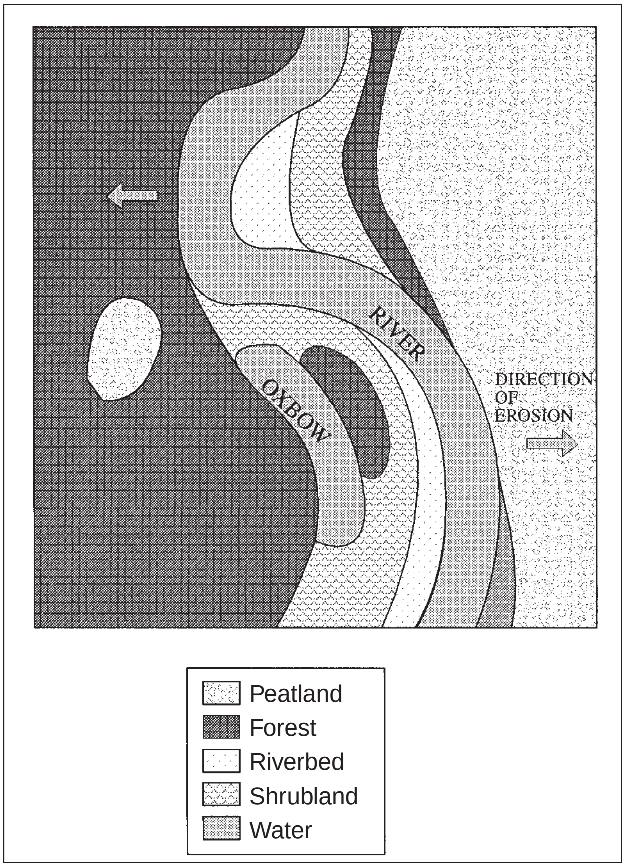

Figure 4—Aerial view of an idealized floodplain.

to terrestrial vegetation, such as alder or cottonwood. Ponds that fill with peat will progress from emergent vegetation to a peatland, such as a fen or bog. Histic soils where peat is mixed with silt or layered together also occur.

Within the system of ponds and levees, water depth, nutrients, pH, and salt concentration drive species composition of a site. Two wetland ecosystems, fens and bogs, dominate the peatlands of the Copper River Delta. Each represents opposing ends of a water and nutrient continuum; fens receive nutrient-rich water from ground water, and bogs receive nutrient-poor water from precipitation. For descriptions of fen and bog succession, see the descriptions of the *Carex sitchensis* (Sitka sedge)-outwash plain s.s. and *Myrica gale/Empetrum nigrum* (sweetgale/crowberry)-outwash plain s.s., respectively.

Floodplain Landscape

Landform—Floodplains are fluvial plains consisting of meandering or straight active streams, abandoned channels, and alluvial terraces (fig. 4). The landscape is dominated by meander scrolls, oxbows, peatlands, and forest or shrub on well-drained terraces of varying levels.

Distribution—Floodplains are an uncommon landscape on the Copper River Delta (figs. 1 and 2). Examples of floodplains include the terraces adjacent to the Katalla River and Martin River Slough.

Processes—Floodplains occupy one end in the continuum of change as a glacially fed system converts to a nonglacially fed system; the fluvial reworking of the outwash deposits are considered floodplains. The formation of new land in floodplain ecosystems is well documented (Friedkin 1972, Leopold and others 1964). Along a meandering river, alluvium typically is deposited on convex curves in the river channel. The opposing concave bank is cut, providing sediment for deposition on convex curves downstream and creating a series of similar bands of alluvial deposits. The channel thus meanders laterally across the floodplain. Vegetation growing on new deposits near the river may be contrasted with that on older deposits inland to recognize and measure successional processes (Linsey and others 1961, Stevens and Walker 1970). Alluvium also is deposited on the soil surface during flooding, further raising the soil surface height, but because surface height is a function of floodwater height, it eventually stabilizes (Leopold and others 1964).

The 1964-uplift of the delta seems to have had little effect on floodplains. They were never tidally influenced, and the land gradient was not significantly altered.

Channel pattern—The movement of a river across its plain determines the river channel pattern: straight, meandering or braided. Each pattern can be found on floodplains. Straight channels typically are formed because of high valley gradients, a constriction in the landscape such as a narrow valley bottom, or downcutting through a terrace. Braided rivers have multiple, wide, shallow channels characterized by rapid erosion, deposition, and channel shifts. Meandering rivers have one or two main channels that migrate like a whip or snake across its floodplain.

Terraces—Water availability on terraces plays a major role in community structure and composition. Water inputs are from overbank flow (flooding), ground water, and precipitation. Deposits with high permeability become progressively drier as they are vertically and horizontally removed from the active channels. This is because of decreased soil water recharge from channel seepage. Vegetation responds to these gradients in soil moisture with changes in composition and structure.

Ponds—Ponds, including meander scrolls and oxbows, on floodplains are common (fig. 4). A meander scroll is formed on the convex side of river bends by alluvial deposition. As alluvium is deposited, it forms point bars and further inland an undulating topography of levees and depressions. The meander scroll depressions often are filled with standing water or act as overflow channels during high flows. Oxbows are formed when a river abruptly changes course cutting off a stream segment. Typically, the oxbow will partially fill with water. In time, accretion or peat buildup will fill the ponds. Sedimentation rates will differ widely among ponds; some ponds may last for centuries whereas others will fill in decades. Ponds closer to the river will fill first because during flooding, more silt is deposited closer to the water source.

Vegetation succession in ponds is highly variable and depends primarily on whether sediment or peat fills the depressions, nutrient availability, and the depth of the water table. Ponds that fill with sediment will progress from aquatic and emergent vegetation to terrestrial vegetation, such as alder or cottonwood. Ponds that fill with peat will progress from emergent vegetation to a peatland, such as a fen or bog. Soils where peat is mixed with silt or layered together also occur.

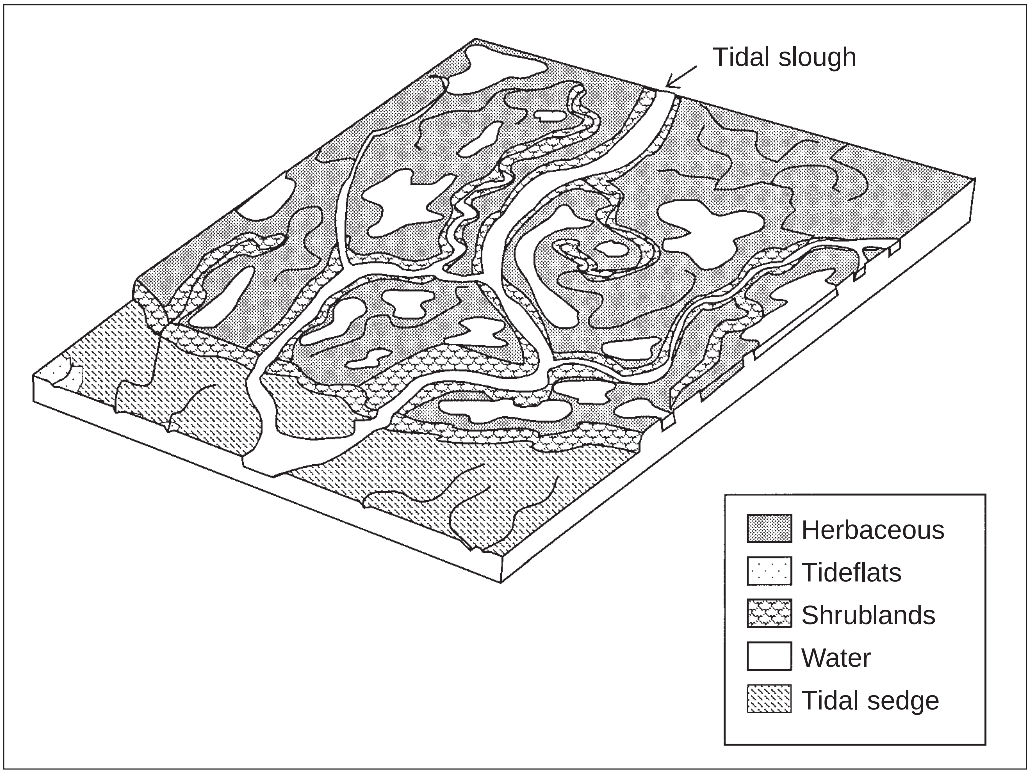

Figure 5—Oblique view of an idealized uplifted tidal marsh.

Within the system of ponds and levees, water depth, nutrients, pH, and salt concentration drive the species composition of a site. Two wetland ecosystems, fens and bogs, dominate the peatlands of the Copper River Delta. Each represents opposing ends of a water and nutrient continuum; fens receive nutrient-rich water from ground water, and bogs receive nutrient-poor water from precipitation. For descriptions of fen and bog succession, see the descriptions of the *Carex sitchensis* (Sitka sedge)-outwash plain s.s. and *Myrica gale/Empetrum nigrum* (sweetgale/crowberry)-outwash plain s.s., respectively (floodplain successional sequences are included in the outwash plain descriptions).

Uplifted Marsh Landscape

Landform—The landforms of the uplifted marsh consist of ponds, levees, freshwater streams, sea cliffs, and tidal creeks (fig. 5). Ponds and levees fed by freshwater streams are found throughout the uplifted marsh, with pond depth ranging from 30 to 45 inches (Thilenius 1990). Sea cliffs front most of the uplifted marsh and range up to 6 feet in height. Tidal creeks form a dendritic pattern within the marsh and are incised because of postearthquake downcutting.

Distribution—Uplifted marshes, along with outwash plains, are the dominant landscapes on the Copper River Delta (figs. 1 and 2). Examples of uplifted marshes are the lands south of the road between Eyak Lake and the Copper River, and land downstream of Martin Lake and Bering Lake. These lands constitute nearly all the area between the outwash plains and the developing tidal marshes.

Processes—The uplifted marsh landscape is the pre-1964 tidal marsh that was tectonically lifted above the tidal influence. The preuplift marsh was flooded by only extreme high tides, and currently the tides no longer flood the marsh. Loss of the tidal influence essentially eliminated tidal salt inputs and the marine deltaic sediment load. The uplifted marsh is currently only tidally affected in that tidal creeks traverse its landscape, eroding creek banks and forming new tidal marshes on its edges. Tidal creeks are theorized to actively erode headward as a marsh develops (Pestrong 1965), and to shift laterally in the manner of meandering streams. The marine deltaic processes that originally formed the preuplifted marsh are described fully in the tidal marsh landscape section.

Excluding the tidal creeks, the system's water inputs are all freshwater from streams and the lateral flow through peat and levees. The ponds are sealed by a thick silt layer (Davidson and Klinge 1992), thereby suggesting that ground water upwellings are infrequent. Flow rates across the uplifted marsh are likely slow on account of the low gradient of the uplifted marsh, and the extensive network of beaver (*Castor canadensis*) dams. Evidence of slow flow rates includes anaerobic conditions within the peatlands, formation of bogs, and visual observations of slow flow.

Even with the loss of the tidal water, the ponds throughout the uplifted marsh are typically filled, except during extended periods of low precipitation. When they are filled, the levee soil surface is level with the pond water surface. Between-pond levees are saturated to the soil surface, but levees adjacent to tidal creeks have a lower water level. This is because of a lowering of levee water level as water drains from the ponds into the adjacent, and lower, tidal creeks.

Beaver significantly influence the dynamics of most wetlands. They are absent from saltwater systems, rare in ombrotrophic bogs, and can be common in other freshwater ecosystems including minerotrophic fens. Beaver populations have increased on the uplifted marsh of the Copper River Delta since the 1964 uplift. The invasion of woody vegetation on nearly all the levees of the uplifted marsh has provided food and dam building material. Beaver activities can severely affect vegetation composition by cutting certain woody species and damming the smaller nontidal creeks that back-flood the land. Phreatophytes such as *Myrica gale* (sweetgale) and *Potentilla palustris* (marsh fivefinger) thrive at the expense of *Alnus crispa* subsp. *sinuata* (Sitka alder), *Picea sitchensis* (Sitka spruce) and *Populus trichocarpa* (black cottonwood). Beaver dams also slow the flow of surface water across the marsh, effectively creating a wetter environment.

The rate of accretion across the uplifted marsh seems to be low. Small streams entering the ponds carry little or no sediment load, and the sediment-heavy glacial rivers flood the ponds only during high flows. When river flooding occurs, sediment is deposited in ponds adjacent to the rivers, but ponds further removed rarely receive sediment. Tidal channels carry a significant sediment load but rarely (if ever) overflow their banks into the uplifted marsh. Consequently, only a small fraction of the ponds will have significant accretion.

The rate of erosion of the uplifted marsh by the tidal creeks is important in that it destroys the freshwater system through erosion and creates a tidal marsh in its place through deposition in the tidal zone. Erosion is limited to the banks of tidal creeks; freshwater creeks across the uplifted marsh exhibit little evidence of bank erosion. Bank erosion is dependent on many factors including tidal water energy, soil particle size, vegetation cover, and freeze-thaw cycles. Tidal water energy is the main component of bank erosion on the tidal creeks and is dependent on tide height and frequency. The rate of bank erosion from water energy, in turn, is dependent on the particle size and clay content of the soils of the bank and its vegetation cover. Erosion-resistant banks have fine-grained or clay-rich soils, or dense vegetation cover, whereas highly erodable banks are coarse grained, clay poor, or sparsely vegetated (Smith 1976). Sand and silt are not cohesive and consequently more erosive than the cohesive clays (Thorne 1982). For coarse-grained banks, riverflow removes individual particles directly from the bank surface (corrasion). Clay-rich banks are the most resistant to corrasion and usually retreat by undercutting and failure of large blocks of the bank (Laury 1971, Stanley and others 1966). The freeze-thaw cycle is the last significant bank erosion factor that reduces the strength of bank materials and results in instability and failure.

Tidal creek banks of the uplifted marshes of the Copper River Delta seem to be eroding at a slow rate. This is in spite of high water flows from twice daily 12-foot tides, and significant fall-through-spring freeze-thaw action. The primary resistance to corrasion is the dense bank vegetation and bank soils that are fine grained, with some clay. As expected with corrasion-resistant banks, the main mode of bank erosion along the tide channels is by undercutting and failure of large blocks (Laury 1971, Stanley and others 1966). When a mineral soil levee is eroded, it creates a hole in the dam, forming the edge of a pond. Because most ponds are bordered by peat, however, the peat functions as a levee and dam, thereby preventing the basin from draining. The hydraulic conductivity of peat, especially fibric peat, is significantly higher than that of the mineral soil of a levee. Consequently, water will drain more rapidly through a peat levee than a mineral soil levee.

A sea cliff fronts most of the uplifted delta. Cliff development on developing tidal marshes is thought to represent either erosion of the marsh front or marsh maturity. If the marsh is mature and cannot extend seaward, the edge gradually rises through accretion, which leaves a stepped profile.

Loss of the tidal influence initiated massive changes in vegetation composition and structure. Immediately after the uplift, the levees showed a herbaceous to shrub to tree gradient moving inland (Crow 1968). The most seaward ponds were dominated by tide-tolerant aquatic and emergent species (Crow 1968). Descriptions for community types of more inland ponds were not recorded. Other vegetation types occurring in the more inland ponds likely follow the successional sequences presented for the ponded basins of the outwash plains. Freshwater species are now invading ponds of the former tidal marsh; some halophytic marsh species and communities described as common in previous studies (Crow 1968) are now rare or absent.

Examples of late-successional postuplift communities on levees and ponds were not found during this study on the uplifted marshes of the Copper River Delta. Shephard (1995), however, identified late-successional communities (which are given in the Successional Sequence descriptions) on the uplifted marshes of the Yakutat foreland. All these late-successional communities occur on the outwash plain landscape of the Copper River Delta.

Within the system of ponds and levees, water depth, nutrients, pH, and salt concentration drive the species composition of a site. Two wetland ecosystems, fens and bogs, dominate the peatlands of the Copper River Delta. Each represents opposing ends of a water and nutrient continuum; fens receive nutrient-rich water from ground water, and bogs receive nutrient-poor water from precipitation. For descriptions of fen and bog succession, see the descriptions of the *Carex sitchensis* (Sitka sedge)-uplifted marsh s.s. and *Myrica gale/Empetrum nigrum* (sweetgale/crowberry)-uplifted marsh s.s., respectively.

Recognizable and consistent vegetation zonation patterns are found in fens. The vegetation is directly associated with different water depths. The vegetation, on a wet-to-moist moisture gradient, typically changes from aquatic, to emergent, to mesic herbaceous, to carr (shrub-dominated wetland). Not all the vegetation zones are always expressed.

On the uplifted marsh of the Copper River Delta, the sampled peatlands were fens, with ground water or stream water flow providing ample nutrients. Because of peat buildup and flow diversion, portions of the peatlands likely will lose the inflows of nutrient-rich water resulting in the conversion of substantial areas of the fens into bogs. These developing peatlands will eventually span the continuum from pure fens or bogs, to a mixture of the two. Continued paludification will encroach on the adjacent levee communities, converting them from shrub and forested communities to peatland communities. Ponds likely will persist, although encroachment by peat may reduce their present size. Fens typically have some ponded stringers or ponds, known as flarks, because of partial damming of drainage ways and freeze-thaw cycles within ponds.

Linear Dune Landscape

Landform—The landforms of the linear dunes consist of dunes intermixed with terraces, levees, and ponds (fig. 6). These additional landforms are described in their appropriate landscape sections (i.e., uplifted marsh and outwash plain). The shape of a linear dune is long and narrow, and wider and steeper at the upwind end, gradually tapering downwind. The dune flanks often are vegetated, and the top may be bare and susceptible to wind transport. Blowouts are common. Bifurcation from blowouts on the upwind end is evident on the study area dunes. Dune dimensions range from 20 to 250 feet tall and 100 feet to 9 miles long; most are less than 100 feet tall and a mile long. Dunes of the world range in height from less than 9 feet to 300 feet, but may range as high as 1,500 feet (Walker 1982). Other dune types may occur within this landscape.

Some linear dunes along the Copper River seem to be seif dunes, a type of linear dune. Like a linear dune, they are elongate but differ in having sharp-crested ridges that often consist of a succession of oppositely oriented curved slip faces. They give the impression of a sinuous or chainlike appearance on the dune crest (Ritter 1986).

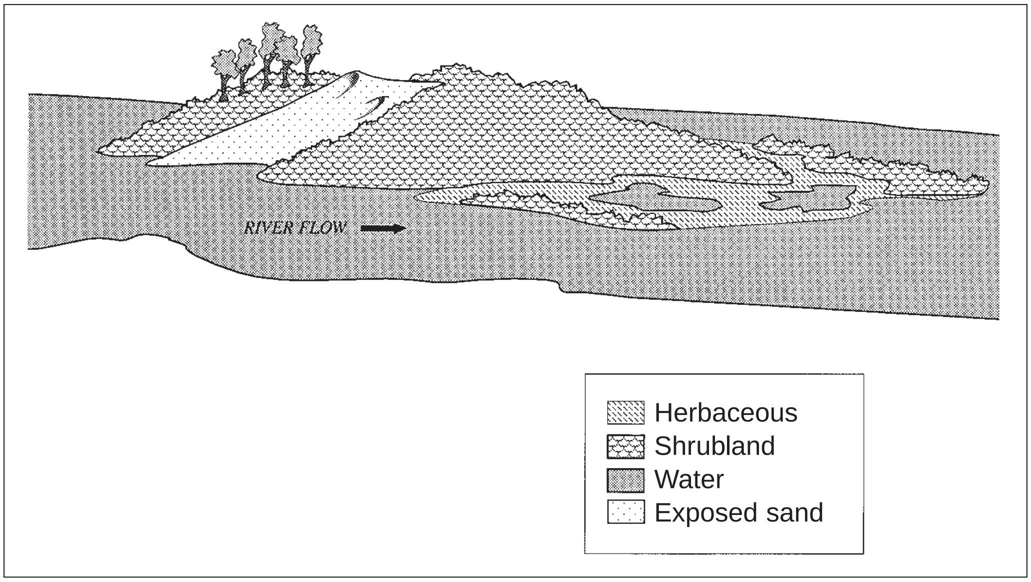

Figure 6—Oblique view of an idealized linear dune.

Distribution—Linear dunes are found only at the mouth of the Copper River from which they radiate linearly (figs. 1 and 2). They occur from Long Island, where the road crosses the Copper River, to the ocean front and include all or portions of Long Island, Heart Island, Castle Island, many unnamed smaller islands, and a narrow dune 9 miles long forming the east edge of the Copper River.

Processes—A rare combination of environmental factors make this ecosystem unique. The Copper River is one of the four rivers (Copper, Alsek, Taku, and Stikine) that dissect the coastal mountain ranges of south-central and southeast Alaska which allows direct contacts between the interior and coastal air masses. The Copper River valley acts as an air corridor between the interior and coast which results in high sustained winter winds as the cold interior air masses move to the coast. There they meet the warmer coastal air mass to create a microclimate of high winter winds, windblown loess, alternating cold and moderate temperatures, high snowfall, and late snowmelts, including some snowbanks that may persist throughout summer.

The location and formation of linear dunes depend primarily on the availability of sand and wind direction. The main source of sand and silt on the study area is the tremendous sediment load delivered by the Copper River and deposited on its outwash plain and delta. Another significant source of sand transport is the high winds blowing loess down the Copper River canyon. Once the sediment is deposited, summer winds may form the dunes, which extend parallel to the forming wind, although multiple winds also are thought to influence dune direction (Ritter 1986). The high-velocity winter winds likely have little effect on dune formation because the landscape is frozen. The eventual quasiequilibrium in sand dunes represents a balance between erosion and deposition (Howard and others 1977) and requires the forward movement of the entire feature. Geomorphologists are only beginning to understand the role of each factor within dune genesis. The issue is further confused because some dunes undoubtedly formed under conditions that no longer exist onsite.

On early successional dunes, vegetation often greatly affects dunes genesis. Obstacles in the windrun, such as vegetation or litter, decrease wind speeds that lead to sand deposition. These obstacles also act as seed and nutrient traps (Carter 1988). Pioneer dune vegetation (primarily *Elymus arenarius* [beach rye] and *Equisetum variegatum* [northern horsetail]) further stabilizes the windblown sand. Most pioneer dune species reproduce vegetatively because germination is difficult owing to burial by sand and desiccation. Clonal colonies develop rapidly; *Elymus arenarius* (beach rye) tillers form directly off the main shoot just below surface level and develop obliquely to the main stem (Carter 1988).

On mid- and late-successional dunes or portions of dunes, fresh sand input decreases, species diversity increases, soil development increases, and dune builders, such as *Elymus arenarius* (beach rye), become senescent and depauperate. Trees and shrubs invade and further stabilize the sites. The higher portions of dunes are dry and nutritionally poor because of leaching, moving the nutrients into the dune bases.

Dune height is primarily controlled by some poorly understood wave motion within the wind. This hypothesis is supported by the fact that dunes normally occur in groups with distinctly regular spacing rather than as randomly placed individuals (Ritter 1986).

Blowouts are a natural phenomenon in many dune fields and are common on most linear dunes of the Copper River. They are a primary method of dune movement and elongation and an initiator of primary succession. Blowouts occur when wind erodes a small hollow on the upwind side of a vegetated dune. The blowout continues to expand, the shape becoming concave with a steep backslope. Much of the wind-transported sand is deposited on the downwind side of the backslope, forming deltalike or plume-like formations. In time, the steep backslope becomes subdued because of mass wasting from sand avalanches and wind erosion. Vegetation then colonizes and stabilizes the blowouts (Carter 1988). Many trigger mechanisms for blowout initiation have been cited and include wind abrasion, desiccation, fire, trampling and disturbance by vehicles, grazing, and soil nutrient depletion leading to degeneration of the surface vegetation.

The effect of the 1964 earthquake on the linear dunes is unknown. The loss of the daily tides for the more seaward dunes and possible changes in sediment size and accretion rate likely will have some effect on the landscape.

Tidal Marsh Landscape

Landforms—The landforms of the tidal marsh consist of tideflats (mudflats), marshes, tidal creeks, and a shrub-dominated zone adjacent to the old sea-cliff fronting the uplifted marsh (fig. 7). Tideflats are included because of the continued advancement of vegetation onto the flats.

Distribution—This landscape extends from the mouth of the Eyak River to Cape Suckling, between the barrier islands and uplifted marsh (figs. 1 and 2). The vegetated portions front the uplifted marsh and the estuarine side of the barrier islands and spits.

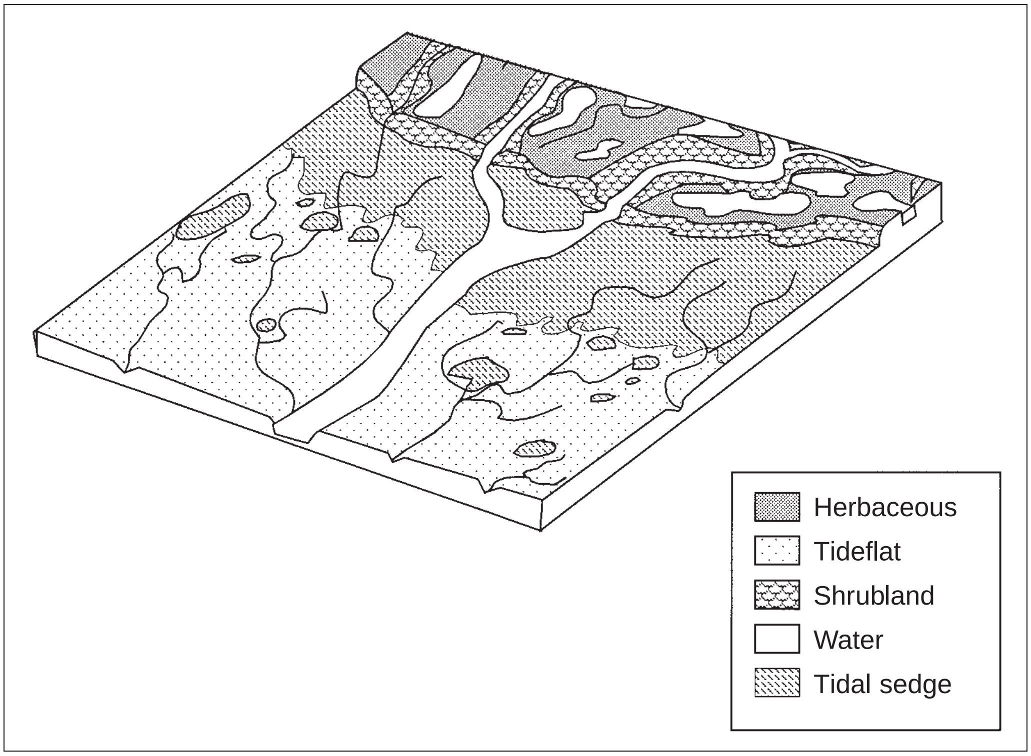

Figure 7—Oblique view of an idealized tidal marsh.

Processes—The 1964 uplift set in motion a new ecosystem balance (fig. 2). The shallower subtidal portions of the tideflats became intertidal after the earthquake and are now developing tidal marshes. In this section, a broad-level description of deltaic processes is presented, followed by more detailed descriptions of tidal marsh landforms and vegetation.

Delta—General deltaic processes have formed the subtidal zone, tidal marsh, and uplifted marsh of the Copper River Delta (figs. 1 and 2). A delta is a depositional feature formed by a river at its mouth, where sediment accumulation results in an irregular progradation of a shoreline (Coleman 1968, Scott and Fisher 1969). It is initiated when a stream enters standing water (such as the ocean) and river velocity decreases thereby resulting in rapid deposition of the bed-load and suspended sediment. At the apex of the delta, the river trunk divides into several radiating distributaries (side channels) that traverse the delta surface and deliver sediment to the delta extremities. Vertical expansion of the delta surface is limited by the maximum water height of the tide or backed up river channels. Consequently, the surface gradients are notably flat. Progradation of the delta front will occur if sedimentation exceeds erosion.

The shape of a delta is a reflection of the balance between riverflow, sedimentation rate, climate, tectonic stability, and shoreline dynamics. The effect of process on the formation of the Copper River Delta is not fully understood and, consequently, not fully described in this section. Although the shape and process of every delta is unique, classification is used for general descriptive purposes. Scott and Fisher (1969) describe two dominant types of deltas, high-destructive and high-constructive. (1) High-destructive deltas have a truncated shape with few or no deltaic lobes, such as the delta of the Columbia River. On this type, the ocean or lake energy is high because of offshore currents, wave energy, or high tides. Consequently, the fluvial sediment delivered to the ocean front is either rapidly transported away from the delta front by ocean currents or reworked by waves, or the tidal currents may rework the sediment and arrange the sediment into sand units that radiate linearly from the river mouth. (2) High-constructive deltas have one or more land lobes formed by a river. This delta type develops when fluvial action is the prevalent influence on the system and ocean or lake energy is low. Progradation of the delta front leads to the formation of lobe-shaped landscapes. As the lobe progrades, shorter routes to the ocean become available. A breach in the levee develops, and new river courses begin to form a new deltaic lobe; the old lobe may then erode. Small subdeltas also form through breaches in levees and new channels forming.

The Copper River Delta primarily has characteristics of a high-destructive delta. These high-destructive delta characteristics are evident including the general truncated shape of the delta, sandy islands radiating linearly from the river mouth, the presence of strong offshore currents (Alaska Current), high energy waves, and high tides. The main landform characteristic of a high-constructive delta, its lobe shape, is not evident on any portion of the delta.

The primary source of sediment for the Copper River Delta is the Copper River, which delivers 97,000,000 metric tons per year (Hampton and others 1987). Most of the sediment is delivered between May and October when the river is at moderate to high flows. Riverflow is low the remainder of the year because the river and watershed are mostly frozen. The plume of sediment and fresh water entering the ocean is pushed northwest, parallel to the coastline, by the Alaska currents and the Coriolis force.

Tidal marsh—Tidal marsh development is dependent on the amount of sediment available, the tide and wave energy available for resuspension and transport of sediment, and the trapping ability of plants and swards (Carter 1988). Within the estuary on the Copper River Delta, the low wave energy and surplus of fine sediment currently provide excellent conditions for marsh development. The wave energy in the estuary is reduced because the barrier islands and spits block the ocean waves.

Primary succession on the tidal marsh will progress through a series of stages leading from pioneer species establishing on the newly exposed tideflats to a marsh with creeks, levees, and ponds. At present, pioneer species such as *Puccinellia pumila* (dwarf alkaligrass) and *Carex lyngbyaei* (Lyngby's sedge) are establishing on the tideflats. The newly established vegetation slows the water, allowing for sediment deposition. Water slowed at the edges of swards cause high rates of deposition, typically of the coarser sediments. Less sediment is available for deposition in the middle of the sward or marsh further removed from the channel. These differential accretion rates and stabilization by the vegetation lead to the formation of levees (on the edge of the swards and channels) and ponds. The soil surface will continue to increase relative to the mean high tide because of accretion. Because soil surface height is a function of water height, it eventually equilibrates at or above mean high tide or the height of the backed up river channels.

Tidal creeks are formed through a combination of previously established drainage patterns and the coalescing of adjacent swards of vegetation (Steers 1977), primarily *Carex lyngbyaei* (Lyngby's sedge) for regions of the northern Pacific coast. The creeks become more entrenched as the surface height increases. Superficially, tidal creeks resemble terrestrial creeks, but they differ in that the creeks are at bankfull nearly every high tide, and water flows both ways through the channels. The tidal creeks found on the uplifted marsh are mature examples of the creeks now forming on the tidal marshes (Thilenius 1990).

At present, the marsh front is advancing onto the tideflats through the establishment of vegetation and sedimentation. Jakobsen (1954) describes one mechanism of progradation. A near-shore channel forms next to the seaward edge of the marsh. Further offshore, a few hundred yards, the tideflat is higher because of accretion. Vegetation will establish on the elevated land leading to further accretion. In time, the near-shore channel will fill and be transformed into a marsh. The extent of the advance will be partially limited by water depth. As stated by Batten and others (1978), "precise leveling done by NOS (National Oceanic Survey) at three study sites (in the Gulf of Alaska) shows that the marshes do not extend far seaward of mean higher high water. Generally, only a few tufts of *Puccinellia nutkaensis* and other halophytes are present at MHHW and transition to the luxuriant stands of *Carex lyngbyaei* that constitute the bulk of most marshes occurs substantially above this mark."

Studies of geology and marsh accretion rates suggest that the Copper River Delta tidal marshes will maintain themselves and likely expand over time. Plafker and others (1990) present a seismotectonic cycle describing repeated tectonic uplifts of the delta with long intervening periods of net submergence. The repeated tectonic uplifts (about every 600 years) lift the tidal mudflats, allowing the development of tidal marshes (fig. 7). During submergence of the uplifted marshes, the mature land supporting peatlands and forest convert to a tidal marsh as the tide invades. Stratigraphy profiles from the Copper River Delta show the marsh maintaining itself and expanding seaward (Plafker and others 1990) because of accretion rates equaling submergence rates in addition to tectonic uplifts. An accretion rate of 0.18 to 0.26 inch per year is necessary to equal the submergence rate and is well within the range of accretion rates, 0 to 0.4 inch per year, summarized by Letzsch and Frey (1980) for the world. Other tidal marshes of the world have shown a loss of tidal marsh habitat to the ocean. Pethick's (1981) model of accretion rates for marshes near Norfolk, Virginia, shows that high rates of accretion can be maintained for long periods, as is necessary on the Copper River Delta. The Norfolk marshes were formed in sheltered bays over the last 2,000 years. An initial accretion rate of 0.4 inch per year was maintained for 1,500 to 2,000 years, with an asymptotic decline thereafter. The rapid decline was ascribed to decreasing frequency of tidal inundation, although the marsh may have reached equilibrium among erosion, deposition, and subsidence.

Presently, the seaward edge of the new tidal marsh grades gently into the subtidal zone. In time, the seaward edge may form an abrupt cliff 6 to 9 feet high, as can be seen on the seaward edge of the uplifted marsh. Cliff development may represent erosion of the marsh front, or may indicate marsh maturity (Carter 1988). If the marsh cannot extend seaward, the edge gradually rises through accretion, leaving a stepped profile. The rate of marsh progradation and vertical expansion is dependent on the factors presented for delta formation. To accurately predict the extent of progradation for the Copper River Delta, additional studies on estuary depth, accretion rate, and submergence rates would need to be done.

Estuary salinity is inversely correlated with freshwater inputs from the rivers of the Copper River Delta. Freshwater inputs between May and October are high because of moderate to high riverflows, snowmelt, glacial melt, and rainfall. The remainder of the year, freshwater inputs are greatly reduced because the watersheds are mostly frozen. The plume of fresh water entering the ocean is pushed northwest, parallel to the coastline, by ocean currents and the Coriolis force. Consequently, the water salinity of the estuary west of the Copper River is less than that of the east side. During the growing season, tide water flooding the tidal marshes of the west estuary is generally fresh, the salinity usually not exceeding 10 parts per thousand (Thilenius 1990). The tidal marshes are still dominated by halophytic vegetation, strongly suggesting that during some period of the growing season, soil or water salinity are high. Salts may enter the system during storm surges, or during winter when freshwater inputs are lower and water salinity is higher.

The vegetation zonal patterns expressed on this landscape are controlled by exposure, salinity, temperature, sediment rate, and tidal depth. The general pattern, moving from deep to shallow waters and saline to fresh, is *Puccinellia nutkaensis* (dwarf alkaligrass), *Potentilla egedii* (Pacific silverweed) or *Ranunculus cymbalaria* (seaside buttercup), *Carex lyngbyaei/Ranunculus cymbalaria* (Lyngby's sedge/seaside buttercup), *Deschampsia beringensis* (bering hairgrass), *Myrica gale /Carex lyngbyaei* (sweetgale/Lyngby's sedge), and *Salix* (willow) community types. Other community types, such as *Carex glareosa*, are more common on the east delta. All the communities are either primary colonizers of the mudflats or secondary invaders. Often one community grades into the next, thereby showing codomination and mosaic patterns. The herbaceous communities are regularly or infrequently tidally inundated, whereas the shrub and tree communities are likely only inundated during extreme storm surges, a pattern representing zonation and not necessarily succession.

Barrier Island-Spit-Coastal Dune Landscape

Barrier islands, spits, and coastal dunes were combined into one landscape because of similarities in landform, geomorphic process, and parent material. Each is a dune-dominated ecosystem derived from the wind, wave, and long-shore transport of sand and silt. Definitions of the components within the landscape are as follows: barrier islands are sandy elongate islands separated from the mainland by an estuary or bay, a spit is a sandy elongate continuation of a coastal dune into the ocean (Ritter 1986), and coastal dunes are beach ridges or dunes superimposed on beaches along the coast. Each is highly dynamic and unstable as are many landscapes of the Copper River Delta.

Landform—Distinct landform and vegetation patterns are common to the barrier islands, spits, and coastal dunes (fig. 8). Landforms on the ocean side include low gradient beaches, sparse to unvegetated dunes, slacks dominated by low herbaceous vegetation and back dunes (or sea cliffs) dominated by tall herbaceous, shrub, or forested communities. On coastal dunes, the dune crest grades into mainland landscapes or uplands (fig. 9). Behind the dune line on barrier islands and spits is a level or low relief zone, which may support herbaceous, shrub, or forested communities (fig. 8).

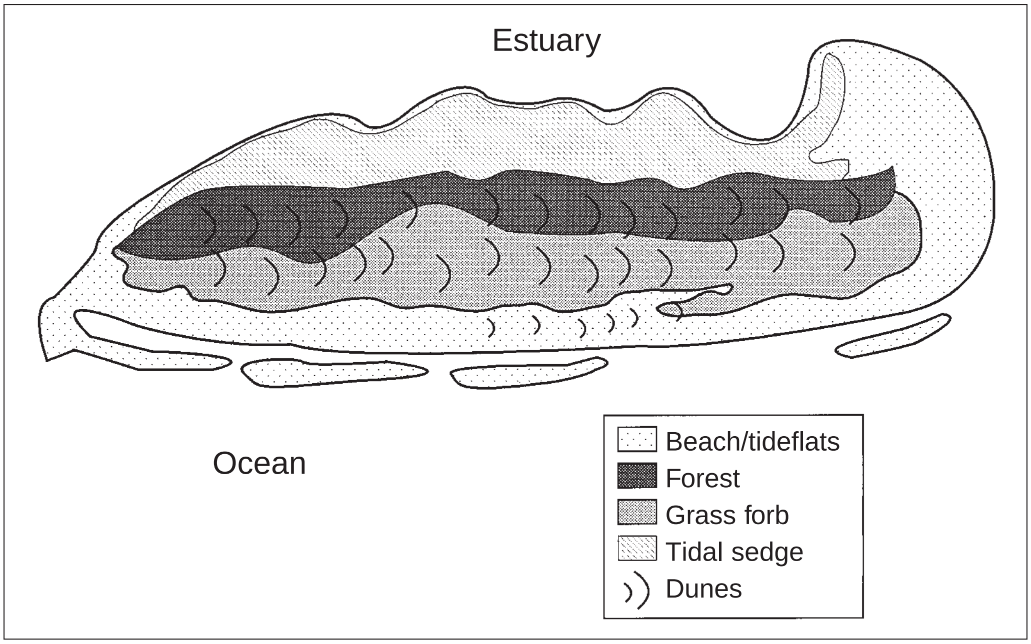

Figure 8—Aerial view of idealized landforms and vegetation zones on barrier islands (and spits) of the Copper River Delta.

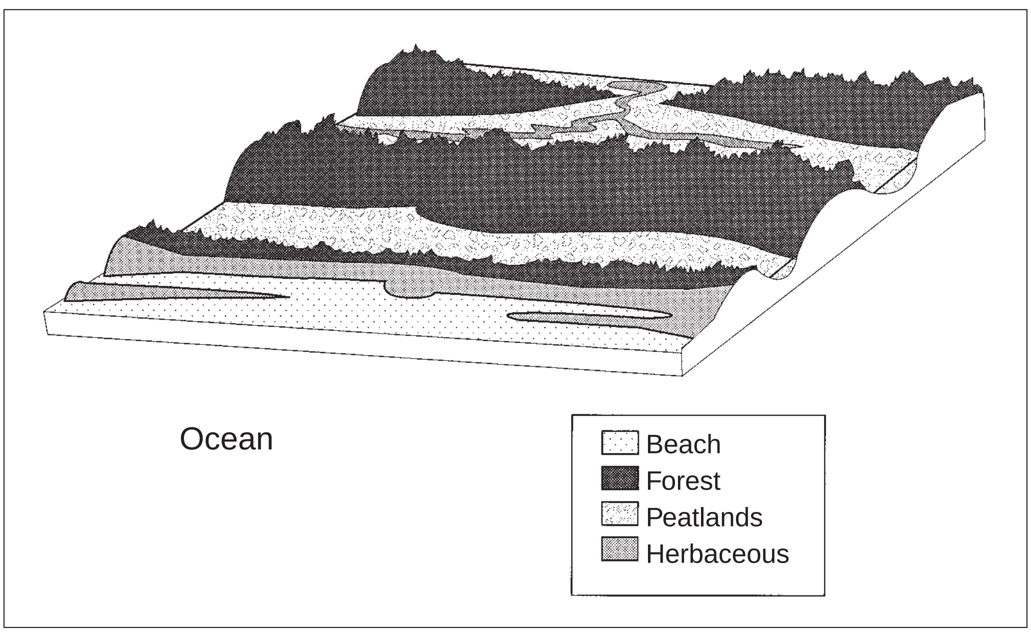

Figure 9—Oblique view of an idealized beach ridge sequence.

These in turn grade into uplifted marshes, tidal marshes, and tideflats. Some confusion may result because of the inclusion of uplifted marshes and tidal marshes (each considered a landscape) in the barrier island-spit-coastal dune landscape. Uplifted marshes and tidal marshes are an integral part of the landforms and geomorphic process on barrier islands and spits. Consequently, they were included and described in the discussion of this landscape.

Barrier islands of the Copper River Delta range up to 1 mile wide and 8 miles long and are typically less than 30 feet in elevation (Thilenius 1990). Spits range up to 1 mile wide, and 10 miles long, and typically less than 30 feet in elevation.

Distribution—The barrier islands and spits form a discontinuous line across the width of the Copper River Delta (figs. 1 and 2). They include Egg Island, Copper Sands, Grass Island, Strawberry Reef, Kanak Island, Softuck Spit, and Okalee Spit. Beaches with coastal dunes dominate the shorelines not fronted by the barrier islands or spits. A series of uplifted forested coastal dunes (beach ridges), up to 4 miles inland, are found near Katalla (fig. 9).

Barrier island and spit processes—Geomorphic processes controlling barrier islands and spits can be described on different spatial and temporal scales. Within this section, these processes are described from the broadest to the narrowest scales, starting with the post-ice-age migration of barrier islands, principal geomorphic processes for the origin and deposition of sediment, to processes forming the beach, dune, slack, and marsh landforms.

The current theory on the origins of barrier islands suggests they have a long developmental history associated with post-ice-age sea level rise (Dolan and others 1980). During the last glaciation, sea level on the Copper River Delta was probably 300 feet lower than it is today, and the shoreline (and glacier terminus) extended as much as 37 miles seaward of the present coastline (Pewe and others 1965). The glaciers retreated toward the end of the Pleistocene, between 14,000 and 10,000 before present (Tarr and Martin 1914). Because of the concurrent rise in sea level, the initial beach ridges migrated landward along with the shoreline. Sea level approached its present level about 4,000 to 5,000 years ago (Bloom 1983), when the barrier islands developed their present characteristics (Ritter 1986).

Spits differ from barrier islands in that spits are a continuation of a coastal beach into the ocean. Spit formation is from longshore transport of drifting beach sediment, which is deposited when the sediment enters a zone of slack water. The spit thus extends the beach parallel to the local onshore currents. Landforms on spits are identical to those of barrier islands.

The principal geomorphic processes required for the formation of barrier islands and spits are deposition of sediment, coasts with low tides, low offshore gradients, and low wave energy. The location and formation of islands and spits depend primarily on the availability of sediment. The main source of sand and silt is the tremendous sediment load delivered to the coasts by major rivers, such as the Copper River.

The sediment load is transferred to the marine environment and deposited on the deltas. Other minor sediment sources are erosion of sea cliffs, onshore transport of sand from the ocean shelf, and sand transported by wind (Ritter 1986). The other primary geomorphic processes necessary for island and spit formation (coasts with low tides, low offshore gradients, and low wave energy) do not occur on the delta or in the region but may be offset by the huge sediment load provided by the Copper River. The lack of these processes is essentially why barrier islands and spits are rare on the north Pacific coast of North America.

The sediment is transported by alongshore currents, waves, and winds until it is eventually stabilized by vegetation. The alongshore currents, generated by waves that strike beaches obliquely, tend to move sediment parallel to the shoreline for considerable distances. The sediment is deposited when it enters a zone of slack water. Islands and spits thus migrate parallel to the alongshore currents. Waves redistribute the sediment across the beach profile, and wind will erode depositional features and transport the sand downwind. Areas with high wave energy resuspend any silt and transport it to lower energy depositional areas. Consequently, the high-energy side of islands and spits (the seaward side) contains primarily sand, and forms beaches and dunes, whereas silt is readily deposited on the low-energy side (the estuary side), to form marshes and tideflats.

The inlets found between barrier islands and spits serve as avenues for water and sediment movement between the estuary and open ocean. Inlets tend to migrate in the direction of alongshore transport as spits or islands erode at one end and deposit sediment at the other. As water and sediment move back and forth through the inlets, small deltas form on both sides. Although not noted in the study area, estuary side inlet deltas may form new tidal marshes when exposed at low tide (Godfrey 1976).

Landforms found on barrier island and spits are strongly affected by overwash (Dolan and others 1980). During storms, portions of barrier islands and spits often are inundated and subjected to wave action known as overwash. Sand is transported from the beach and deposited further inland on the island or spit. The overwash may affect only the front portion of the landform or during severe storms can completely wash over low portions. In such cases, the sand is deposited on the back side as a washover fan (Ritter 1986).

Dune vegetation has to contend with strong gradients in salinity, soils, shelter, nutrition, exposure, sand engulfment, drought, and the usual competition, predation and disease. Consequently, the communities usually comprise a complex spatial mosaic. Rapid temporal succession is often evident. Olson (1958) describes succession on dunes of Lake Michigan in 40 to 100 years changing from dry open communities to closed mesic communities, and soil pH changing from 6 to 8 to 4 to 5. Succession may be cyclical, and progression toward a climax is far from straightforward.

Dune genesis on barrier islands and spits exhibits a relatively consistent pattern. Early successional dunes are located seaward and receive significant windblown sand and contain pioneer communities. There is often a rapid readjustment to changing environmental conditions. Newly formed dunes are dependent on vegetation, the size and abundance of sand, and the prevailing wind(s). Obstacles in the windrun perturb the flow and cause a decrease in wind speed leading to sand deposition. Vegetation is often the main obstacle although beach litter is another important obstacle, and acts as a seed and nutrient trap (Carter 1988). Pioneer dune vegetation (primarily *Elymus arenarius* [beach rye]) then stabilizes the windblown sand. The initial invaders are salt tolerant, although not halophytic, and sand-accumulation tolerant. *Ammophila breviligulata*, an east coast dune grass, at Cape Cod, Massachusetts, can survive 1 to 1.5 feet per year of sand accretion (Carter 1988). Most dune species reproduce vegetatively because germination is difficult owing to burial by sand and desiccation. Clonal colonies develop rapidly; *Elymus arenarius* (beach rye) tillers form directly off the main shoot just below surface level and develop obliquely to the main stem (Carter 1988). Pioneer dunes owe their strength to roots that penetrate 3 to 6 feet and deeper to water. The equilibrium in sand dunes represents a balance between erosion and deposition (Howard and others 1977). Equilibrium requires the forward movement of the entire feature.

On mid-successional dunes, species diversity increases, and dune builders such as *Elymus arenarius* (beach rye) and *Festuca rubra*, become senescent and depauperate. They are aggressive colonizers but less exposure tolerant. Trees begin to invade but are depauperate. Pemadasa and others (1974) show that plant distribution is strongly controlled by moisture gradients on both the microtopographic and mesotopographic scales. The higher portions of dunes are dry and nutritionally poor because of leaching, which moves the moisture and nutrients into the dune bases and slacks.

The late successional dunes are located inland from the earlier stages and have little fresh sand input but significant soil development (Carter 1988). The organic and nutrient status develops and supports shrub and forest vegetation. Removal of vegetation typically leads to destabilization, blowouts, and erosion of the dunes.

Blowouts are a natural phenomenon in many dune fields. They are a primary method of dune movement and elongation and an initiator of primary succession. Blowouts occur when wind exposes bare sand, forming a small hollow on the upwind side of a vegetated dune. The blowout continues to expand, the shape becoming concave with a steep back slope. Much of the wind-transported sand is deposited on the downwind side of the back slope and forms deltalike or plumelike formations. In time, the steep back slope becomes subdued because of mass wasting from sand avalanches and wind erosion. Vegetation then colonizes and stabilizes the blowouts (Carter 1988). Many trigger mechanisms for blowout initiation have been cited and include fire, trampling and disturbance by vehicles, grazing, and soil nutrient depletion, all of which can degenerate the surface vegetation (Ritchie 1972).

Dunes on the estuarine side of the spits and islands grade into uplifted marshes, tidal marshes, and tideflats. Each is subject to the same processes as given in their respective landscape descriptions. Overwash from storms, however, deposits sand in the uplifted marshes and tidal marshes, often creating a coarse-grained substrate. Consequently, these marshes are better drained than those found on the landward side of the estuary.

In general, the 1964 uplift of the delta set in motion a new ecosystem balance for the barrier islands, spits, and coastal dunes. Island length, width, and elevations have all increased since the 1964 uplift (Thilenius 1990). Higher elevated portions of the dunes were further removed horizontally and vertically from the influence of the tide and salt-spray, allowing for increased establishment of nonhalophytic vegetation including trees and shrubs. The pre-1964 tidal marshes on the estuary side of the barrier islands and spits were lifted above the tidal influence, and the shallower portions of the estuary were exposed. Extensive portions of the tideflats are now developing tidal marshes. In addition, because of the uplift, it is expected that the barrier islands will migrate seaward (Thilenius 1990), although it will be offset somewhat by the yearly rise in sea level (subsidence and sea level rise).

Coastal dune processes—The geomorphic processes and landforms of coastal dunes are similar to those of barrier islands and spits, except there are no landward side marshes. For a description of dune genesis, see the above description of barrier islands and spits. Primarily, coastal dunes are formed by the wave, wind, and along-shore transport of drifting sediment, which is deposited on beach fronts. The dunes and beaches tend to migrate in the direction of the prevailing winds and nearshore currents. Wind, waves, and nearshore currents change their properties daily or seasonally, resulting in changes in sediment transport constantly changing the beach and dune profiles (Ritter 1986).

Uplifted beach ridges supporting dense forests also occur within coastal dunes (fig. 9). They are formed because of the lowering of sea level relative to the dunes (dune building, tectonic uplift, and isostatic rebound). The uplifted beach ridges may extend several miles inland in some areas, such as Katalla.

Slacks—The level, tidally flooded areas between dunes are colonized by *Equisetum variegatum* (northern horsetail) and other herbaceous species. The sites are elevated by deposition of tidal and windblown sand, and rising of the land. This further removes the sites from salt inputs and allows shrubs, such as *Salix commutata* (undergreen willow), *Salix sitchensis* (Sitka willow), and *Myrica gale* (sweetgale) to invade. Organic mats also develop.

Young slacks in Northern Ireland (Murray 1980) were occasionally tidally inundated and received significant amounts of litter. Older slacks were not tidally inundated, which led to desalinization of the soils, a decrease in soil organic matter, and an increase in soil bulk density because of fine windblown sand.

Key to Successional Sequences

The key to successional sequences was developed to improve the ability of land managers to predict the future vegetation on a particular site. The key directs the user to one to several successional sequences. Within each successional sequence, descriptions are given for the potential native vegetation (plant association), seral stages (all community types), and landform development. Successional sequences are not presented for moraines.

The ability to predict the future vegetation that will occupy a site is dependent on the accumulated knowledge on vegetation and landform succession for a region. Consequently, limitations are inherent to this key and classification. Some successional sequences seem clear-cut, others are less so. In the successional sequence descriptions, I state whether the results are speculative or supported by quantitative and qualitative results. Some limitations are as follows:

1. It is difficult to predict the successional trajectory of early-seral stages. Consequently, more than one succession sequence often is given. On mid- to late-seral stages, the successional trajectory can be narrowed, often keying to only one successional sequence. The keys using mid- to late-seral stages are constructed similarly to plant association and habitat type keys.

2. Predicting whether the many small ponds found on the uplifted marsh will stay as open water or progress to a bog or a fen is difficult. Presently, nearly all the uplifted marsh ponds have at least partial open water or are fens. The scientific literature within the region, however, states that ponds of this type will partially fill with peat, resulting in peatlands intermixed with ponds (Klinger and others 1990, Shephard 1995).

3. Predicting the exact plant association that will occur on a peatland (bog or fen) or future peatland site is currently not possible. It is possible, however, to give a list of potential plant associations that may some day occupy the site; they are given in the successional sequence descriptions. General patterns of community development are evident in mature peatlands, and further study may enable land managers to better characterize these patterns. This will lead to better predictive capabilities on early- and mid-seral sites.

4. Successional sequence descriptions are not given for peatland and emergent communities found on the Copper River Subsection because of a lack of late-seral examples.

Instructions

1. Use this key for identifying successional sequences on the Copper River Delta. A successional sequence is named after two identifying site factors:
   a. The oldest community type (plant association) identified within the successional sequence.
   b. The landscape the site occurs on.

2. Locate a representative portion of the site in question. The vegetation and environment within the site should be relatively homogeneous.

3. Estimate the canopy cover for all indicator species. The indicator species are those species used in the key.

4. Identify the landscape and landform the site occurs on.

5. While in the plot, use the key literally to identify the successional sequence. Start with the “Key to Life forms and Landscape Groups,” couplet number 1.

Key to Life Forms and Landscape Groups

1. Tidal marsh that is inundated by tides and storm tides or halophytic species present such as *Carex mackenziei, Carex glareosa, Juncus bufonius, Ranunculus cymbalaria* (seaside buttercup), *Triglochin maritimum* (arrow grass) or *Puccinellia* (alkaligrass) species (but not *Carex lyngbyaei* [Lyngby's sedge] or *Potentilla egedii* [Pacific silverweed]) . . . . Tidal marsh s.s.
1. Site not tidal, and halophytic species not present 2

2. Site located on a linear dune or a dune along the Copper River . . . . Linear dune s.s.
2. Site not located on a linear dune or a dune along the Copper River 3

3. Dwarf trees, typically less than 25 feet tall, with a cover of at least 10 percent; **caution:** seedling and sapling trees are not trees . . . . a or b
   a. Site located on an outwash plain or floodplain . . . . *Picea sitchensis/Sphagnum* (Sitka spruce/peat moss)-outwash s.s.
   b. Site located on an uplifted marsh . . . . *Picea sitchensis/Sphagnum* (Sitka spruce/peat moss) -uplifted marsh s.s.
3. Dwarf trees with a cover of less than 10 percent 4

4. Trees present and reproducing successfully 5
4. Dwarf trees present, or trees absent, or trees not reproducing successfully . . . . Other successional sequences

5. Trees, other than dwarf trees, with greater than 25 percent cover **and** with an average d.b.h. greater than 9 inches, present and reproducing successfully . . . . Tree successional sequences
5. Trees, with an average d.b.h. less than 9 inches, present and reproducing successfully . . . . Other successional sequences

Key to Tidal Marsh Successional Sequences

(**Caution:** Most sites on the tidal marshes of the Copper River Delta exhibit inadequate site development for an accurate determination of the successional sequences.)

1. Levee and basin development evident 2
1. Levee and basin development not evident . . . . . Sites will, in time, develop levees and basins and support the successional sequences given in couplets 2, 3, and 4.

2. Sites on levees 3
2. Sites on basins 4

3. Inundated at mean high tide . . . . *Hedysarum alpinum-Deschampsia beringensis* (alpine sweet vetch/bering hairgrass)-tidal marsh s.s.

3. Not inundated at mean high tide; likely flooded during extreme storm tides . . . . One of the following successional sequences:
Alnus crispa/Calamagrostis canadensis (Sitka alder/bluejoint)-tidal marsh s.s.
Myrica gale/Poa eminens (sweetgale/bluegrass)-tidal marsh s.s.
Salix/Festuca rubra (willow/red fescue)-tidal marsh s.s.

4. Inundated by mean high tide . . . . One of the following successional sequences:
Carex lyngbyaei-Cicuta douglasii (Lyngby's sedge-water hemlock)-tidal marsh s.s.
Carex lyngbyaei-Lathyrus palustris (Lyngby's sedge-vetchling)-tidal marsh s.s.
Carex lyngbyaei-Triglochin maritimum (Lyngby's sedge-seaside arrow grass)-tidal marsh s.s.
Hippuris tetraphylla (four-leaf marestail)-tidal marsh s.s.
Menyanthes trifoliata (buckbean)-tidal marsh s.s.

4. Not inundated by mean high tides; likely flooded during storm tides . . . . Successional sequences in basins that are intermittently tidally flooded are not described

Key to Tree Successional Sequences

1. *Tsuga heterophylla* (western hemlock), *Tsuga mertensiana* (mountain hemlock), and *Picea sitchensis* (Sitka spruce) absent, **and** sites found only on outwash plains of the Copper River (Copper River Subsection) . . . *Alnus crispa/Rubus spectabilis* (Sitka alder/salmonberry)-outwash s.s.

1. *Tsuga heterophylla* (western hemlock), *Tsuga mertensiana* (mountain hemlock), or *Picea sitchensis* (Sitka spruce) present, **or** sites not found on the outwash plain of the Copper River (Copper River Subsection) 2

2. *Tsuga mertensiana* (mountain hemlock) present and reproducing successfully . . . . Unclassified *Tsuga mertensiana* (mountain hemlock) s.s.

2. *Tsuga mertensiana* (mountain hemlock) absent or not reproducing successfully 3

3. *Tsuga heterophylla* (western hemlock) or *Picea sitchensis* (Sitka spruce) present 4

3. *Tsuga heterophylla* (western hemlock) and *Picea sitchensis* (Sitka spruce) absent . . . . Unclassified forested successional sequence

4. *Vaccinium alaskensis* (Alaska blueberry) and *V. ovalifolium* (tall blueberry), individually or combined, with at least 5 percent cover. 5

4. *Vaccinium alaskensis* (Alaska blueberry) and *V. ovalifolium* (tall blueberry), individually or combined with less than 5 percent cover. . . . . Unclassified *Tsuga heterophylla* (western hemlock) s.s.

5. *Lysichiton americanum* (yellow skunk-cabbage) with at least 1 percent cover . . . . a, b, or c
   a. Site located on an outwash plain or floodplain . . . . *Tsuga heterophylla/Vaccinium ovalifolium/ Lysichiton americanum* (western hemlock/ tall blueberry/yellow skunk cabbage)-outwash s.s.
   b. Site located on an uplifted marsh . . . . *Tsuga heterophylla/Vaccinium ovalifolium/Lysichiton americanum* (western hemlock/tall blueberry/ yellow skunk-cabbage)-uplifted marsh s.s.
   c. Site located on a barrier island, spit, or coastal dune . . . . *Tsuga heterophylla/Vaccinium ovalifolium/ Lysichiton americanum* (western hemlock/tall blueberry/yellow skunk-cabbage)-coastal dune s.s.

5. *Lysichiton americanum* (yellow skunk-cabbage) with less than 1 percent cover 6

6. *Echinopanax horridum* (devil's club) with at least 1 percent cover . . . . a, b, or c
   a. Site located on an outwash plain or floodplain . . . . *Tsuga heterophylla/Vaccinium ovalifolium-Echinopanax horridum* (western hemlock/tall blueberry-devil's club)-outwash s.s.
   b. Site located on an uplifted marsh . . . *Tsuga heterophylla/Vaccinium ovalifolium-Echinopanax horridum* (western hemlock/ tall blueberry-devil's club)-uplifted marsh s.s.
   c. Site located on a barrier island, spit or coastal dune . . . . *Tsuga heterophylla/Vaccinium ovalifolium-Echinopanax horridum* (western hemlock/tall blueberry-devil's club)-coastal dune s.s.

6. *Echinopanax horridum* (devil's club) with less than 1 percent cover . . . . a, b, or c
   a. Site located on an outwash plain or floodplain . . . . *Tsuga heterophylla/Vaccinium ovalifolium* (western hemlock/tall blueberry)-outwash s.s.
   b. Site located on an uplifted marsh . . . . *Tsuga heterophylla/Vaccinium ovalifolium* (western hemlock/tall blueberry)-uplifted marsh s.s.
   c. Site located on a barrier island, spit, or coastal dune . . . . *Tsuga heterophylla/Vaccinium ovalifolium* (western hemlock/tall blueberry)-coastal dune s.s.

Other Successional Sequences

1. Sites with well to moderately well-drained mineral soils; such as sandbars, levees, alluvial terraces, and dunes 2
1. Sites with poorly drained soils, histic soils **or** sites with a thin (greater than 1-inch) histic mat; such as level sites that are poorly drained, ponds, bogs, fens, or carrs 5

2. Needleleaf trees absent **and** sites found only on the outwash plain and moraines of the Copper River (sites often dominated by *Populus trichocarpa* [black cottonwood] or *Alnus crispa* subsp. *sinuata* [Sitka alder]) . . . . *Alnus crispa/Rubus spectabilis* (Sitka alder/salmonberry)-outwash s.s.
2. Needleleaf trees present or sites not found on the outwash plain and moraines of the Copper River 3

3. Site located on an outwash plain or floodplain . . . . One of the following successional sequences:
   Tsuga heterophylla/Vaccinium ovalifolium/Lysichiton americanum (western hemlock/tall blueberry/yellow skunk-cabbage)-outwash s.s.
   Tsuga heterophylla/Vaccinium ovalifolium-Echinopanax horridum (western hemlock/tall blueberry-devil's club)-outwash s.s.
   Tsuga heterophylla/Vaccinium ovalifolium (western hemlock/tall blueberry)-outwash s.s.
3. Site not located on an outwash plain or floodplain 4

4. Site located on an uplifted marsh . . . . One of the following successional sequences:
   Tsuga heterophylla/Vaccinium ovalifolium/Lysichiton americanum (western hemlock/tall blueberry/yellow skunk-cabbage)-uplifted marsh s.s.
   Tsuga heterophylla/Vaccinium ovalifolium-Echinopanax horridum (western hemlock/tall blueberry-devil's club)-uplifted marsh s.s.
   Tsuga heterophylla/Vaccinium ovalifolium (western hemlock/tall blueberry)-uplifted marsh s.s.
4. Site located on a dune of a barrier island, spit, beach or uplifted beach ridge . . . . One of the following successional sequences:
   Tsuga heterophylla/Vaccinium ovalifolium/Lysichiton americanum (western hemlock/tall blueberry/yellow skunk-cabbage)-coastal dune s.s.
   Tsuga heterophylla/Vaccinium ovalifolium-Echinopanax horridum (western hemlock/tall blueberry-devil's club)-coastal dune s.s.
   Tsuga heterophylla/Vaccinium ovalifolium (western hemlock/tall blueberry)-coastal dune s.s.

5. Sites without histic soils (histic layer less than 16 inches) 6

5. Sites with histic soils (histic layer greater than 16 inches) . . . . a or b

a. Site located on an outwash plain or floodplain . . . . One of the following successional sequences:

Carex sitchensis (Sitka sedge)-outwash s.s.

Carex sitchensis/Sphagnum (Sitka sedge/peat moss)-outwash s.s.

Empetrum nigrum-Carex pluriflora (crowberry-several-flowered sedge)-outwash s.s.

Eriophorum angustifolium (tall cottongrass)-outwash s.s.

Myrica gale/Carex sitchensis (sweetgale/Sitka sedge)-outwash s.s.

Myrica gale/Empetrum nigrum (sweetgale/crowberry)-outwash s.s.

Salix barclayi/Carex pluriflora (Barclay willow/several-flowered sedge)-outwash s.s.

Salix barclayi/Carex sitchensis (Barclay willow/Sitka sedge)-outwash s.s.

Vaccinium uliginosum/Empetrum nigrum (bog blueberry/crowberry)-outwash s.s.

b. Site located on an uplifted marsh . . . . One of the following successional sequences:

Carex pluriflora-Carex lyngbyaei (several-flowered sedge-Lyngby's sedge)-uplifted marsh s.s.

Carex sitchensis (Sitka sedge)-uplifted marsh s.s.

Carex sitchensis/Sphagnum (Sitka sedge/peat moss)-uplifted marsh s.s.

Empetrum nigrum/Carex pluriflora (crowberry-several-flowered sedge)-uplifted marsh s.s.

Eriophorum angustifolium (tall cottongrass)-uplifted marsh s.s.

Myrica gale/Carex sitchensis (sweetgale/Sitka sedge)-uplifted marsh s.s.

Myrica gale/Empetrum nigrum (sweetgale/crowberry)-uplifted marsh s.s.

Salix barclayi/Carex pluriflora (Barclay willow/several-flowered sedge)-uplifted marsh s.s.

Salix barclayi/Carex sitchensis (Barclay willow/Sitka sedge)-uplifted marsh s.s.

Vaccinium uliginosum/Empetrum nigrum (bog blueberry/crowberry)-uplifted marsh s.s.

6. Shrub species, individually or combined, with greater than 25 percent cover 7
6. Shrub species, individually or combined, with less than 25 percent cover; herbaceous species with the greatest canopy cover 15

7. *Salix* (willow) species, individually or combined, with greater than 25 percent cover 8
7. *Salix* (willow) species, individually or combined, with less than 25 percent cover 10

8. *Carex pluriflora* (several-flowered sedge) and *Carex lyngbyaei* (Lyngby's sedge), individually or combined, with greater than 25 percent cover . . . . a or b
   a. Site located on an outwash plain or floodplain . . . . *Salix barclayi/Carex pluriflora* (Barclay willow/several-flowered sedge)-outwash s.s.
   b. Site located on an uplifted marsh . . . . *Salix barclayi/Carex pluriflora* . . . .(Barclay willow/several-flowered . . . . .sedge)-uplifted marsh s.s.
8. *Carex pluriflora* (several-flowered sedge) and *Carex lyngbyae*i (Lyngby's sedge), individually or combined, with less than 25 percent cover 9

9. *Carex sitchensis* (Sitka sedge), *Potentilla palustris* (marsh fivefinger), and *Menyanthes trifoliata* (buckbean), individually or combined, with greater than 25 percent cover . . . . a or b
   a. Site located on an outwash plain or floodplain . . . . *Salix barclayi/Carex sitchensis* (Barclay willow/Sitka sedge)-outwash s.s.
   b. Site located on an uplifted marsh . . . . *Salix barclayi/Carex sitchensis* (Barclay willow/Sitka sedge)-uplifted marsh s.s.
9. *Carex sitchensis* (Sitka sedge), *Potentilla palustris* (marsh fivefinger), and *Menyanthes trifoliata* (buckbean), individually or combined, with less than 25 percent cover . . . . Unclassified *Salix* (willow)-peatland s.s.

10. *Myrica gale* (sweetgale) with at least 25 percent cover 11
10. *Myrica gale* (sweetgale) with less than 25 percent cover 13

11. *Eriophorum angustifolium* (tall cottongrass), *Empetrum nigrum* (crowberry), and *Andromeda polifolia* (bog rosemary), individually or combined, with at least 20 percent cover . . . . a or b
   a. Site located on an outwash plain or floodplain . . . . *Myrica gale/Empetrum nigrum* (sweetgale/crowberry)-outwash s.s.
   b. Site located on an uplifted marsh . . . . *Myrica gale/Empetrum nigrum* (sweetgale/crowberry)-uplifted marsh s.s.

11. *Eriophorum angustifolium* (tall cottongrass), *Empetrum nigrum* (crowberry), and *Andromeda polifolia* (bog rosemary), individually or combined, with less than 20 percent cover 12

12. *Carex sitchensis* (Sitka sedge), *Potentilla palustris* (marsh fivefinger), and *Menyanthes trifoliata* (buckbean), individually or combined, with at least 25 percent cover . . . . a or b
   a. Site located on an outwash plain or floodplain . . . . *Myrica gale/Carex sitchensis* (sweetgale/Sitka sedge)-outwash s.s.
   b. Site located on an uplifted marsh . . . . *Myrica gale/Carex sitchensis* (sweetgale/Sitka sedge)-uplifted marsh s.s.

12. *Carex sitchensis* (Sitka sedge), *Potentilla palustris* (marsh fivefinger), and *Menyanthes trifoliata* (buckbean), individually or combined, with less than 25 percent cover . . . . unclassified *Myrica gale* (sweetgale)-peatland s.s.

13. *Vaccinium uliginosum* (bog blueberry) with at least 25 percent cover, **or** with the greatest cover in the dwarf shrub layer . . . . a or b
   a. Site located on an outwash plain or floodplain . . . . *Vaccinium uliginosum/Empetrum nigrum* (bog blueberry/crowberry)-outwash s.s.
   b. Site located on an uplifted marsh . . . . *Vaccinium uliginosum/Empetrum nigrum* (bog blueberry/crowberry)-uplifted marsh s.s.

13. *Vaccinium uliginosum* (bog blueberry) with less than 25 percent cover, **and** without the greatest cover in the dwarf shrub layer 14

14. *Empetrum nigrum* (crowberry) with the greatest cover in the dwarf shrub layer . . . . a or b
   a. Site located on an outwash plain or floodplain . . . . *Empetrum nigrum/Carex pluriflora* (crowberry/several-flowered sedge)-outwash s.s.
   b. Site located on an uplifted marsh . . . . *Empetrum nigrum/Carex pluriflora* . . . .(crowberry/several-flowered sedge)-uplifted marsh s.s.

14. *Empetrum nigrum* (crowberry) without the greatest cover in the dwarf shrub layer 15

15. *Carex pluriflora* (several flowered sedge) with at least 20 percent cover . . . . a or b
   a. Site located on an outwash plain or floodplain . . . . *Carex pluriflora-Carex lyngbyaei* (several-flowered sedge-Lyngby's sedge)-outwash s.s.
   b. Site located on an uplifted marsh . . . . *Carex pluriflora-Carex lyngbyaei* (several-flowered sedge-Lyngby's sedge)-uplifted marsh s.s.

15. *Carex pluriflora* (several-flowered sedge) with less than 20 percent cover 16

16. *Eriophorum angustifolium* (tall cottongrass) with the greatest cover . . . . a or b
   a. Site located on an outwash plain or floodplain . . . . *Eriophorum angustifolium* (tall cottongrass)-outwash s.s.
   b. Site located on an uplifted marsh . . . . *Eriophorum angustifolium* (tall cottongrass)-uplifted marsh s.s.

16. *Eriophorum angustifolium* (tall cottongrass) without the greatest cover 17

17. *Carex sitchensis* (Sitka sedge) with the greatest cover 18

17. *Carex sitchensis* (Sitka sedge) without the greatest cover . . . . Unclassified herbaceous-peatland s.s.

18. *Sphagnum* (peat moss) species with at least 25 percent cover . . . . .a or b
   a. Site located on an outwash plain or floodplain . . . .*Carex sitchensis/Sphagnum* (Sitka sedge/peat moss)-outwash s.s.
   b. Site located on an uplifted marsh . . . .*Carex sitchensis/Sphagnum* (Sitka sedge/peat moss)-uplifted marsh s.s.

18. *Sphagnum* (peat moss) species with less than 25 percent cover . . . . .a or b
   a. Site located on an outwash plain or floodplain . . . .*Carex sitchensis* (Sitka sedge)-outwash s.s.
   b. Site located on an uplifted marsh . . . .*Carex sitchensis* (Sitka sedge)-uplifted marsh s.s.

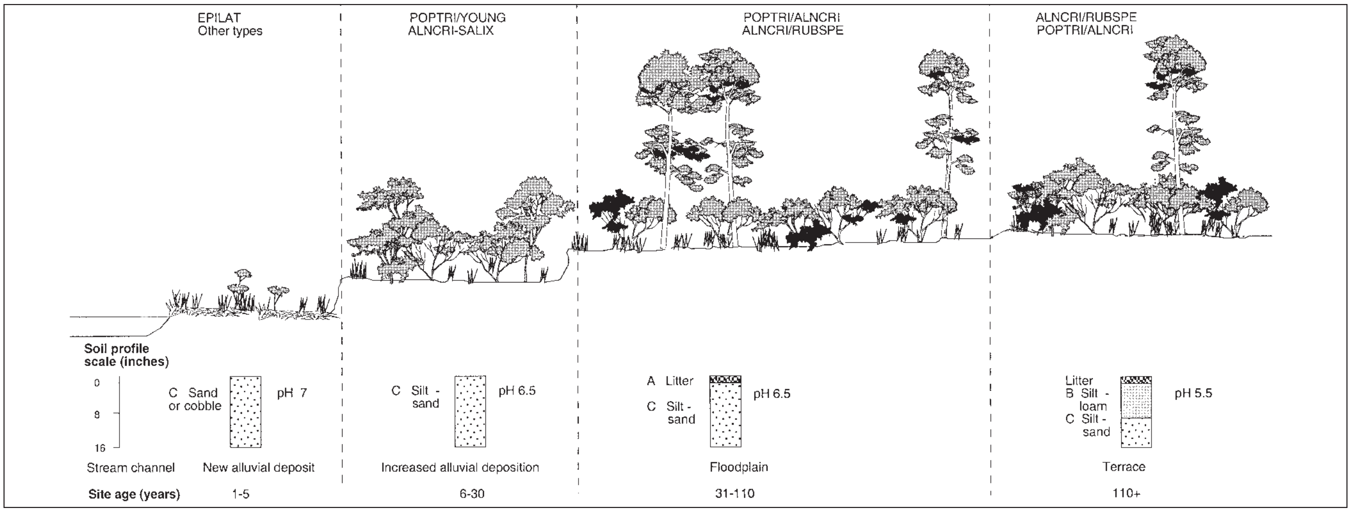

Figure 10—Idealized cross section of vegetation succession, and soil and landform development on well-drained terraces of the Copper River outwash plain, within the Copper River Subsection (ECOMAP 1993).

Successional Sequence Descriptions

Each successional sequence is named after the oldest observed community type in the sequence, and the landscape on which it occurs. Essentially, the oldest community in the successional sequence is analogous to a plant association (DeMeo and others 1992, Martin and others 1995). By identifying the site conditions under which it develops (i.e., landscape), we can greatly increase our understanding of the successional pathways. The geomorphology associated with these aeolian and fluvial derived landscapes has an overriding influence on vegetation succession. Communities dominated by aquatic vegetation were not included as late-successional communities.

Using a chronosequence approach for describing succession presents certain problems in accuracy. Studies have shown that a consistent stepwise progression in seral stages is not an accurate portrayal of succession on any given surface (Boggs and Weaver 1994, Fastie 1995). Multiple pathways occur and are likely a function of landscape characteristics and species life history. This classification does not attempt to describe absolute steps in community succession but rather presents general or multiple pathways.

Outwash Plain and Floodplain Successional Sequences

Because of the similarity in succession of vegetation, soils, and landform between outwash plains and floodplains, they are presented together.

The term outwash plain was used within the descriptive name (e.g., *Alnus crispa/Rubus spectabilis* [Sitka alder/salmonberry]-outwash s.s.) instead of floodplain, because of the dominance of outwash plains on the Copper River Delta. Thirteen successional sequences were identified on the outwash plains and floodplains; one sequence ending in an *Alnus* (alder) community (fig. 10), three sequences ending in forested communities (fig. 11 and table 7), and nine sequences ending in peatland communities (fig. 12). Each successional sequence is named for one of the 13 late-successional community types identified and the landscape identifier (outwash plain). The successional pathway diagrams (figs. 10 to 12) typically group several successional sequences together when site and vegetation development are similar. Each successional sequence description gives (or refers to) the vegetation successional pathways and site development. Descriptions of each community type are given in the various community type description sections.

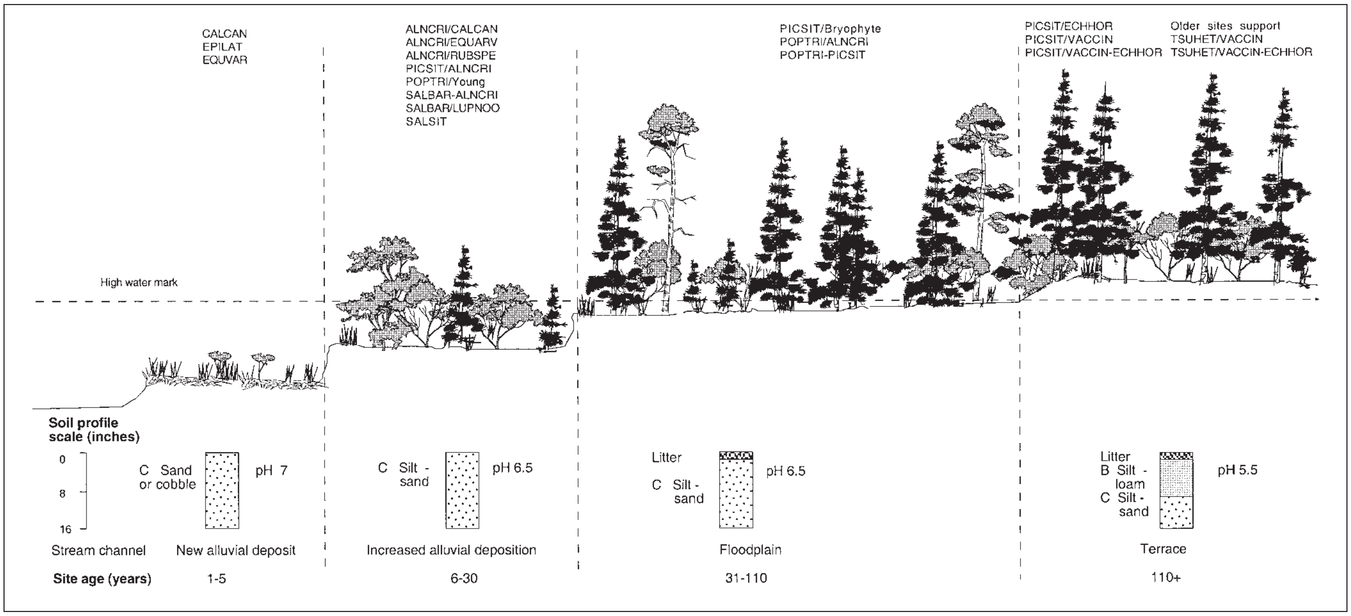

Figure 11—Idealized cross section of vegetation succession, and soil and landform development on well-drained terraces of outwash plains and floodplains, within the Copper River Delta subsection (ECOMAP 1993).

Table 7—Two hypothesized successional pathways for forested community types on poorly drained terraces of glacial outwash plains, floodplains, and uplifted marshes, excluding the Copper River floodplain

	Community types and site factors	
Stage	Hypothesis 1	Hypothesis 2
Late	(*Tsuga heterophylla* invades and eventually codominates with *Picea sitchensis*) *Tsuga heterophylla/ Vaccinium ovalifolium-Lysichiton americanum*	(*Tsuga heterophylla* invades and eventually codominates with *Picea sitchensis) Tsuga heterophylla/ Vaccinium ovalifolium-Lysichiton americanum*
Mid	(Hummocks form from alluvium or from root wads) *Picea sitchensis/ Vaccinium ovalifolium/ Lysichiton americanum*	(Hydric vegetation invades the hollows between root wads) *Picea sitchensis/Vaccinium ovalifolium/Lysichiton americanum*
Early	(Newly deposited alluvium supporting mesic communities) *Alnus crispa/ Calamagrostis canadensis* *Salix barclayi/Carex sitchensis* *Myrica gale/Carex sitchensis* *Calamagrostis canadensis*	(Water table rises on established dry to mesic communities) *Picea sitchensis/Vaccinium ovalifolium* *Picea sitchensis/Echinopanax horridum* *Picea sitchensis/Vaccinium ovalifolium-Echinopanax horridum*

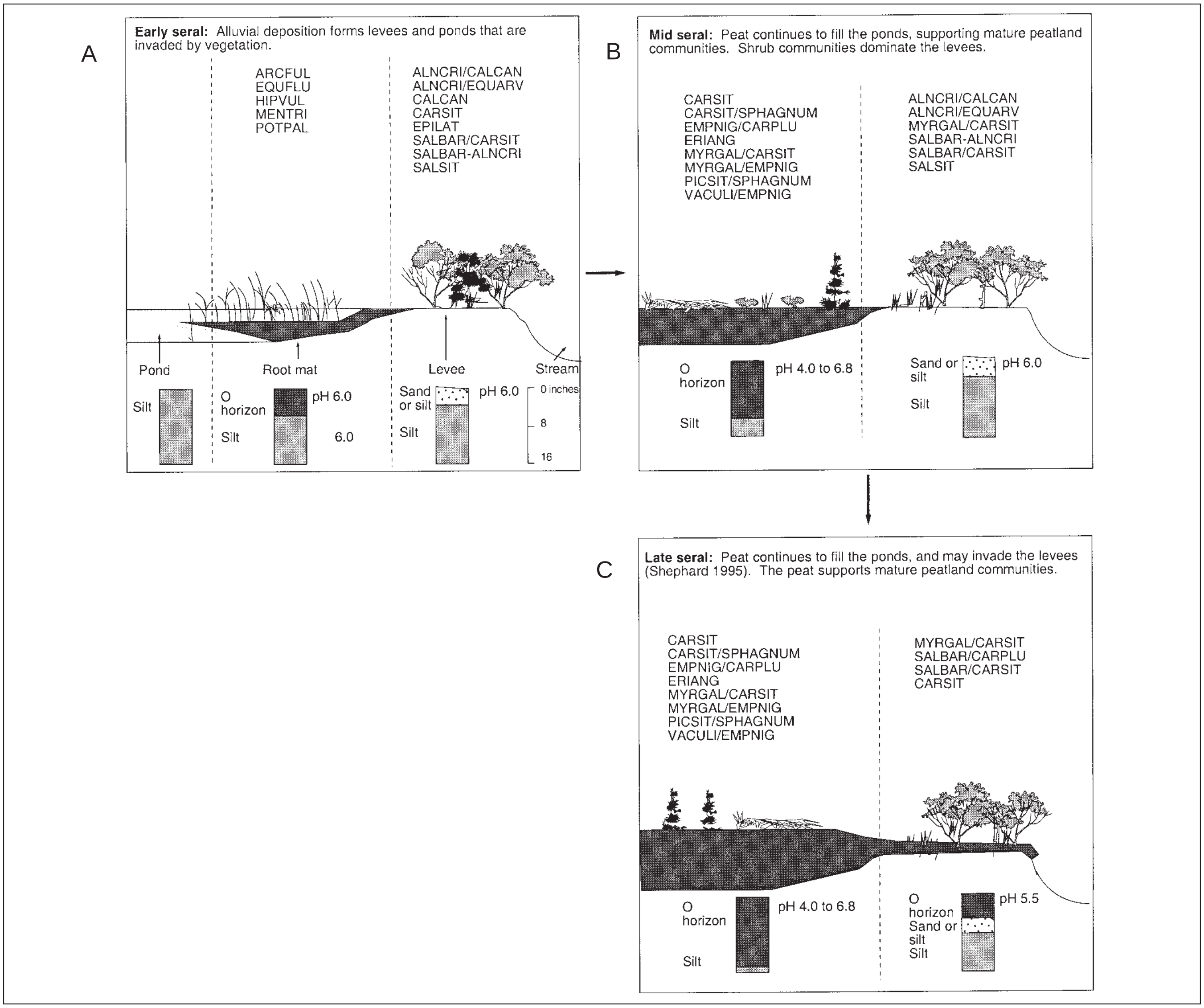

Figure 12—Idealized cross section of vegetation succession and soil and landform development on wet levees (terraces) and ponds of outwash plains and floodplains.

***Alnus crispa/Rubus spectabilis* (Sitka alder/salmonberry)-outwash s.s.—**This successional sequence is found only on well-drained outwash terraces within the Copper River Subsection (fig. 1). It is initiated by colonization of new alluvial bars or abandoned river channels by various pioneer species (fig. 10). These include *Alnus crispa* subsp. *sinuata, Epilobium latifolium* (river beauty), and a scattering of *Populus trichocarpa* (black cottonwood). Four community types were identified on the new alluvial bars including the *Populus trichocarpa/*young (black cottonwood/young) c.t. (without *Picea sitchensis* [Sitka spruce]), *Alnus crispa/Equisetum arvense* (Sitka spruce/meadow horsetail) c.t., *Alnus crispa-Salix* (Sitka alder-willow) c.t., and the *Epilobium latifolium* c.t. Sites without black cottonwood develop into the *Alnus crispa/Rubus spectabilis* c.t. Sites with black cottonwood persist and grow in height and girth into the *Populus trichocarpa/Alnus crispa* (black cottonwood/Sitka alder) c.t., characterized by large expanses of widely spaced mature cottonwood over a dense understory of *Alnus crispa* subsp. *sinuata, Rubus spectabilis*, and *Echinopanax horridum* (devil's club). Black cottonwood seems to regenerate primarily on new alluvial deposits but also may regenerate on older sites and persist indefinitely. If black cottonwood does not regenerate in an area, *Alnus crispa/Rubus spectabilis* c.t. dominates. This community type is dominated by *Alnus crispa* subsp. *sinuata, Rubus spectabilis*, and *Echinopanax horridum*. The outwash of the Copper River is relatively young, and may, in time, support other late-seral *Alnus crispa* subsp. *sinuata*, black cottonwood, or Sitka spruce communities.

***Tsuga heterophylla/Vaccinium ovalifolium* (western hemlock/tall blueberry)-outwash s.s.—**On the floodplains of the smaller rivers of the Copper River Delta (but not the Copper River), new alluvial bars or abandoned stream channels are colonized by tree, shrub, and herbaceous species including *Populus trichocarpa* (black cottonwood), *Picea sitchensis* (Sitka spruce), *Alnus crispa* subsp. *sinuata* (Sitka alder), *Salix barclayi* (Barclay willow), *Epilobium latifolium* (river beauty), and *Equisetum variegatum* (northern horsetail) (fig. 11). Eleven community types were identified on the young alluvial bars including *Populus trichocarpa*/young (black cottonwood/young), *Alnus crispa/Equisetum arvense* (Sitka alder/meadow horsetail), and *Epilobium latifolium* c.t.'s.

The next successional stage on these well-drained deposits includes the *Populus trichocarpa-Picea sitchensis* (black cottonwood-Sitka spruce), *Populus trichocarpa/ Alnus crispa* (black cottonwood/sitka alder), and *Picea sitchensis*/bryophyte (Sitka spruce/ bryophyte) c.t.'s (fig. 11). The tall shrub component of the early-successional stages diminishes rapidly, probably because of decreased light from the dense tree overstory. *Populus trichocarpa* does not regenerate and, consequently, dies out within 150 years, whereas *Picea sitchensis* exhibits healthy regeneration and dominates the sites with a multilayered tree canopy. Several mature *Picea sitchensis* communities eventually will develop. *Tsuga heterophylla* (western hemlock) ultimately invades the sites, typically codominating with *Picea sitchensis*, and forms either the *Tsuga heterophylla/Vaccinium ovalifolium* (western hemlock/tall blueberry) c.t. or the *Tsuga heterophylla/Vaccinium ovalifolium-Echinopanax horridum* (western hemlock/tall blueberry-devil's club) c.t. During succession, the loss of mature *Populus trichocarpa* and *Picea sitchensis* does not seem to significantly alter the understory structure and composition of the forest. Browsing by moose and cutting by beaver will alter the structure and composition of shrub- or tree-dominated communities (Stephenson 1995). If woody species utilization is intense enough, conversion from a shrub- or tree-dominated community to herbaceous-dominated community is possible.

Peatlands may encroach (paludification) on these forested sites. This is especially true of stringers of trees found next to peatlands. Examples include forested levees on uplifted marshes, distal outwash, and floodplains. See figure 12 for a list of these peatland community types.

***Tsuga heterophylla/Vaccinium ovalifolium-Echinopanax horridum* (western hemlock/tall blueberry-devil's club)-outwash s.s.—**This successional sequence is similar to the above (fig. 11). It seems to occupy moister sites than the *Tsuga heterophylla/ Vaccinium ovalifolium* (western hemlock/tall blueberry) s.s. as indicated by the understory component. All other site dynamics and conditions are similar. Peatlands may encroach (paludification) on forested sites found adjacent to peatlands.

***Tsuga heterophylla/Vaccinium ovalifolium/Lysichiton americanum* (western hemlock/tall blueberry/yellow skunk cabbage)-outwash s.s.—**Two hypotheses are proposed for the development of the site and vegetation characteristics of this successional sequence (table 7). (1) On moist (possibly wet) sites, hummocks form from either alluvial deposition or herbaceous and shrub root wads. The root wads will decompose and eventually become soil. The hummocks at first support shrubs or even herbaceous vegetation, but over time, *Picea sitchensis* (Sitka spruce) invades, and further hummocks develop from stumps, logs, and toppled root wads (DeMeo and others 1992). Site information suggests that the successional sequence proceeds from the *Picea sitchensis/Vaccinium ovalifolium/Lysichiton americanum* (Sitka spruce/tall blueberry/ yellow skunk-cabbage) c.t. to the *Tsuga heterophylla/Vaccinium ovalifolium/ Lysichiton americanum* (western hemlock/tall blueberry/yellow skunk-cabbage) c.t. (2) An alternate hypothesis is that well-drained sites supporting *Picea sitchensis* (Sitka spruce) or *Tsuga heterophylla* (western hemlock) are flooded because of a general elevation in the water table level, as often occurs with beaver activity. The understory vegetation composition will then change from mesic tolerant species to wetland species, such as *Lysichiton americanum* (yellow skunk-cabbage). The tree species survive because of their elevated root bases and their ability to germinate on stumps, logs, and toppled root wads. Peatlands may encroach (paludification) on forested sites found adjacent to peatlands.

***Carex sitchensis* (Sitka sedge)-outwash s.s.—**This successional sequence develops on ponded basins that often support small- to mid-size lakes, and low-gradient (< 3 percent) slopes with an elevated water table such as wet levees. They typically occur on distal glacial outwash plains and floodplains. For purposes of classification, the moisture gradient was divided into two general successional pathways: ponded basins and wet levees (fig. 12).

Within ponds, aquatic vegetation colonizes open water, and emergent vegetation will typically colonize the edge of a pond (fig. 12). Examples of aquatic communities include the *Myriophyllum spicatum* (water milfoil) and *Potamogeton natans* (floating-leaved pondweed) community types. Emergent vegetation communities, such as *Equisetum fluviatile* (swamp horsetail) and *Potentilla palustris* (marsh fivefinger) community types, typically form floating root mats. In time, the root mats thicken and become anchored to the mineral substrate, developing into peatlands.

On low-gradient wet levees or terraces, shrub and herbaceous communities develop on the mineral substrate (fig. 12). These community types include *Salix barclayi/Carex sitchensis* (Barclay willow/Sitka sedge), *Myrica gale/Carex sitchensis* (sweetgale/Sitka sedge), and *Carex sitchensis* (Sitka sedge). In time, peat accumulates and the sites form peatlands. Further thickening of the peat may lead to development of peatland communities found within the ponded basins.

Plots sampled for the *Carex sitchensis* c.t. were all found to be fens. Fens are wetlands with wet organic (histic, peat) soils, dominated by aquatic, emergent, and dwarf shrubs, or raised peat dominated by shrubs and trees. Ground water, the primary water source in a fen, is nutrient rich because of its contact with mineral soils. Waters may be acidic or basic, but typically with a pH above 4.7. Water is lost through evapotranspiration, seepage (infiltration through the soil), and surface outflow.

Peatlands exhibit recognizable and consistent vegetation zonation patterns in all successional stages. The vegetation is directly associated with different water depths. The vegetation, on a wet to dry moisture gradient, typically changes from aquatic to emergent, to mesic herbaceous, to carr (shrub-dominated wetland), to dwarf tree. Not all the vegetation zones are always expressed, and the zonation may change abruptly, such as from a pond to a carr.

Water regimes and nutrients are the principal factors controlling plant community distribution in fens, and beaver and fire also can play major roles (Sims and others 1982). Stagnant water-dominated sites have lower available nutrients because of anaerobic conditions. At some lakes, floating mats of peat form on the edge of the lake and have the potential to gradually cover the lake. At other lakes, peat accumulates on the bottom and over time fills in the lake. Ground with a slight gradient and with heavy subsurface and surface waterflow often develops a pattern of vegetated ridges and vegetated or unvegetated hollows filled with water.

Beavers typically have a major effect on the development and maintenance of fens by creating pools, forming hummocks with their dams, and consuming woody vegetation. They often increase the width of a fen by damming the edge of the peatland and increasing the area of water. Peat occurring above the water table is usually temporary, often caused by a drop in water table from a drought or when a beaver pond drains. The peat will decompose and subside. In interior Alaska, fire will burn the raised peat and return the cycle to standing water.

Peat buildup, patterned ground, and changes in water table are recurrent aspects of peatland development rather than unidirectional successional events. It is unlikely that any of the late-seral peatland communities are stable in the sense of climax vegetation. Stable site conditions are the exception rather than the rule (McAllister 1990). Consequently, the same site may support several late-successional types over time.

Myrica gale/Empetrum nigrum **(sweetgale/crowberry)-outwash s.s.—**This successional sequence occurs within ponded basins supporting small to mid size lakes, or low gradient (< 3 percent) slopes with an elevated water table. These sites typically occur on distal glacial outwash plains and floodplains. For purposes of classification, the moisture gradient was divided into two general successional pathways: ponds and moist to wet terraces (fig. 12).

Within ponds, aquatic vegetation colonizes open water, and emergent vegetation will typically colonize a pond's edge (fig. 12). Examples of aquatic communities include *Myriophyllum spicatum* (water milfoil) c.t. and *Potamogeton natans* (floating-leaved pondweed) c.t. Emergent vegetation communities, such as the *Equisetum fluviatile* (swamp horsetail) and *Potentilla palustris* (marsh fivefinger) community types, typically form floating root mats. In time, the root mats thicken, become anchored to the mineral substrate, and develop into peatlands.

On low gradient wet terraces, shrub and herbaceous communities develop on the mineral substrate (fig. 12). These community types include *Salix barclayi/Carex sitchensis* (Barclay willow/Sitka sedge), *Myrica gale/Carex sitchensis* (sweetgale/Sitka sedge), and *Carex sitchensis* (Sitka sedge). In time, peat accumulates and the sites form peatlands.

Plots sampled for the *Myrica gale/Empetrum nigrum* (sweetgale/crowberry) c.t. were all bogs. Bogs are wetlands with organic (histic, peat) soils, typically dominated by *Sphagnum* (peat moss) species, sedges, grasses, or reeds. Bogs require depressions (ponds) in level areas where precipitation exceeds evapotranspiration. Precipitation is the primary water source in a bog, with little or no ground-water flow. Consequently, the sites are nutrient poor and acidic, commonly with a pH less than 4.7. The water table is at or close to the surface most of the year.

Peatlands exhibit recognizable and consistent vegetation zonation patterns in all successional stages. The vegetation is directly associated with different water depths. The vegetation, on a wet to dry moisture gradient, typically changes from aquatic, to emergent, to mesic herbaceous, to carr (shrub-dominated wetland), to dwarf tree. Not all the vegetation zones are always expressed, and in bogs, the zonation may change more abruptly, such as from a pond to a carr.

A new pond or depression often will start out as a fen, with ground-water or stream-water flow providing plentiful nutrients. Because of peat buildup and flow diversion, a fen may lose the inflows of nutrient-rich water, thereby resulting in the conversion of all or only portions of the peatland into a bog. Consequently, because of the continuum of site and vegetation change, it is difficult to clearly separate a fen from a bog in the field or conceptually. Peatlands of the Copper River Delta range from pure fens or bogs to a continuum between the two.

Peat buildup, patterned ground, and changes in water table are recurrent aspects of peatland development rather than unidirectional successional events. It is unlikely that any of the late-seral peatland communities are stable in the sense of climax vegetation. Stable site conditions are the exception rather than the rule (McAllister 1990). Consequently, the same site may support several late-successional types over time.

***Carex sitchensis/Sphagnum* (Sitka sedge/peat moss)-outwash s.s.—**Plots sampled for the late-seral community of this successional sequence were fens or bogs. Consequently, succession is similar to both the (fen) *Carex sitchensis* (Sitka sedge)-outwash s.s. and (bog) *Myrica gale/Empetrum nigrum* (sweetgale/crowberry)-outwash s.s. (fig. 12).

***Empetrum nigrum/Carex pluriflora* (crowberry/several-flowered sedge)-outwash s.s.—**Plots sampled for the late-seral community of this successional sequence were fens or bogs. Consequently, succession is similar to both the (fen) *Carex sitchensis* (Sitka sedge)-outwash s.s. and (bog) *Myrica gale/Empetrum nigrum* (sweetgale/crowberry)-outwash s.s. (fig. 12).

***Eriophorum angustifolium* (tall cottongrass)-outwash s.s.—**Plots sampled for the late-successional community of this successional sequence were all bogs. Succession is similar to the (bog) *Myrica gale/Empetrum nigrum* (sweetgale/crowberry)-outwash s.s. (fig. 12).

***Myrica gale/Carex sitchensis* (sweetgale/Sitka sedge)-outwash s.s.—**Plots sampled for the late-successional community of this successional sequence were all fens. Succession is similar to the (fen) *Carex sitchensis* (Sitka sedge)-outwash s.s. (fig. 12).

***Picea sitchensis/Sphagnum* (Sitka spruce/peat moss)-outwash s.s.—**Plots sampled for the late-successional community of this successional sequence were all fens. Succession is similar to the (fen) *Carex sitchensis* (Sitka sedge)-outwash s.s. (fig. 12).

***Salix barclayi/Carex pluriflora* (Barclay willow/several-flowered sedge)-outwash s.s.—**Plots sampled for the late-successional community of this successional sequence were all fens. Succession is similar to the (fen) *Carex sitchensis* (Sitka sedge)-outwash s.s. (fig. 12).

***Salix barclayi/Carex sitchensis* (Barclay willow/Sitka sedge)-outwash s.s.—**Plots sampled for the late-successional community of this successional sequence were all fens. Succession is similar to the (fen) *Carex sitchensis* (Sitka sedge)-outwash s.s. (fig. 12).

***Vaccinium uliginosum/Empetrum nigrum* (bog blueberry/crowberry)-outwash s.s.—**Plots sampled for the late-successional community of this successional sequence were fens or bogs. Consequently, succession is similar to both the (fen) *Carex sitchensis* (Sitka sedge)-outwash s.s. and (bog) *Myrica gale/Empetrum nigrum* (sweetgale/crowberry)-outwash s.s. (fig. 12).

Uplifted Marsh Successional Sequences

Fourteen successional sequences were identified on the uplifted marsh landscape; three sequences ending in forested communities and 11 sequences ending in peatland communities (fig. 13). Each successional sequence is named for one of the 14 late-successional community types identified and the landscape identifier (uplifted marsh). The successional pathway diagram (fig. 13) groups the successional sequences together because site and vegetation development are often similar. Each successional sequence description gives (or refers to) the vegetation successional pathways and site development. The forested communities are listed as mid-seral in figure 13 because of the possibility of paludification from the adjacent peatlands; however, they are considered late-seral communities within the text. Community type descriptions are given in the various community types sections.

***Tsuga heterophylla/Vaccinium ovalifolium* (western hemlock/tall blueberry)-uplifted marsh s.s.—**Before the 1964 tectonic uplift, the levees of the tidal marsh were dominated by tide-tolerant communities. The following belts of vegetation progressing from the sea inland on levees, from herbaceous to shrub to forest: *Hedysarum-Deschampsia, Myrica-Poa, Salix-Festuca, Alnus-Calamagrostis*, and *Picea-Streptopus*. Only the *Hedysarum-Deschampsia* belt was regularly inundated by tides and consequently contained salt-tolerant species. The *Myrica-Poa* and *Salix-Festuca* vegetation zones were flooded only by extreme storm tides, and the *Alnus-Calamagrostis* and *Picea-Streptopus* zones were rarely, if ever, tidally flooded.

After the uplift of the tidal marsh, freshwater-tolerant species such as *Alnus crispa* subsp. *sinuata* (Sitka alder), *Salix barclayi* (Barclay willow), and *Picea sitchensis* (Sitka spruce) invaded the levees (fig. 13). These and additional species have persisted and grown in height and girth and have formed several community types including *Picea sitchensis/Alnus crispa* (Sitka spruce/Sitka alder), *Alnus crispa/Equisetum arvense* (Sitka alder/meadow horsetail), and *Athyrium filix-femina* (lady-fern). The drier levees are seral to tree communities, whereas the moist to wet levees will not support tree communities (except possibly the *Tsuga heterophylla/Vaccinium ovalifolium/Lysichiton americanum* [western hemlock/tall blueberry/yellow skunk cabbage] c.t.) and are seral to peatland communities (see the *Carex sitchensis* [Sitka sedge]-uplifted marsh s.s.).

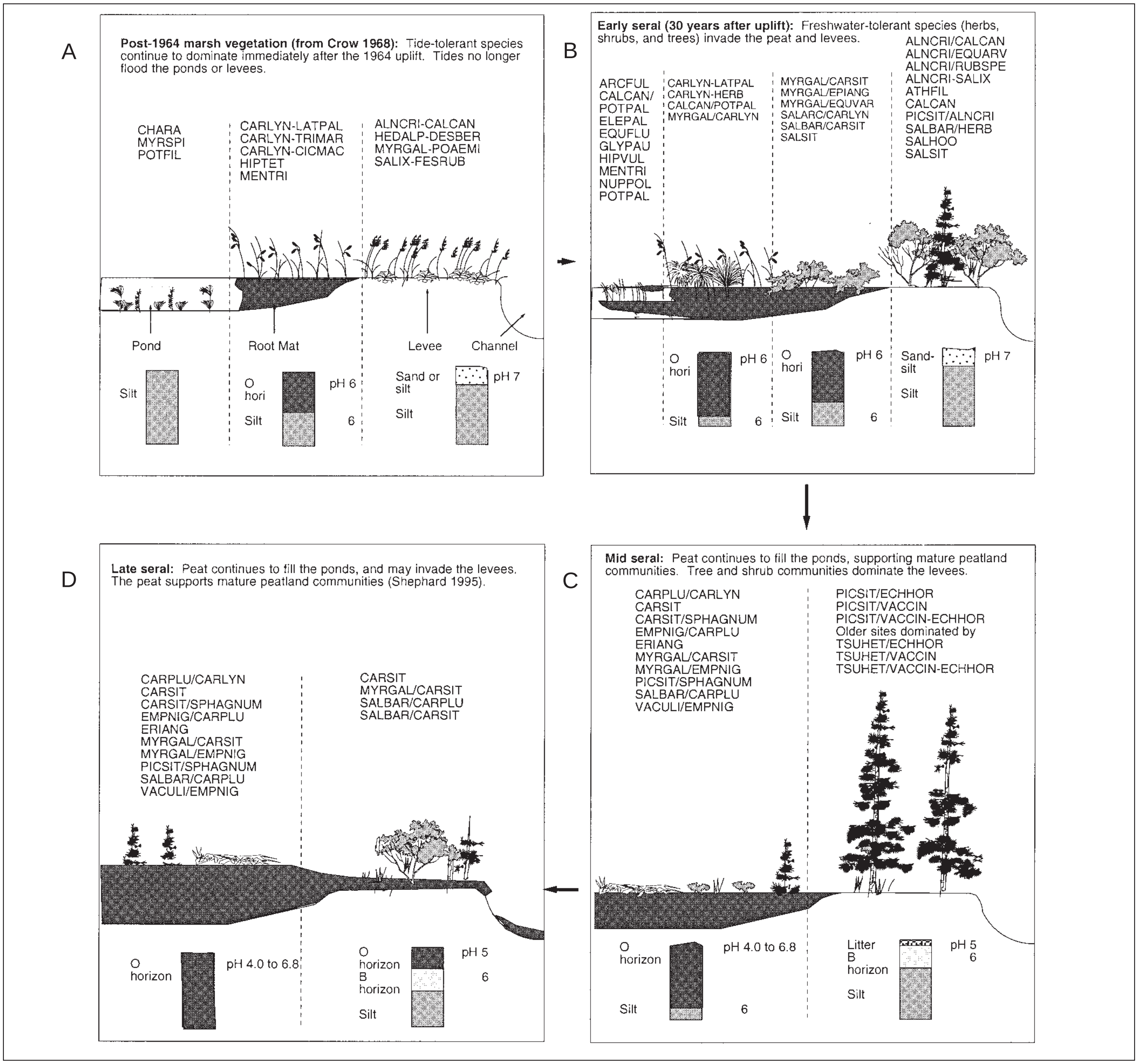

Figure 13—Idealized cross section of vegetation succession, and soil and landform development on uplifted tidal marshes.

Subsequent successional stages on the moist to dry levees were determined from observations of older uplifted tidal marshes on the Yakutat Forelands. The next stage of succession may be forested with a dense shrub understory. The tall shrub component (*Alnus crispa* subsp. *sinuata* and *Salix* [willow] species) diminishes rapidly, probably because of decreased light from the dense tree overstory. *Picea sitchensis* exhibits healthy regeneration and eventually dominates the levees which results in a multi-layered tree canopy, and the forming of communities such as the *Picea sitchensis/ Vaccinium ovalifolium* (Sitka spruce/tall blueberry) (fig. 13).

Tsuga heterophylla eventually invades the sites and typically codominates with *Picea sitchensis* to form communities such as the *Tsuga heterophylla/Vaccinium ovalifolium* (western hemlock/tall blueberry) c.t. Browsing by moose and cutting by beaver will alter the structure and composition of shrub- or tree-dominated communities (Stephenson 1995). Intense use of woody species could result in conversion from a shrub- or tree-dominated community to a herbaceous-dominated community.

Peatlands may encroach (paludification) on forested sites (fig. 13). This is especially true of stringers of trees adjacent to peatlands—*Tsuga heterophylla/Vaccinium ovalifolium-Echinopanax horridum* (western hemlock/tall blueberry-devil's club)-uplifted marsh s.s. This successional sequence is similar to the above. It seems to occupy moister sites than the *Tsuga heterophylla/Vaccinium ovalifolium* (western hemlock/tall blueberry) c.t., however, as indicated by the understory component. All other site dynamics and conditions are similar.

***Tsuga heterophylla/Vaccinium ovalifolium/Lysichiton americanum* (western hemlock/tall blueberry/yellow skunk-cabbage)-uplifted marsh s.s.—**Two hypotheses are proposed for the development of the site and vegetation characteristics of this successional sequence. (1) On moist (possibly wet) sites, hummocks form from either alluvial deposition or herbaceous and shrub root wads. The root wads will decompose and eventually become soil. The hummocks at first support shrubs or even herbaceous vegetation, but over time, *Picea sitchensis* (Sitka spruce) invades. Additional hummocks develop from stumps, logs, and toppled root wads (DeMeo and others 1992). Site information suggests that the successional sequence proceeds from the *Picea sitchensis/Vaccinium ovalifolium/Lysichiton americanum* (Sitka spruce/tall blueberry/yellow skunk cabbage) c.t. to the *Tsuga heterophylla/Vaccinium ovalifolium/Lysichiton americanum* (western hemlock/tall blueberry/yellow skunk-cabbage) c.t. (2) The other hypothesis is that well-drained sites supporting *Picea sitchensis* or *Tsuga heterophylla* are flooded because of a general elevation in the water table level, as often occurs with beaver activity. The understory vegetation composition will then change from mesic-tolerant species to wetland species, such as *Lysichiton americanum* (yellow skunk-cabbage). The tree species survive because of their elevated root bases and their ability to germinate on stumps, logs, and toppled root wads. Peatlands may encroach (paludification) on these forested sites. This is especially true of stringers of trees found next to peatlands. Examples include forested levees on uplifted marshes, distal outwash, and floodplains. See figure 13 for a list of these peatland community types.

***Carex sitchensis* (Sitka sedge)-uplifted marsh s.s.—**This successional sequence develops on ponded basins, nontidal channels and wet levees throughout the uplifted marsh. Before the uplift, the ponded basins supported emergent vegetation on the edge of a pond and aquatic vegetation within a pond. Channel edges supported emergent vegetation, and levees supported herbaceous and woody communities.

Within the seaward ponds, Crow (1968) identified three aquatic community types: *Potamogeton filiformis* (pondweed), *Myriophyllum spicatum* (water milfoil), and *Chara* (chara) (fig. 13). With the loss of the tidal influence, other aquatic species have invaded, such as *Ranunculus trichophyllus* (white water crowfoot) and *Utricularia vulgaris* (bladderwort). Emergent vegetation communities, such as *Equisetum fluviatile* (swamp horsetail) c.t. and *Potentilla palustris* (marsh fivefinger) c.t., typically invade the aquatic communities by forming floating root mats on the edge of a pond. In time, the root mats thicken and become anchored to the mineral substrate. In nutrient-rich peatlands (fen), various species invade the root mats and help to form peat. Species such as *Carex sitchensis, Potentilla palustris*, and *Menyanthes trifoliata* (buckbean) come to dominate the sites (fig. 13). Various community types occupy the mid-successional stages, ranging from shrublands to herbaceous meadows. The late-successional stage of a peatland also supports various community types, depending on the pH, water flow, and nutrient status of the site. One of these late-successional communities is the *Carex sitchensis* (Sitka sedge) c.t.

Crow (1968) also describes emergent communities within the ponded basins including three *Carex lyngbyaei* (Lyngby's sedge) communities, a *Hippuris tetraphylla* (four-leaf marestail) community, and a *Menyanthes trifoliata* (buckbean) (fig. 13). *Carex lyngbyaei* and *Hippuris tetraphylla* prefer tidal marshes and rarely develop in nontidal situations. Even so, as a species and community, *Carex lyngbyaei* has persisted on the uplifted marsh on the Copper River Delta. *Hippuris tetraphylla*, however, is no longer found on the uplifted marsh landscape. The *Carex lyngbyaei* community types currently dominate large portions of the uplifted marshes, but freshwater species such as *Lathyrus palustris* (vetchling), *Myrica gale* (sweetgale), and *Calamagrostis canadensis* (bluejoint) have invaded the sites. Four communities with high *Carex lyngbyaei* canopy values were identified within this classification: *Myrica gale/Carex lyngbyaei* (sweetgale/Lyngby's sedge), *Salix arctica-Carex lyngbyaei* (arctic willow-Lyngby's sedge), *Carex lyngbyaei-Lathyrus palustris* (Lyngby's sedge-vetchling), and *Carex lyngbyaei*-mixed herb (Lyngby's sedge-mixed herb). These sites will convert to mature peatlands, and *Carex lyngbyaei* is not expected to persist. The successional pathways of sites occupied by *Carex lyngbyaei* versus aquatic communities are separate, yet the pathways converge in late succession ending in peatland types.

Grazing by geese significantly affect the persistence of tidal species such as *Carex lyngbyaei.* Jefferies and Sinclair (1992) demonstrated on an isostatically uplifted marsh along Hudson Bay that grazing of herbaceous species by snow geese allows the persistence of certain tidal species. Tidal marsh species persist in the uplifted marsh (now fresh water) because of selective grazing of the freshwater-tolerant species. When swards are protected from grazing, rapid invasion of freshwater-tolerant species occurs.

For the levees of the tidal marsh, Crow (1968) defined the following belts of vegetation moving from herbaceous to shrub to forest: *Hedysarum-Deschampsia, Myrica-Poa, Salix-Festuca, Alnus-Calamagrostis*, and *Picea-Streptopus*. After the uplift of the tidal marsh, freshwater-tolerant species such as *Alnus crispa* subsp. *sinuata* (Sitka alder), *Salix barclayi* (Barclay willow), and *Picea sitchensis* (Sitka spruce) have invaded all the levees (fig. 13). The drier levees are seral to forested types (see the *Tsuga heterophylla/Vaccinium ovalifolium* (western hemlock/tall blueberry)-uplifted marsh s.s.), and the wetter levees are seral to various shrub and herbaceous peatland types, including the *Carex sitchensis* (Sitka sedge) c.t.

Plots sampled for the *Carex sitchensis* (Sitka sedge) c.t. were all fens. Fens are wetlands with organic (histic, peat) soils, typically dominated by aquatic or emergent vegetation, open peatlands with water tables at or close to the surface with sedges and short shrubs, and raised peat dominated by shrubs and trees. Ground water, the primary water source in a fen, is nutrient rich because of its contact with mineral soils. Waters may be acidic or basic, but typically with a pH above 4.7. Water is lost through evapotranspiration, seepage (infiltration through the soil), and surface outflow.

Peatlands exhibit recognizable and consistent vegetation zonation patterns in all successional stages. The vegetation, on a wet to dry moisture gradient, typically changes from aquatic, to emergent, to mesic herbaceous, to carr (shrub-dominated wetland), to dwarf tree. All the vegetation zones are not always expressed, and the zonation may change abruptly, such as from a pond to a carr.

Water regimes and nutrients are the principal factors controlling plant community distribution in fens, and beaver and fire also can play major roles (Sims and others 1982). Stagnant water-dominated sites have lower available nutrients because of anaerobic conditions. On some lakes, floating mats of peat form on the edge and have the potential to gradually cover the lake. On other lakes, peat accumulates on the bottom and, over time, fills in the lake. Ground with a slight gradient and with heavy subsurface and surface water-flow often develops a pattern of vegetated ridges and vegetated or unvegetated hollows filled with water.

Beavers typically have a major effect on the development and maintenance of fens by creating pools, forming hummocks with their dams, and consuming woody vegetation. They often increase the width of a fen by damming the edge of the peatland and increasing the area of water. Peat occurring above the water table is typically temporary, often caused by a drop in water table because of a drought or when a beaver pond drains. The peat will decompose and subside. In interior Alaska, fire will burn the raised peat and return the cycle to standing water.

Peat buildup, patterned ground, and changes in water table are recurrent aspects of peatland development instead of unidirectional successional events. It is unlikely that any of the late-seral peatland communities are stable in the sense of climax vegetation. Stable site conditions are the exception rather than the rule (McAllister 1990). Consequently, the same site may support several late-successional types over time.

Myrica gale/Empetrum nigrum **(sweetgale/crowberry)-uplifted marsh s.s.—**This successional sequence develops on ponded basins and nontidal channels throughout the uplifted marsh. Before the uplift, the ponded basins supported emergent vegetation on the edge of a pond, and aquatic vegetation within a pond. Channel edges supported emergent vegetation.

Within ponds, Crow (1968) identified three aquatic community types (*Potamogeton filiformis* [pondweed], *Myriophyllum spicatum* [water milfoil], and *Chara* [chara]) in the seaward ponds (fig. 13). With the loss of the tidal influence, other aquatic species have invaded, such as *Ranunculus trichophyllus* (white water crowfoot) and *Utricularia vulgaris* (bladderwort). Emergent vegetation communities, such as the *Equisetum fluviatile* (swamp horsetail) and *Potentilla palustris* (marsh fivefinger), typically invade the aquatic communities by forming floating root mats on the edge of a pond. In time, the root mats thicken and become anchored to the mineral substrate. Various community types were found to occupy the mid-successional stages, ranging from shrublands to herbaceous meadows. In nutrient-poor peatlands (bog), *Sphagnum* (peat moss) species invade the surface of the root mats, often with greater than 90 percent cover, and help in forming peat. Acidic and nutrient-poor tolerant vascular species eventually dominate the sites, such as *Myrica gale* (sweetgale), *Empetrum nigrum* (crowberry), *Vaccinium uliginosum* (bog blueberry), *Andromeda polifolia* (bog rosemary), and *Oxycoccus microcarpus* (cranberry) (fig. 13). The late-successional stage of a peatland supports various community types, depending on the pH, waterflow, and nutrient status of a site. One of these late-successional communities is the *Myrica gale/Empetrum nigrum* (sweetgale/crowberry) c.t.

Crow (1968) also describes emergent communities including three *Carex lyngbyaei* (Lyngby's sedge) communities, a *Menyanthes trifoliata* (buckbean) community, and a *Hippuris tetraphylla* (four-leaf marestail) community within the ponded basins (fig. 13). *Carex lyngbyaei* and *Hippuris tetraphylla* prefer tidal marshes and are rarely found in nontidal situations. Even so, as a species, *Carex lyngbyaei* has persisted on the uplifted marsh on the Copper River Delta; *Hippuris tetraphylla,* however, is no longer found. The *Carex lyngbyaei* community types currently dominate large portions of the uplifted marshes, but freshwater species such as *Lathyrus palustris* (vetchling), *Myrica gale, Calamagrostis canadensis* (bluejoint), and *Menyanthes trifoliata* have invaded the sites. Four communities with high *Carex lyngbyaei* cover were identified within this classification: *Myrica gale/Carex lyngbyaei* (sweetgale/Lyngby's sedge), *Salix arctica/Carex lyngbyaei* (arctic willow/Lyngby's sedge), *Carex lyngbyaei-Lathyrus palustris* (Lyngby's sedge-vetchling), and *Carex lyngbyaei*-mixed herb (Lyngby's sedge-mixed herb). The successional pathways of sites occupied by *Carex lyngbyaei* versus aquatic communities are separate, yet the pathways converge in late succession ending in peatland types. *Carex lyngbyaei* is not expected to persist as the ponds convert to mature peatlands.

Plots sampled for the *Myrica gale/Empetrum nigrum* (sweetgale/crowberry) c.t. were all bogs. Bogs are wetlands with organic (histic, peat) soils, typically dominated by *Sphagnum* (peat moss) species, sedges, grasses, or reeds. Bogs require depressions (ponds) in level areas where precipitation exceeds evapotranspiration. Precipitation is the primary water source in a bog, with little or no ground-water flow. Consequently, the sites are nutrient poor and acidic, commonly with a pH less than 4.7. The water table is at or close to the surface most of the year. Peatlands exhibit recognizable and consistent vegetation zonation patterns in all successional stages. The vegetation, on a wet to dry moisture gradient, typically changes from aquatic, to emergent, to mesic herbaceous, to carr (shrub-dominated wetland), to dwarf tree. Not all the vegetation zones are always expressed, and in bogs the zonation may change more abruptly, such as from a pond to a carr.

A new pond or depression often will start out as a fen, with ground-water or streamwater flow providing plentiful nutrients. Because of peat buildup and flow diversion, a fen may lose the inflows of nutrient-rich water, resulting in the conversion of all or only portions of the peatland into a bog. Consequently, because of the continuum of site and vegetation change, it is difficult to clearly separate a fen from a bog in the field or conceptually. Peatlands of the Copper River Delta range from pure fens or bogs to a continuum between the two.

Peat buildup, patterned ground, and changes in water table are recurrent aspects of peatland development instead of unidirectional successional events. It is unlikely that any of the late-seral peatland communities are stable in the sense of climax vegetation. Stable site conditions are the exception rather than the rule (McAllister 1990). Consequently, the same site may support several late-successional types over time.

Carex pluriflora-Carex lyngbyaei **(several-flowered sedge-Lyngby's sedge)-uplifted marsh s.s.—**Plots sampled for the late-seral community of this successional sequence were fens or bogs. Consequently, succession is similar to both the (fen) *Carex sitchensis* (Sitka sedge)-uplifted marsh s.s. and (bog) *Myrica gale/Empetrum nigrum* (sweetgale/crowberry)-uplifted marsh s.s. (fig. 13).

Carex sitchensis/Sphagnum **(Sitka sedge/peat moss)-uplifted marsh s.s.—**Plots sampled for the late-seral community of this successional sequence were fens or bogs. Consequently, succession is similar to both the (fen) *Carex sitchensis* (Sitka sedge)-uplifted marsh s.s. and (bog) *Myrica gale/Empetrum nigrum* (sweetgale/crowberry)-uplifted marsh s.s. (fig. 13).

Empetrum nigrum/Carex pluriflora **(crowberry/several-flowered sedge)-uplifted marsh s.s.—**Plots sampled for the late-seral community of this successional sequence were fens or bogs. Consequently, succession is similar to both the (fen) *Carex sitchensis* (Sitka sedge)-uplifted marsh s.s. and (bog) *Myrica gale/Empetrum nigrum* (sweetgale/crowberry)-uplifted marsh s.s. (fig. 13).

Eriophorum angustifolium **(tall cottongrass)-uplifted marsh s.s.—**Plots sampled for the late-successional community of this successional sequence were all bogs. Succession is similar to the (bog) *Myrica gale/Empetrum nigrum* (sweetgale/crowberry)-uplifted marsh s.s. (fig. 13).

Myrica gale/Carex sitchensis **(sweetgale/Sitka sedge)-uplifted marsh s.s.—**Plots sampled for the late-successional community of this successional sequence were all fens. Succession is similar to the (fen) *Carex sitchensis* (Sitka sedge)-uplifted marsh s.s. (fig. 13).

Picea sitchensis/Sphagnum **(Sitka spruce/peat moss)-uplifted marsh s.s.—**Plots sampled for the late-successional community of this successional sequence were all fens. Succession is similar to the (fen) *Carex sitchensis* (Sitka sedge)-uplifted marsh s.s. (fig. 13).

Salix barclayi/Carex pluriflora **(Barclay willow/several-flowered sedge)-uplifted marsh s.s.—**Plots sampled for the late-successional community of this successional sequence were all fens. Succession is similar to the (fen) *Carex sitchensis* (Sitka sedge)-uplifted marsh s.s. (fig. 13).

Salix barclayi/Carex sitchensis **(Barclay willow/Sitka sedge)-uplifted marsh s.s.—**Plots sampled for the late-successional community of this successional sequence were all fens. Succession is similar to the (fen) *Carex sitchensis* (Sitka sedge)-uplifted marsh s.s. (fig. 13).

***Vaccinium uliginosum/Empetrum nigrum* (bog blueberry/crowberry)-uplifted marsh s.s.—**Plots sampled for the late-seral community of this successional sequence were fens or bogs. Consequently, succession is similar to both the (fen) *Carex sitchensis* (Sitka sedge)-uplifted marsh s.s. and (bog) *Myrica gale/Empetrum nigrum* (sweetgale/crowberry)-uplifted marsh s.s. (fig. 13).

Linear Dune Successional Sequences

Late-successional communities were not identified on the dunes. Consequently, complete successional sequences ending in late-successional communities are not presented for this landscape. This was because of inadequate sampling and does not imply that late-successional types do not exist within the region of study. Further research should clarify succession of vegetation and soil on this landscape. A summary of succession on linear dunes is given below and in table 8. Descriptions of each community type are given in the various community type description sections.

Succession may not always be unidirectional on linear dunes as implied by the following diagrams and discussion. The shifting sands and unstable soil surfaces make for unstable and inconsistent site conditions. Consequently, setbacks in succession or spurts of succession are likely common.

Successional sequence—Blowouts are natural phenomenons in many dune fields and are common on most linear dunes of the Copper River. They are a primary method of dune movement and elongation, and initiator of primary succession. Blowouts occur when wind erodes a small hollow on the upwind side of a vegetated dune. The blowout continues to expand, the shape becoming concave with a steep back slope. Much of the wind-transported sand is deposited on the downwind side of the back slope, forming deltalike or plumelike formations. In time, the steep back slope becomes subdued because of mass wasting from sand avalanches and wind erosion. Many trigger mechanisms for blowout initiation have been cited and include fire, trampling and disturbance by vehicles, grazing, and soil nutrient depletion leading to degeneration of the surface vegetation.

Pioneer dune vegetation (primarily *Elymus arenarius* [beach rye] and *Equisetum variegatum* [northern horsetail]) stabilizes the blowout sand (table 8, Carter 1988). Clonal colonies develop rapidly; *Elymus arenarius* tillers form directly off the main shoot just

Table 8—Successional pathways of community types on linear dunes

Stage	Community types and site factors
Late	Community types unknown
Mid	(Increased stabilization of dunes by plants) *Populus trichocarpa/Alnus crispa* (black cottonwood/Sitka alder) *Populus trichocarpa/Aruncus sylvester* (black cottonwood/goatsbeard) *Alnus crispa/Equisetum arvense* (Sitka alder/meadow horsetail) *Alnus crispa/Rubus spectabilis* (Sitka alder/salmonberry) *Rubus spectabilis-Echinopanax horridum* (salmonberry-devil's club)
Early	(Dune blowouts invaded by pioneer species) *Salix alaxensis* (feltleaf willow) *Equisetum variegatum* (meadow horsetail) *Elymus arenarius* (beach rye)

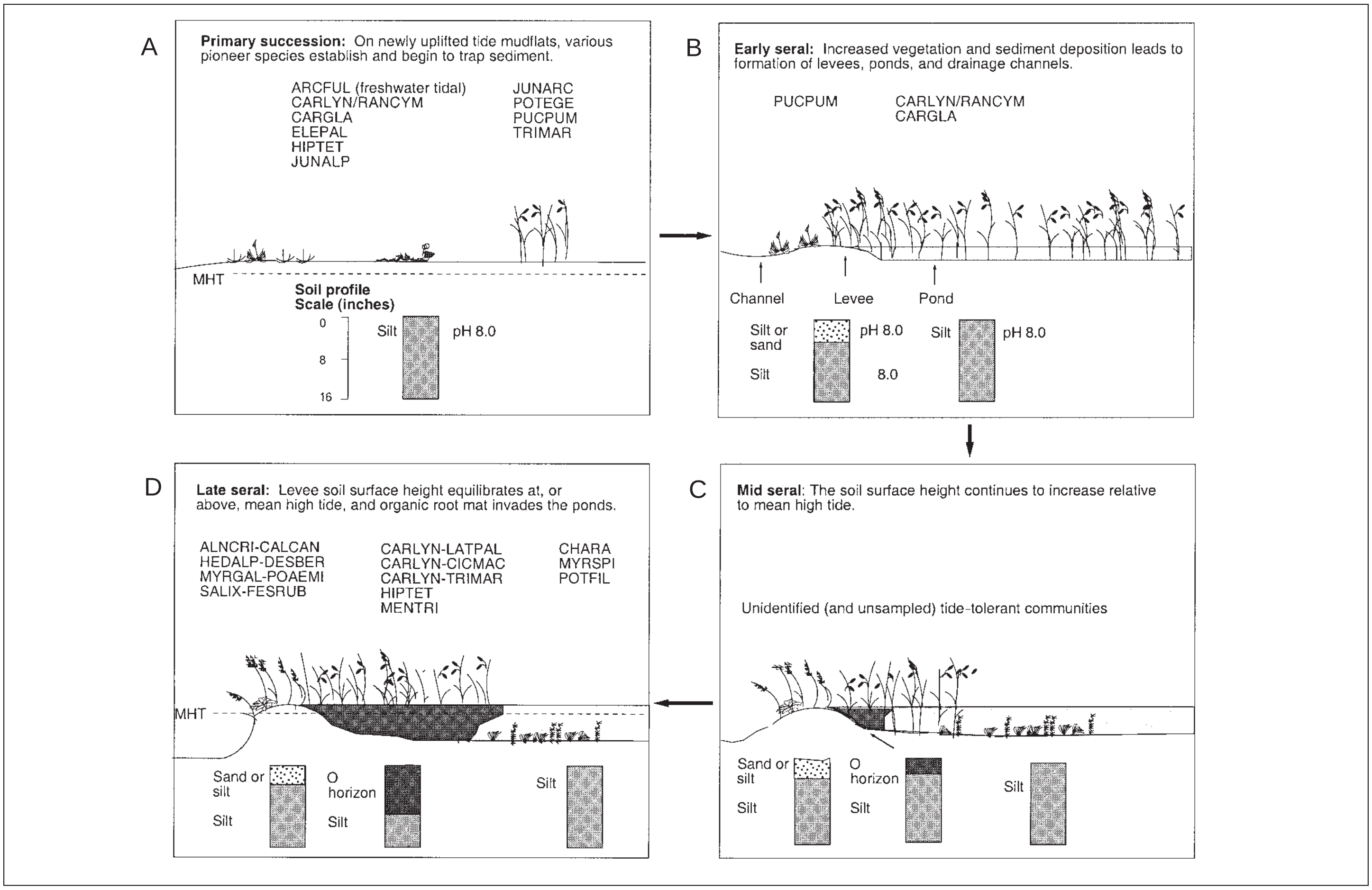

Figure 14—Idealized cross section of vegetation succession, and soil and landform development on tidal marshes.

below surface level and develop obliquely to the main stem (Carter 1988). On mid- and late-successional dunes or portions of dunes, fresh sand input decreases, species diversity increases, and dune builders, such as *Elymus arenarius*, become senescent and depauperate. Trees and shrubs, such as *Alnus crispa* subsp. *sinuata* (Sitka alder), *Rubus spectabilis* (salmonberry), and *Populus trichocarpa* (black cottonwood) invade and further stabilize the sites.

Tidal Marsh Successional Sequences

Nine successional sequences were identified on the tidal marsh landscape; four sequences occurring on levees and five sequences found in ponded basins and tide channels (fig. 14). Each successional sequence is named for one of the nine late-successional community types identified and the landscape identifier (tidal marsh). Aquatic communities are not considered late seral. The successional pathway diagram (fig. 14) groups several successional sequences together because site and vegetation development are often similar. Each successional-sequence description gives (or refers to) the vegetation successional pathways and site development. Descriptions of early-successional community types are given in the various community type descriptions sections. Mid-successional communities were not found on the Copper River Delta and, consequently, were not described. The late-successional types are described in Crow (1968).

***Alnus crispa/Calamagrostis canadensis* (Sitka alder/bluejoint)-tidal marsh s.s.—** The 1964 tectonic uplift lifted portions of the subtidal zone into the intertidal zone, initiating formation of a new tidal marsh. Primary succession on the tidal marsh progresses through a series of stages leading from pioneer species establishing on the newly exposed tideflats to a marsh with creeks, levees, and ponds (figs. 7 and 14). Now, pioneer species such as *Puccinellia pumila* (dwarf alkaligrass), *Ranunculus cymbalaria* (seaside buttercup), *Potentilla egedii* (Pacific silverweed), and *Carex lyngbyaei* (Lyngby's sedge) are establishing on the tideflats.

The newly established vegetation slows the water, which increases sediment deposition. Water slowed at the edges of swards causes high rates of deposition, typically of the coarser sediments. Less sediment is available for deposition in the middle of the sward or marsh further removed from the channel. These differential accretion rates and stabilization by the vegetation lead to the formation of levees (on the edge of the swards and channels) and ponds. The soil surface will continue to increase relative to the high tide because of accretion. Because soil surface height is a function of water height, it eventually equilibrates above mean high tide. Mid- and late-successional tidal ponds and levees were not found on the Copper River Delta. Consequently, mid-successional levee communities could not be determined. Late-successional communities, however, can be inferred from Crow (1968).

On levees, progressing from the sea inland, Crow (1968) defined the following belts of vegetation: *Hedysarum alpinum-Deschampsia beringensis* (alpine sweetvetch-bering hairgrass), *Myrica gale-Poa eminens* (sweetgale-large flower speargrass), *Salix-Festuca rubra* (willow-red fescue), *Alnus-Calamagrostis canadensis* (Sitka alder-bluejoint), and *Picea-Streptopus* (Sitka spruce-twisted stalk). Only the *Hedysarum alpinum-Deschampsia beringensis* (alpine sweetvetch-bering hairgrass) belt was regularly inundated by storm tides. The *Myrica gale-Poa eminens* (sweetgale-large flower speargrass), *Salix-Festuca rubra* (willow-red fescue), *Alnus-Calamagrostis canadensis* (Sitka alder-bluejoint), and *Picea-Streptopus* (Sitka spruce-twisted stalk) vegetation zones were rarely, if ever, flooded by storm tides. The *Picea-Streptopus* (Sitka spruce-twisted stalk) zone appeared to have significant gravel inputs from glacial outwash. Consequently, within this classification, this zone was considered a *Picea sitchensis* (Sitka spruce) community on glacial outwash and not tidal.

The late-successional *Alnus-Calamagrostis canadensis* community (see Crow 1968 for community description) was not only the farthest inland levee community but also the most poorly drained.

***Carex lyngbyaei-Lathyrus palustris* (Lyngby's sedge-vetchling)-tidal marsh s.s.—** The 1964 tectonic uplift lifted portions of the subtidal zone into the intertidal zone, which initiated formation of a new tidal marsh. Primary succession on the tidal marsh progresses through a series of stages leading from pioneer species establishing on the newly exposed tideflats to a marsh with creeks, levees, and ponds (fig. 14). Now, pioneer species such as *Puccinellia pumila* (dwarf alkaligrass), *Ranunculus cymbalaria* (seaside buttercup), *Potentilla egedii* (Pacific silverweed), and *Carex lyngbyaei* (Lyngby's sedge) are establishing on the tideflats above mean high tide (+1.9 yards mean sea level).

The newly established vegetation slows the water, allowing for sediment deposition. Water slowed at the edges of swards causes high rates of deposition, typically of the coarser sediments. Less sediment is available for deposition in the middle of the sward or marsh farther removed from the channel. These differential accretion rates, and stabilization by the vegetation, lead to the formation of levees (on the edge of the swards and channels) and ponds. The soil surface will continue to increase compared with the mean high tide because of accretion.

Before levee formation, only high tides flood the marshes. As the system of ponded basins and levees develop, however, the outflow of tidal water from the basins is slowed, effectively increasing the time of inundation. On a mature tidal marsh, ponded basins are flooded continuously with little change in water level during the growing season.

Mid- and late-successional tidal ponds and levees were not found on the Copper River Delta during this study. Consequently, mid-successional pond communities could not be determined. Late-successional communities of the seaward ponds, however, were described by Crow (1968) and include *Hippuris tetraphylla* (four-leaf marestail), *Carex lyngbyaei-Lathyrus palustris* (Lyngby's sedge-vetchling), *Carex lyngbyaei-Triglochin maritimum* (Lyngby's sedge-seaside arrow grass), and *Carex lyngbyaei-Cicuta mackenzieana* (Lyngby's sedge-water hemlock). Farther inland, the *Hippuris vulgaris* (common marestail) c.t. was common.

Site conditions of emergent vegetation communities, such as the *Carex lyngbyaei-Lathyrus palustris* (Lyngby's sedge-vetchling) c.t., range from poorly drained mineral soil, such as along levee-pond ecotones, to tidal peatlands. This community invades the aquatic communities by forming floating root mats on the edge of a pond. In time, the root mats thicken and become anchored to the mineral substrate. These late-successional tidal peatlands support a variety of community types, depending on the water flow, water depth, and nutrient status on a site.

Crow (1968) also described several aquatic community types, such as *Potamogeton filiformis* (pondweed), *Myriophyllum spicatum* (water milfoil), and *Chara* (chara). It is uncertain whether the aquatic types are stable late-successional communities. Consequently, they are not included as end points in any successional sequence.

Intense grazing of herbaceous species by waterfowl may significantly alter the species composition of both emergent and aquatic communities. On sites with intense grazing, disturbance-maintained communities may be the norm rather than the exception.

Carex lyngbyaei-Cicuta mackenzieana **(Lyngby's sedge-water hemlock)-tidal marsh s.s.—**This successional sequence is similar to that of the *Carex lyngbyaei-Lathyrus palustris* (Lyngby's sedge-vetchling)-tidal marsh s.s. (fig. 14). Site conditions are about the same.

Carex lyngbyaei-Triglochin maritimum **(Lyngby's sedge-seaside arrow grass)-tidal marsh s.s.—**This successional sequence is similar to that of the *Carex lyngbyaei-Lathyrus palustris* (Lyngby's sedge-vetchling)-tidal marsh s.s. (fig. 14). Site conditions are about the same.

***Hedysarum alpinum-Deschampsia beringensis* (alpine sweet vetch-bering hairgrass)-tidal marsh s.s.—**This successional sequence is also similar to the *Alnus-Calamagrostis canadensis* (Sitka alder-bluejoint)-tidal marsh s.s. (fig. 14) in that both develop on levees. The *Hedysarum alpinum-Deschampsia beringensis* (alpine sweet vetch-bering hairgrass) c.t., however, is regularly flooded by storm tides and, consequently, supports tide-tolerant species.

***Hippuris tetraphylla* (four-leaf marestail)-tidal marsh s.s.—**This successional sequence is similar to that of the *Carex lyngbyaei-Lathyrus palustris* (Lyngby's sedge-vetchling)-tidal marsh s.s. (fig. 14). The sites, however, have less peat development. In time, the adjacent *Carex lyngbyaei* (Lyngby's sedge) communities may invade the *Hippuris tetraphylla* (four-leaf marestail) c.t.

***Menyanthes trifoliata* (Buckbean)-tidal marsh s.s.—**This successional sequence is similar to that of the *Carex lyngbyaei-Lathyrus palustris* (Lyngby's sedge-vetchling)-tidal marsh s.s. (fig. 14). The sites, however, are wetter with less peat development. It is unclear whether *Carex lyngbyaei* (Lyngby's sedge) communities would invade the *Menyanthes trifoliata* (buckbean) c.t.

***Myrica gale-Poa eminens* (sweetgale-large flower speargrass)-tidal marsh s.s.—** This successional sequence is similar to that of the *Alnus-Calamagrostis canadensis* (Sitka alder-bluejoint)-tidal marsh s.s. (fig. 14). The *Myrica gale-Poa eminens* (sweetgale-large flower speargrass) c.t. was found mid distance on the levees of the delta and was as well, or better, drained than other levee communities. All other levee site dynamics and conditions seem to be similar.

***Salix-Festuca rubra* (willow-red fescue)-tidal marsh s.s.—**This successional sequence is similar to that of the *Alnus-Calamagrostis canadensis* (Sitka alder-bluejoint)-tidal marsh s.s. (fig. 14). The *Salix-Festuca rubra* (willow-red fescue) c.t. was found mid distance on the levees of the delta, and was as well, or better, drained than other levee communities. All other levee site dynamics and conditions seem to be similar.

Barrier Island-Spit-Coastal Dune Successional Sequences

Three successional sequences were identified on the barrier island-spit-coastal dune landscape, all ending in forested communities (fig. 15). Each successional sequence is named for a late-successional community type identified, and the landscape identifier (the shorter identifier "coastal dune" was used in place of "barrier island-spit-coastal dune"). The successional pathway diagram (fig. 15) groups two successional sequences together because site and vegetation development are similar. Each successional sequence description gives (or refers to) the vegetation successional pathways and site development. On slacks (level areas between dunes), late-successional communities were not identified because of inadequate sampling. I summarize succession on slacks in table 9. Descriptions of each community type are given in the various community type descriptions sections.

Succession may not always be unidirectional in dune systems as implied by the following diagrams and discussion. The shifting sands and unstable soil surfaces make for unstable and inconsistent site conditions. Consequently, setbacks in succession or spurts of succession are likely common; often, a mid-successional stage may be skipped.

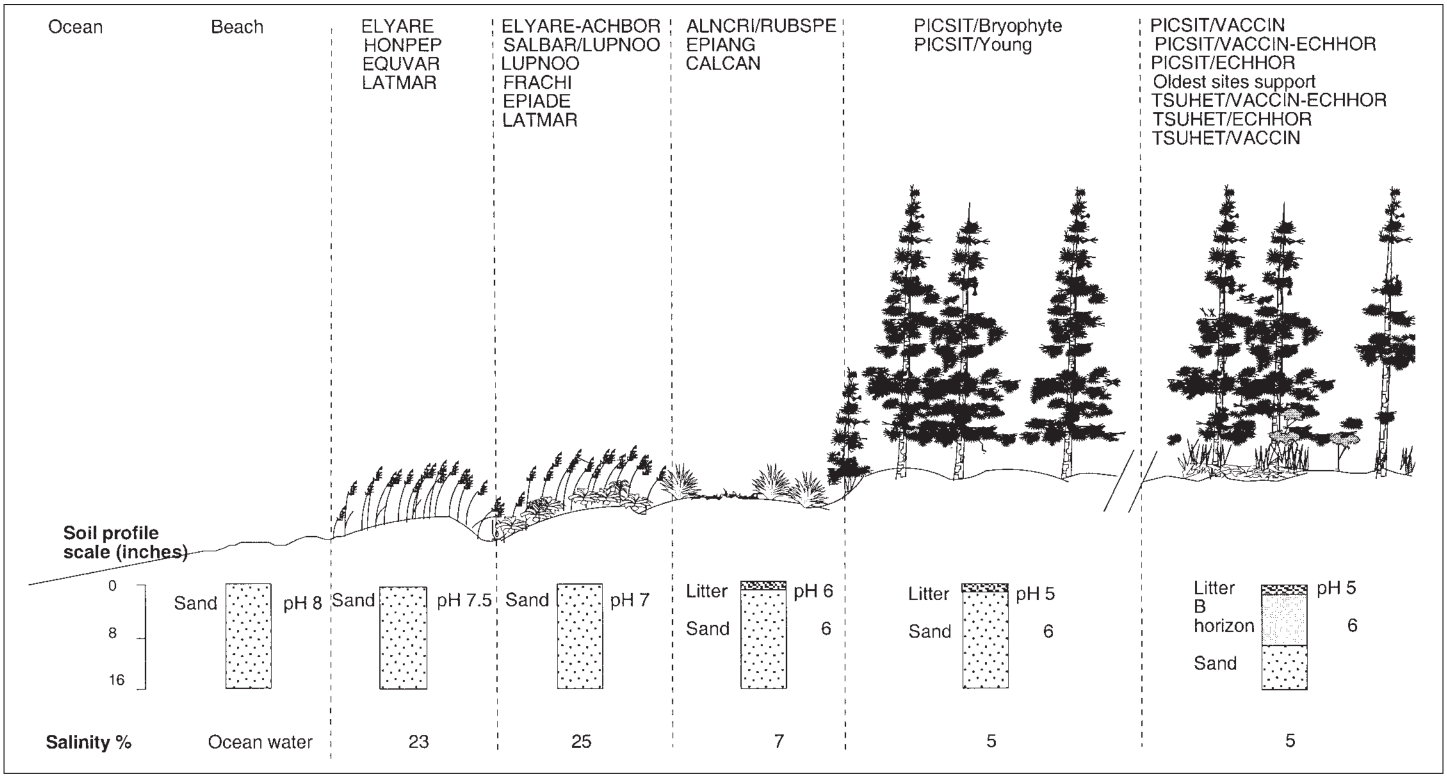

Figure 15—Idealized cross section of vegetation succession, and soil and landform development on the barrier island-spit-coastal dune landscape.

Table 9—Successional pathways of community types found on slacks of barrier islands, spits, and coastal dunes

Stage	Community types and site factors
Late	Some slacks may develop into forested sites or peatlands, whereas other slacks may not persist to late succession because of dune encroachment.
Mid	The sites are elevated by deposition of tidal and windblown sand, and rising of the land. *Picea sitchensis/Alnus crispa* (Sitka spruce/Sitka alder) *Salix barclayi/Lupinus nootkatensis* (Barclay willow/nootka lupine) *Salix barclayi/Equisetum variegatum* (Barclay willow/northern horsetail) *Salix barclayi/*mixed herb (Barclay willow/mixed herb) *Alnus crispa/Equisetum arvense* (Sitka alder/meadow horsetail) *Myrica gale/Epilobium angustifolium* (sweetgale/fireweed) *Carex lyngbyaei*-mixed herb (Lyngby's sedge-mixed herb) *Equisetum arvense* (meadow horsetail)
Early	Newly formed slacks are stabilized by vegetation. Tidally influenced. *Equisetum variegatum* (northern horsetail) *Eleocharis palustris* (common spike-rush) *Poa macrantha* (seashore bluegrass) *Carex lyngbyaei/Ranunculus cymbalaria* (Lyngby's sedge/seaside buttercup)

***Tsuga heterophylla/Vaccinium ovalifolium* (western hemlock/tall blueberry)-coastal dune s.s.—**Dune genesis on barrier islands and spits exhibits a relatively consistent pattern. Early-successional dunes are located seaward closest to the sea and receive significant windblown sand, and contain pioneer communities. Pioneer dune vegetation, primarily E*lymus arenarius* (beach rye), stabilizes windblown dunes (fig. 15). Clonal colonies develop rapidly; *Elymus arenarius* (beach rye) tillers form directly off the main shoot just below surface level and develop obliquely to the main stem (Carter 1988). Pioneer dunes owe their strength to roots, penetrating 3 to 6 feet and deeper.

On mid-successional dunes, dune height and distance from the ocean increases. Herbaceous species diversity increases, and the sites support the *Elymus arenarius/Achillea borealis* (beach rye/yarrow), *Lupinus nootkatensis* (nootka lupine), and *Fragaria chiloensis* (beach strawberry) c.t. (fig. 15). Species such as *Elymus arenarius* (beach rye) and *Festuca rubra* (red fescue) are aggressive colonizers but less exposure tolerant; consequently, they become senescent and depauperate. *Picea sitchensis* (Sitka spruce) and *Alnus crispa* subsp. *sinuata* (Sitka alder) begin to invade but are depauperate. Pemadasa and others (1974) showed plant distribution is strongly controlled by moisture gradients on both the microtopographic and mesotopographic scales. The higher portions of dunes are dry and nutritionally poor because of leaching, moving the moisture and nutrients into the dune bases and slacks.

Epilobium angustifolium (fireweed) c.t. is often the next stage of succession and occupies sites more removed vertically and horizontally from the ocean (fig. 15). In time, *Picea sitchensis* (Sitka spruce) invades the sites and develops into the *Picea sitchensis/*bryophyte (Sitka spruce/bryophyte) c.t. *Alnus crispa* subsp. *sinuata* (Sitka alder) communities are often present but only as stringers along the edge of *Picea sitchensis* communities. Tree ring counts within the *Picea sitchensis*/bryophyte (Sitka spruce/bryophyte) c.t. suggest high productivity; this type likely converts rapidly to one of the other *Picea sitchensis* communities such as the *Picea sitchensis/Vaccinium ovalifolium-Echinopanax horridum* (Sitka spruce/tall blueberry-devil's club) c.t. The late-successional dunes are located inland from the earlier stages and have little fresh sand input and significant soil development (Carter 1988). The organic and nutrient status develops and helps support the shrub and forest vegetation. All the *Picea sitchensis* communities typically occupy the higher topographic positions of the dunes. *Tsuga heterophylla* (western hemlock) eventually invades the sites and typically codominates with *Picea sitchensis* and forms the T*suga heterophylla/Vaccinium ovalifolium* (western hemlock/tall blueberry) c.t.

Blowouts are natural phenomenons in many dune fields. They are a primary method of coastal dune movement and elongation and an initiator of primary succession. Vegetation succession on blowouts likely follows a similar pathway to that of pioneer dunes (above). Blowouts occur when wind exposes bare sand forming a small hollow on the upwind side of a vegetated dune. The blowout continues to expand, the shape becoming concave with a steep back slope. Much of the wind-transported sand is deposited on the downwind side of the back slope to form deltalike or plumelike formations. In time, the steep back slope becomes subdued because of mass wasting from sand avalanches and wind erosion. Vegetation then colonizes and stabilizes the blowouts (Carter 1988).

***Tsuga heterophylla/Vaccinium ovalifolium-Echinopanax horridum* (western hemlock/tall blueberry-devil's club)-coastal dune s.s.—**This successional sequence is similar to that of the *Tsuga heterophylla/Vaccinium ovalifolium* (western hemlock/tall blueberry)-coastal dune s.s. (fig. 15). The *Tsuga heterophylla/Vaccinium ovalifolium-Echinopanax horridum* (western hemlock/tall blueberry-devil's club) c.t. seems to occupy moister sites than the *Tsuga heterophylla/Vaccinium ovalifolium* (western hemlock/tall blueberry) c.t., as indicated by the understory species. All other site dynamics and conditions are similar.

***Tsuga heterophylla/Vaccinium ovalifolium/Lysichiton americanum* (western hemlock/tall blueberry/yellow skunk-cabbage)-coastal dune s.s.—**Two hypotheses are proposed for the development of the site and vegetation characteristics of this successional sequence. (1) On moist (possibly wet) sites at the base of dune systems next to wet sites, hummocks form from either alluvial deposition, or herbaceous-shrub root wads. The root wads will decompose and eventually become soil. The hummocks at first support shrubs or even herbaceous vegetation, but over time, *Picea sitchensis* (Sitka spruce) invades, and further hummocks develop from stumps, logs, and toppled root wads (DeMeo and others 1992). Site information suggests that the successional sequence proceeds from the *Picea sitchensis/Vaccinium ovalifolium/Lysichiton americanum* (Sitka spruce/tall blueberry/yellow skunk cabbage) c.t. to the *Tsuga heterophylla/Vaccinium ovalifolium/Lysichiton americanum* c.t. (2) The other hypothesis is that well-drained sites at the base of dune systems supporting *Picea sitchensis* or *Tsuga heterophylla* (western hemlock) are flooded because of a general elevation in the water table level, as often occurs with beaver activity. The understory vegetation composition will then change from mesic-tolerant species to wetland species, such as *Lysichiton americanum* (yellow skunk-cabbage). The tree species survive because of their elevated root bases, and their ability to germinate on stumps, logs, and toppled root wads. Peatlands may encroach (paludification) on these forested sites.

Slacks—Late-successional communities were not identified on the slacks, the level tidally flooded areas between dunes. Consequently, complete successional sequences ending in late-successional communities are not presented. This was because of inadequate sampling and does not imply that late-successional types do not exist within the region of study. I summarize succession on slacks in table 9. Descriptions of each community type are given in the various community type descriptions sections.

Slacks are colonized by *Equisetum variegatum* (northern horsetail) and other herbaceous species. The sites are elevated by deposition of tidal and windblown sand and rising of the land. This further removes the sites from salt inputs and allows shrubs, such as *Salix commutata* (undergreen willow), *Salix sitchensis* (Sitka willow), and *Myrica gale* (sweetgale), to invade. Organic mats also develop. Some slacks may develop into forested sites or peatlands, whereas other slacks may not persist to late succession because of dune encroachment.

Key to Community Types

Instructions

1. Use this key for identifying vegetation communities on the Copper River Delta.
2. Locate a representative portion of the site in question. The vegetation and environment within the site should be relatively homogeneous.
3. Estimate the canopy cover for all indicator species. The indicator species are those species used in the key.
4. While in the plot, use the key literally to identify the community type. Start with the "Key to Life Form Groups," couplet number 1.
5. To ensure accuracy, compare the written description of the community type with the composition, structure, and site characteristics of the site. If the written description and site characteristics are not compatible, some level of additional site data collection is advised.

Key to Life Form Groups

1 Dwarf trees, typically less than 25 feet tall, with a cover of at least 10 percent and peat soils present; **caution:** seedling and sapling trees are not dwarf trees . . . . *Picea sitchensis/Sphagnum* (Sitka spruce/peat moss) c.t.

1. Dwarf trees with a cover of less than 10 percent and peat soils absent 2

2. Tree species with a combined cover of at least 25 percent or *Populus trichocarpa* (black cottonwood) with a cover of at least 10 percent. . . . . Tree communities

2. Trees with a cover of less than 25 percent and *Populus trichocarpa* (black cottonwood) with a cover of less than 10 percent 3

3. Erect or decumbent shrubs with a combined cover of at least 25 percent . . . . Shrub communities

3. Erect or decumbent shrubs with a combined cover of less than 25 percent 4

4. Herbaceous species with a combined cover of at least 15 percent 5

4. Herbaceous species absent or present with a combined cover of less than 15 percent . . . . .Sparse to unvegetated mudflats, sand dunes, or beaches

5. Emergent or terrestrial herbaceous vegetation with at least 15 percent cover 6

5. Emergent or terrestrial vegetation with less than 15 percent cover; aquatic vegetation, submerged or floating in water, with at least 15 percent cover . . . . Aquatic communities

6. Individual graminoid species (sedge [*Carex*], grass [*Calamagrostis, Deschampsia,* etc.], rush [*Juncus*], cotton grass [*Eriophorum*], spike rush [*Eleocharis*], etc.) with the greatest canopy cover, or *Carex* (sedge) species and *Lathyrus palustris* (vetchling) codominating the site .Graminoid communities
6. Individual graminoid species (sedge [*Carex*], grass [*Calamagrostis, Deschampsia,* etc.], rush [*Juncus*], cotton grass [*Eriophorum*], spike rush [*Eleocharis*], etc.) without the greatest canopy cover, and *Carex* (sedge) species and *Lathyrus palustris* (vetchling) not codominating the site . . . . Forb communities

Key to Tree Communities

Trees species with a combined cover of at least 25 percent or *Populus trichocarpa* (black cottonwood) with a cover of at least 10 percent.

1. *Tsuga heterophylla* (western hemlock) with at least 50 percent of the total tree cover 2
1. *Tsuga heterophylla* (western hemlock) with less than 50 percent of the total tree cover 6

2. *Vaccinium alaskensis* (Alaska blueberry) and *V. ovalifolium* (tall blueberry), individually or combined, with at least 5 percent cover. 3
2. *Vaccinium alaskensis* (Alaska blueberry) and *V. ovalifolium* (tall blueberry), individually or combined, with less than 5 percent cover 5

3. *Lysichiton americanum* (yellow skunk-cabbage) with at least 5 percent cover . . . . *Tsuga heterophylla/Vaccinium ovalifolium/Lysichiton americanum* (western hemlock/tall blueberry/yellow skunk cabbage) c.t.
3. *Lysichiton americanum* (yellow skunk-cabbage) with less than 5 percent cover 4

4. *Echinopanax horridum* (devil's club) with at least 5 percent cover . . . . *Tsuga heterophylla/Vaccinium ovalifolium-Echinopanax horridum* (western hemlock/tall blueberry-devil's club) c.t.
4. *Echinopanax horridum* (devil's club) with less than 5 percent cover . . . . *Tsuga heterophylla/Vaccinium ovalifolium* (western hemlock/tall blueberry) c.t.

5. *Echinopanax horridum* (devil's club) with at least 5 percent cover . . . . *Tsuga heterophylla/Echinopanax horridum* (western hemlock/devil's club) c.t. This is an uncommon community not described within this classification. See Martin and others (1995) for a full description.
5. *Echinopanax horridum* (devil's club) with less than 5 percent cover . . . . Unclassified *Tsuga heterophylla* (western hemlock) communities.

6. *Picea sitchensis* (Sitka spruce) with at least 50 percent of the total tree cover 7

6. *Picea sitchensis* (Sitka spruce) with less than 50 percent of the total tree cover 14

7. *Alnus crispa* subsp. *sinuata* (Sitka alder) with at least 25 percent cover . . . . *Picea sitchensis/Alnus crispa* (Sitka spruce/Sitka alder) c.t.

7. *Alnus crispa* subsp. *sinuata* (Sitka alder) with less than 25 percent cover. 8

8. *Rubus spectabilis* (salmonberry) with at least 25 percent cover. . . . . *Picea sitchensis/Rubus spectabilis* (Sitka spruce/salmonberry) c.t.

8. *Rubus spectabilis* (salmonberry) with less than 25 percent cover 9

9. *Vaccinium alaskensis* (Alaska blueberry) and *V. ovalifolium* (tall blueberry), individually or combined, with at least 5 percent cover 10

9. *Vaccinium alaskensis* (Alaska blueberry) and *V. ovalifolium* (tall blueberry), individually or combined, with less than 5 percent cover 12

10. *Lysichiton americanum* (yellow skunk-cabbage) with at least 5 percent cover . . . . *Picea sitchensis/Vaccinium ovalifolium/Lysichiton americanum* (Sitka spruce/tall blueberry/yellow skunk-cabbage) c.t.

10. *Lysichiton americanum* (yellow skunk-cabbage) with less than 5 percent cover. 11

11. *Echinopanax horridum* (devil's club) with at least 5 percent cover . . . . *Picea sitchensis/Vaccinium ovalifolium-Echinopanax horridum* (Sitka spruce/tall blueberry-devil's club) c.t.

11. *Echinopanax horridum* (devil's club) with less than 5 percent cover . . . . *Picea sitchensis/Vaccinium ovalifolium* (Sitka spruce/tall blueberry) c.t.

12. *Echinopanax horridum* (devil's club) with at least 5 percent cover . . . . *Picea sitchensis/Echinopanax horridum* (Sitka spruce/devil's club) c.t.

12. *Echinopanax horridum* (devil's club) with less than 5 percent cover 13

13. Shrubs (live), graminoids and ferns with a combined cover of less than 20 percent; forbs (primarily *Equisetum* [horsetail]) may dominate the understory . . . . *Picea sitchensis/*bryophyte (Sitka spruce/bryophyte) c.t.

13. Shrubs, graminoids, and forbs with a combined cover of more than 20 percent . . . . Unclassified *Picea sitchensis* (Sitka spruce) communities.

14. *Populus trichocarpa* (black cottonwood) with at least 50 percent of the total tree cover 15

14. *Populus trichocarpa* (black cottonwood) with less than 50 percent of the total tree cover; *Tsuga mertensiana* (mountain hemlock) the dominant tree species . . . . Unclassified *Tsuga mertensiana* (mountain hemlock) communities.

15. Mature age classes (d.b.h. greater than 9 inches) of trees with at least 10 percent cover 16

15. Mature age classes (d.b.h. greater than 9 inches) of trees with less than 10 percent cover; sapling and pole age classes (d.b.h. less than 9 inches) with at least 10 percent cover . . . . *Populus trichocarpa*/young (black cottonwood/young) c.t.

16. *Picea sitchensis* (Sitka spruce) with at least 10 percent cover . . . . *Populus trichocarpa-Picea sitchensis* (black cottonwood-Sitka spruce) c.t.

16. *Picea sitchensis* (Sitka spruce) with less than 10 percent cover 17

17. *Alnus crispa* subsp. *sinuata* (Sitka alder) with at least 25 percent cover . . . . *Populus trichocarpa/Alnus crispa* (black cottonwood/Sitka alder) c.t.

17. *Alnus crispa* subsp. *sinuata* (Sitka alder) with less than 25 percent cover . . . . *Populus trichocarpa/Aruncus sylvester* (black cottonwood/goatsbeard) c.t.

Key to Shrub Communities

Erect or decumbent shrubs with a combined cover of at least 25 percent.

1. *Alnus crispa* subsp. *sinuata* (Sitka alder) with at least 25 percent cover, and with a greater cover than the combined cover of all *Salix* (willow) species (excluding prostrate willows less than 1 foot tall) . . . . Sitka alder communities

1. *Alnus crispa* subsp. *sinuata* (Sitka alder) with less than 25 percent cover, or with less cover than the combined cover of all *Salix* (willow) species (excluding prostrate willows less than 1 foot tall) 2

2. *Salix* (willow) species, individually or combined, with at least 25 percent cover . . . . Willow communities
2. *Salix* (willow) species, individually or combined, with less than 25 percent cover 3

3. *Myrica gale* (sweetgale) with at least 25 percent cover . . . . Sweetgale communities
3. *Myrica gale* (sweetgale) with less than 25 percent cover 4

4. *Rubus spectabilis* (salmonberry) or *Echinopanax horridum* (devil's club) with at least 25 percent cover . . . . *Rubus spectabilis-Echinopanax horridum* (salmonberry-devil's club) c.t.
4. *Rubus spectabilis* (salmonberry) or *Echinopanax horridum* (devil's club) with less than 25 percent cover 5

5. Dwarf ericaceous shrubs (*Empetrum nigrum* [crowberry], *Vaccinium uliginosum* [bog blueberry], *Andromeda polifolia* [bog rosemary], *Vaccinium vitis-idaea* [mountain cranberry], *Oxycoccus microcarpus* [cranberry]), individually or combined, with at least 25 percent cover; typically on peat soils. . . . . Dwarf shrub communities
5. Dwarf ericaceous shrubs (*Empetrum nigrum* [crowberry], *Vaccinium uliginosum* [bog blueberry], *Andromeda polifolia* [bog rosemary], *Vaccinium vitis-idaea* [mountain cranberry], *Oxycoccus microcarpus* [cranberry]), individually or combined, with less than 25 percent cover . . . . Unclassified shrub communities

Key to Sitka Alder Communities

Alnus crispa subsp. *sinuata* (Sitka alder) with at least 25 percent cover and with a greater cover than the combined cover of all *Salix* (willow) species (excluding prostrate willows less than 1 foot tall).

1. *Equisetum arvense* (meadow horsetail) or *Equisetum variegatum* (northern horsetail), individually or combined, with greater than 25 percent cover . . . . *Alnus crispa/Equisetum arvense* (Sitka alder/meadow horsetail) c.t.
1. *Equisetum arvense* (meadow horsetail) or *Equisetum variegatum* (northern horsetail), individually or combined, with less than 25 percent cover. 2

2. *Calamagrostis canadensis* (bluejoint) or *Carex* (sedges), individually or combined, with greater than 25 percent cover . . . . *Alnus crispa/Calamagrostis canadensis* (Sitka alder/bluejoint) c.t.
2. *Calamagrostis canadensis* (bluejoint) or *Carex* (sedges), individually or combined, with less than 25 percent cover 3

3. *Rubus spectabilis* (salmonberry) and *Sambucus racemosa* (red elderberry), individually or combined, with greater than 25 percent cover . . . . *Alnus crispa/Rubus spectabilis* (Sitka alder/salmonberry) c.t.

3. *Rubus spectabilis* (salmonberry) and *Sambucus racemosa* (red elderberry), individually or combined, with less than 25 percent cover 4

4. *Salix* (willow) species, individually or combined, with greater than 10 percent cover . . . . *Alnus crispa/Salix* (Sitka alder/willow) c.t.

4. *Salix* (willow) species, individually or combined, with less than 10 percent cover . . . . Unclassified *Alnus crispa* (Sitka alder) communities.

Key to Willow Communities

Salix (willow) species, individually or combined, with at least 25 percent cover.

1. *Salix alaxensis* (feltleaf willow) cover greater than any other individual willow species . . . . . . *Salix alaxensis* (feltleaf willow) c.t.

1. *Salix alaxensis* (feltleaf willow) cover less than any other individual willow species 2

2. *Salix hookeriana* (Hooker willow) cover greater than any other individual willow species . . . . *Salix hookeriana* (Hooker willow) c.t.

2. *Salix hookeriana* (Hooker willow) cover less than any other individual willow species 3

3. *Lupinus nootkatensis* (nootka lupine) and *Fragaria chiloensis* (beach strawberry), individually or combined, with greater than 10 percent cover . . . . *Salix barclayi/Lupinus nootkatensis* (Barclay willow/nootka lupine) c.t.

3. *Lupinus nootkatensis* (nootka lupine) and *Fragaria chiloensis* (beach strawberry), individually or combined, with less than 10 percent cover 4

4. *Salix arctica* (arctic willow) with at least 20 percent cover, and the combined cover of all other shrub species is less than 20 percent . . . . *Salix arctica/Carex lyngbyaei* (arctic willow-Lyngby's sedge) c.t.

4. *Salix arctica* (arctic willow) with less than 20 percent cover, or the combined cover of all other shrub species is greater than 20 percent 5

5. *Carex pluriflora* (several-flowered sedge) and *Carex lyngbyaei* (Lyngby's sedge), individually or combined, with greater than 25 percent cover . . . . *Salix barclayi/Carex pluriflora* (Barclay willow/several-flowered sedge) c.t.
5. *Carex pluriflora* (several-flowered sedge) and *Carex lyngbyaei* (Lyngby's sedge), individually or combined, with less than 25 percent cover 6

6. *Carex sitchensis* (Sitka sedge), *Potentilla palustris* (marsh fivefinger), and *Menyanthes trifoliata* (buckbean), individually or combined, with greater than 25 percent cover . . . . *Salix barclayi/Carex sitchensis* (Barclay willow/Sitka sedge) c.t.
6. *Carex sitchensis* (Sitka sedge), *Potentilla palustris* (marsh fivefinger), and *Menyanthes trifoliata* (buckbean), individually or combined, with less than 25 percent cover 7

7. *Equisetum variegatum* (northern horsetail) with greater than 20 percent cover . . . . *Salix barclayi/Equisetum variegatum* (Barclay willow/northern horsetail) c.t.
7. *Equisetum variegatum* (northern horsetail) with less than 20 percent cover 8

8. *Salix sitchensis* (Sitka willow) cover greater than any other individual willow species . . . . *Salix sitchensis* (Sitka willow) c.t.
8. *Salix sitchensis* (Sitka willow) cover less than any other individual willow species 9

9. *Equisetum arvense* (meadow horsetail), *Athyrium filix-femina* (lady-fern), *Calamagrostis canadensis* (bluejoint), and *Angelica genuflexa* (bent-leaved angelica), individually or combined, with greater than 25 percent cover . . . . *Salix barclayi*/mixed herb (Barclay willow/mixed herb) c.t.
9. *Equisetum arvense* (meadow horsetail), *Athyrium filix-femina* (lady-fern), *Calamagrostis canadensis* (bluejoint), and *Angelica genuflexa* (bent-leaved angelica), individually or combined, with less than 25 percent cover . . . . Listed below are undersampled *Salix* (willow) communities found on the Copper River Delta. They are named after the species with the greatest canopy cover in the tallest layer with greater than 25 percent canopy cover. Additional communities likely occur.

Salix commutata (undergreen willow) c.t.
Salix setchelliana (setchell willow) c.t.

Key to Sweetgale Communities

Myrica gale (sweetgale) with at least 25 percent cover.

1. *Carex lyngbyaei* with at least 25 percent cover . . . . *Myrica gale/Carex lyngbyaei* (sweetgale/Lyngby's sedge) c.t.
1. *Carex lyngbyaei* (Lyngby's sedge) with less than 25 percent cover 2

2. *Eriophorum angustifolium* (tall cottongrass), *Empetrum nigrum* (crowberry), and *Andromeda polifolia* (bog-rosemary), individually or combined, with at least 20 percent cover . . . . *Myrica gale/Empetrum nigrum* (sweetgale/crowberry)c.t.
2. *Eriophorum angustifolium* (tall cottongrass), *Empetrum nigrum* (crowberry), and *Andromeda polifolia* (bog-rosemary), individually or combined, with less than 20 percent cover 3

3. *Carex sitchensis* (Sitka sedge), *Potentilla palustris* (marsh fivefinger), and *Menyanthes trifoliata* (buckbean), individually or combined, with at least 25 percent cover . . . . *Myrica gale/Carex sitchensis* (sweetgale/Sitka sedge) c.t.
3. *Carex sitchensis* (Sitka sedge), *Potentilla palustris* (marsh fivefinger), and *Menyanthes trifoliata* (buckbean), individually or combined, with less than 25 percent cover 4

4. *Equisetum variegatum* (northern horsetail), *Sanguisorba stipulata* (burnet), and *Lupinus nootkatensis* (nootka lupine), individually or combined, with at least 10 percent cover . . . . . *Myrica gale/Equisetum variegatum* (sweetgale/northern horsetail) c.t.
4. *Equisetum variegatum* (northern horsetail), *Sanguisorba stipulata* (burnet), and *Lupinus nootkatensis* (nootka lupine), individually or combined, with less than 10 percent cover 5

5. *Epilobium angustifolium* (fireweed) with at least 25 percent cover . . . . *Myrica gale/Epilobium angustifolium* (sweetgale/fireweed) c.t.
5. *Epilobium angustifolium* (fireweed) with less than 25 percent cover . . . . Listed below are miscellaneous or undersampled *Myrica gale* (sweetgale) communities found on the Copper River Delta. They are named after the species with the greatest canopy cover in the herbaceous layer with greater than 25 percent canopy cover. Additional communities likely occur.

Myrica gale/Carex livida (sweetgale/pale sedge) c.t.
Myrica gale/Carex pluriflora (sweetgale/several-flowered sedge) c.t.

Key to Dwarf Shrub Communities

Dwarf ericaceous shrubs (*Empetrum nigrum* [crowberry], *Vaccinium uliginosum* [bog blueberry], *Andromeda polifolia* [bog rosemary], *Vaccinium vitis-idaea* [mountain cranberry], and *Oxycoccus microcarpus* [cranberry]), individually or combined, with at least 25 percent cover; typically on peat soils.

1. *Vaccinium uliginosum* (bog blueberry) with at least 25 percent cover, or with the greatest cover in the dwarf shrub layer . . . . *Vaccinium uliginosum/Empetrum nigrum* (bog blueberry/crowberry) c.t.
1. *Vaccinium uliginosum* (bog blueberry) with less than 25 percent cover, and without the greatest cover in the dwarf shrub layer 2

2. *Empetrum nigrum* (crowberry) with the greatest cover in the dwarf shrub layer . . . . *Empetrum nigrum-Carex pluriflora* (crowberry-several flowered sedge) c.t.
2. *Empetrum nigrum* (crowberry) without the greatest cover in the dwarf shrub layer . . . Unclassified dwarf shrub communities.

Key to Graminoid Communities

Individual graminoid species (sedge [*Carex*], grass [*Calamagrostis, Deschampsia* etc.], rush [*Juncus*], cotton grass [*Eriophorum*], spike rush [*Eleocharis*], etc.) with the greatest canopy cover, or *Carex* (sedge) species and *Lathyrus palustris* (vetchling) codominating the site.

1. Individual *Carex* (sedge) species with the greatest canopy cover or *Carex* (sedge) species and *Lathyrus palustris* (vetchling) codominating the site 2
1. Individual *Carex* (sedge) species without the greatest canopy cover and *Carex* (sedge) species and *Lathyrus palustris* (vetchling) not codominating the site 10

2. *Carex rostrata* with the greatest cover . . . .*Carex rostrata* (beaked sedge) c.t.
2. *Carex rostrata* without the greatest cover 3

3. *Carex pluriflora* (several-flowered sedge) with at least 20 percent cover . . . . *Carex pluriflora-Carex lyngbyaei* (several-flowered sedge-Lyngby's sedge) c.t.
3. *Carex pluriflora* (several-flowered sedge) with less than 20 percent cover 4

4. *Carex sitchensis* with the greatest cover 5
4. *Carex sitchensis* without the greatest cover 6

5. *Sphagnum* (peat moss) species with at least 25 percent cover . . . . *Carex sitchensis/Sphagnum* (Sitka sedge/peat moss) c.t.
5. *Sphagnum* (peat moss) species with less than 25 percent cover . . . .*Carex sitchensis* (Sitka sedge) c.t.

6. *Carex lyngbyaei* (Lyngby's sedge) with the greatest cover, or codominating the community with *Lathyrus palustris* (vetchling) 7

6. *Carex lyngbyaei* (Lyngby's sedge) without the greatest cover, and not codominating the community with *Lathyrus palustris* (vetchling) 19

7. Tidally influenced, or one of the following salt-tolerant species present: *Puccinellia* (alkaligrass) species, *Carex mackenziei*, *Plantago maritima* (plantain), *Triglochin maritimum* (arrow grass), or *Ranunculus cymbalaria* (seaside buttercup) . . . . *Carex lyngbyaei-Ranunculus cymbalaria* (Lyngby's sedge-seaside buttercup) c.t.

7. Not tidally influenced, and all of the following salt-tolerant species absent: *Puccinellia* (alkaligrass) species, *Carex mackenziei, Plantago maritima* (plantain), *Triglochin maritimum* (arrow grass), and *Ranunculus cymbalaria* (seaside buttercup) 8

8. *Lathyrus palustris* (vetchling) with at least 20 percent cover . . . . *Carex lyngbyaei-Lathyrus palustris* (Lyngby's sedge-vetchling) c.t.

8. *Lathyrus palustris* (vetchling) with less than 20 percent cover 9

9. Herbaceous cover, other than *Carex lyngbyaei* (Lyngby's sedge), with at least 30 percent cover . . . . *Carex lyngbyaei*-mixed herb (Lyngby's sedge-mixed herb) c.t.

9. Herbaceous cover, other than *Carex lyngbyaei* (Lyngby's sedge), with less than 30 percent cover . . . . *Carex lyngbyaei* (Lyngby's sedge) c.t.

10. *Eleocharis palustris* (common spike-rush) with the greatest cover . . . . . . *Eleocharis palustris* (common spike-rush) c.t.

10. *Eleocharis palustris* (common spike-rush) without the greatest cover 11

11. *Arctophila fulva* (pendent grass) with the greatest cover . . . . *Arctophila fulva* (pendent grass) c.t.

11. *Arctophila fulva* (pendent grass) without the greatest cover 12

12. *Eriophorum angustifolium* (tall cottongrass) with the greatest cover . . . . *Eriophorum angustifolium* (tall cottongrass) c.t.

12. *Eriophorum angustifolium* (tall cottongrass) without the greatest cover 13

13. *Puccinellia pumila* (dwarf alkaligrass) or *Puccinellia nutkaensis* (Pacific alkaligrass), individually or combined, with the greatest cover . . . . *Puccinellia nutkaensis* (dwarf alkaligrass) c.t.

13. *Puccinellia pumila* (dwarf alkaligrass) or *Puccinellia nutkaensis* (Pacific alkaligrass), individually or combined, without the greatest cover 14

14. *Calamagrostis canadensis* (bluejoint) with at least 25 percent cover, and with the greatest cover in the tallest layer 15

14. *Calamagrostis canadensis* (bluejoint) with less than 25 percent cover, or without the greatest cover in the tallest layer 16

15. *Potentilla palustris* (marsh fivefinger), *Carex* (sedge) species, *Equisetum palustre* (marsh horsetail), or *Equisetum fluviatile* (swamp horsetail), individually or combined, with at least 10 percent cover . . . . *Calamagrostis canadensis/ Potentilla palustris* (bluejoint/marsh fivefinger) c.t.

15. *Potentilla palustris* (marsh fivefinger), *Carex* (sedge) species, *Equisetum palustre* (marsh horsetail), or *Equisetum fluviatile* (swamp horsetail), individually or combined, with less than 10 percent cover . . . . *Calamagrostis canadensis* (bluejoint) c.t.

16. *Deschampsia caespitosa* (tufted hairgrass) or *Deschampsia beringensis* (Bering hairgrass), individually or combined, with the greatest cover . . . . . . *Deschampsia beringensis* (Bering hairgrass) c.t.

16. *Deschampsia caespitosa* (tufted hairgrass) or *Deschampsia beringensis* (Bering hairgrass), individually or combined, without the greatest cover 17

17. *Elymus arenarius* (beach rye) with the greatest cover 18

17. *Elymus arenarius* (beach rye) without the greatest cover 19

18. Bryophytes (moss, liverwort or hornwort) with at least 10 percent cover, or *Fragaria chiloensis* (beach strawberry), and *Achillea borealis* (yarrow), individually or in combination, with at least 5 percent canopy cover . . . . *Elymus arenarius/Achillea borealis* (beach rye/yarrow) c.t.

18. Bryophytes (moss, liverwort or hornwort) with less than 10 percent cover, and *Fragaria chiloensis* (beach strawberry), and *Achillea borealis* (yarrow), individually or in combination, with less than 5 percent canopy cover . . . .*Elymus arenarius* (beach rye) c.t.

19. Listed below are miscellaneous or undersampled graminoid communities found on the Copper River Delta. They are named after the species with the greatest canopy cover in the herbaceous layer with greater than 15 percent canopy cover. Additional communities likely occur.

Calamagrostis canadensis/Lathyrus palustris (bluejoint/vetchling) c.t.
Carex chordorrhiza (creeping sedge) c.t.
Carex glareosa c.t.
Carex limosa (livid sedge) c.t.
Carex saxatilis (russet sedge) c.t.
Eriophorum russeolum (russett cottongrass) c.t.
Glyceria pauciflora c.t.
Hierochloe odorata (vanilla grass) c.t.
Juncus alpinus (northern rush) c.t.
Juncus arcticus c.t.
Poa eminens (large flower speargrass) c.t.

Key to Forb Communities

Individual graminoid species (sedge [*Carex*], grass [*Calamagrostis, Deschampsia* etc.], rush [*Juncus*], cotton grass [*Eriophorum*], spike rush [*Eleocharis*], etc.) or *Lathyrus palustris* (vetchling), without the greatest canopy cover.

1. *Sparganium* (bur reed) species
   with the greatest cover . . . . *Sparganium* species (bur reed) c.t.
1. *Sparganium* (bur reed) species
   without the greatest cover 2

2. *Hippuris vulgaris* (common marestail)
   with the greatest cover . . . . *Hippuris vulgaris* (common marestail) c.t.
2. *Hippuris vulgaris* (common marestail)
   without the greatest cover 3

3. *Equisetum fluviatile* (swamp horsetail)
   with the greatest cover . . . . *Equisetum fluviatile* (swamp horsetail) c.t.
3. *Equisetum fluviatile* (swamp horsetail)
   without the greatest cover 4

4. *Potentilla palustris* (marsh fivefinger)
   with the greatest cover . . . . *Potentilla palustris* (marsh fivefinger) c.t.
4. *Potentilla palustris* (marsh fivefinger)
   without the greatest cover 5

5. *Menyanthes trifoliata* (buckbean)
   with the greatest cover . . . . *Menyanthes trifoliata* (buckbean) c.t.
5. *Menyanthes trifoliata* (buckbean)
   without the greatest cover 6

6. *Potentilla egedii* (Pacific silverweed)
   with the greatest cover . . . . *Potentilla egedii* (Pacific silverweed) c.t.
6. *Potentilla egedii* (Pacific silverweed)
   without the greatest cover 7

7. *Equisetum variegatum* (horsetail)
with the greatest cover . . . . *Equisetum variegatum* (horsetail) c.t.
7. *Equisetum variegatum* (horsetail)
without the greatest cover 8

8. *Lathyrus maritimus* (beach pea)
with the greatest cover . . . . *Lathyrus maritimus* (beach pea) c.t.
8. *Lathyrus maritimus* (beach pea)
without the greatest cover 9

9. *Fragaria chiloensis* (beach strawberry)
with the greatest cover . . . . *Fragaria chiloensis* (beach strawberry) c.t.
9. *Fragaria chiloensis* (beach strawberry)
without the greatest cover 10

10. *Lupinus nootkatensis* (nootka lupine)
with the greatest cover . . . . *Lupinus nootkatensis* (nootka lupine) c.t.
10. *Lupinus nootkatensis* (nootka lupine)
without the greatest cover 11

11. *Epilobium angustifolium* (fireweed)
with the greatest cover . . . . *Epilobium angustifolium* (fireweed) c.t.
11. *Epilobium angustifolium* (fireweed)
without the greatest cover . . . . Listed below are undersampled forb communities found on the Copper River Delta. They are named after the species with the greatest canopy cover in the herbaceous layer with greater than 15 percent canopy cover.

Athyrium filix-femina (lady-fern) c.t.
Epilobium adenocaulon (northern willow-herb) c.t.
Epilobium latifolium (river beauty) c.t.
Equisetum arvense (horsetail) c.t.
Equisetum palustre (marsh horsetail) c.t.
Fauria crista-galli (deer cabbage) c.t.
Hedysarum alpinum (alpine sweet-vetch) c.t.
Hippuris tetraphylla (four-leaf marestail) c.t.
Honckenya peploides (seabeach sandwort) c.t.
Iris setosa (wild iris) c.t.
Lysimachia thyrsiflora (tufted loosestrife) c.t.
Nuphar polysepalum (lily-pad) c.t.
Ranunculus cymbalaria (seaside buttercup) c.t.
Triglochin maritimum (seaside arrow-grass) c.t.
Triglochin palustre (marsh arrow-grass) c.t.

Key to Aquatic Communities

Emergent or terrestrial vegetation with less than 15 percent cover; aquatic vegetation, submerged or floating in water, with at least 15 percent cover.

1. *Chara* (chara) species or *Potamogeton filiformis* (slender-leaved pondweed) with less than 70 percent of the total aquatic herbaceous cover 2
1. *Chara* (chara) species or *Potamogeton filiformis* (slender-leaved pondweed) with greater than 70 percent of the total aquatic herbaceous cover 6

2. *Myriophyllum spicatum* (spiked water-milfoil) and *Myriophyllum alterniflorum* (water-milfoil) with the greatest cover . . . . *Myriophyllum spicatum* (spiked water milfoil) c.t.
2. *Myriophyllum spicatum* (spiked water-milfoil) and *Myriophyllum alterniflorum* (water-milfoil) without the greatest cover. 3

3. *Callitriche hermaphroditica* (water starwort) with the greatest cover. . . . . *Callitriche hermaphroditica* (water starwort) c.t.
3. *Callitriche hermaphroditica* (water starwort) without the greatest cover. 4

4. *Ranunculus trichophyllus* (white water crowfoot) with the greatest cover . . . . *Ranunculus trichophyllus* (white water crowfoot) c.t.
4. *Ranunculus trichophyllus* (white water crowfoot) without the greatest cover 5

5. *Potamogeton perfoliatus* (pondweed) with the greatest cover . . . . *Potamogeton perfoliatus* (pondweed) c.t.
5. *Potamogeton perfoliatus* (pondweed) without the greatest cover 8

6. *Potamogeton filiformis* (slender-leaved pondweed) with the greatest cover . . . . *Potamogeton filiformis* . . . . (slender-leaved pondweed) c.t.
6. *Potamogeton filiformis* (slender-leaved pondweed) without the greatest cover 7

7. *Chara* (chara) species with the greatest cover. . . . . *Chara* (chara) species c.t.
7. *Chara* (chara) species without the greatest cover 8

8. Listed below are miscellaneous or undersampled aquatic communities found on the Copper River Delta. They are named after the species with the greatest canopy cover in the aquatic layer with greater than 15 percent canopy cover. Additional communities likely occur. . . . .

. . . .*Callitriche heterophylla* (different-leaved water starwort) c.t.
Callitriche verna (spring water starwort) c.t.
Potamogeton gramineus (grass-leaved pondweed) c.t.
Potamogeton natans (pondweed) c.t.
Potamogeton pectinatus (fennel-leaved pondweed) c.t.
S*ubularia aquatica* (awlwort) c.t.
Utricularia vulgaris (bladderwort) c.t.
Zannichellia palustris (horned pondweed) c.t.

Tree Community Type Descriptions

Community types are ordered alphabetically within each life form (tree, shrub, graminoid, forb, and aquatic).

Picea sitchensis/ Alnus crispa Community Type Sitka Spruce/ Sitka Alder Community Type PICSIT/ALNCRI G5; S5

Other studies—The *Picea sitchensis/Alnus crispa* (Sitka spruce/Sitka alder) c.t. has been previously described for south-central Alaska by Borchers and others (1989) and DeVelice and others (1994). It has been reported from the Yakutat Foreland as a "wetland variant" *Picea sitchensis/Alnus crispa* c.t. (Shephard 1995). Martin and others (1995) describe this c.t. for floodplains of the Chatham Area, and Pawuk and Kissinger (1989) report a related type *Picea sitchensis/Echinopanax horridum-Alnus* spp. (Sitka spruce/devil's club-alder) c.t. for the Stikine Area of the Tongass National Forest. Worley (1977) describes a related early-seral type for the outer coast of Glacier Bay National Park.

Vegetation—Stands are composed of dense, sapling-pole size *Picea sitchensis*. A *Tsuga heterophylla* (western hemlock) seedling was found at one site. Tree height ranges from 6 to 50 feet, and their age ranges from 20 to 100 years. The stands are typically a single cohort. *Alnus crispa* occurs as a major component in all stands; shrub height ranges from 10 to 20 feet. Bryophyte, forb, graminoid, fern, and other shrub species have highly variable cover values.

The following tabulation lists the species that occur in more than 50 percent of the sites (50 percent constancy) and gives the percentage of constancy, average percentage of canopy cover for sites in which they occur, and range of cover values (number of sites sampled = 9; species richness = 57):

Species	Constancy	Average	Range
	- - - - - - - - - - - -	*Percent*	- - - - - - - - - - - -
Trees:			
Picea sitchensis	100	61	30-80
Shrubs:			
Alnus crispa subsp. *sinuata*	100	55	25-95
Forbs:			
Equisetum arvense	78	46	0-80
Pyrola asarifolia	56	8	0-30
Rubus arcticus	56	2	0-3
Ferns:			
Athyrium filix-femina	67	6	0-20

Environmental characteristics—The *Picea sitchensis/Alnus crispa* c.t. is a minor, yet widespread type on the delta. It occurs on outwash deposits (except that of the Copper River), stabilized dunes of beaches and spits, levees of the uplifted marsh, and as an incidental type on portions of uplifted mudflats that are above high tide. On outwash plains, it occurs on recently disturbed lands including new alluvial deposits, ice-scoured islands, and abandoned river channels. The sites are well drained, although during high riverflows, they are nearly always inundated. The surface topography differs from level to pitted with hummocks. Site shape is usually a stringer or small patch.

Soils—The soils are characterized by a litter layer less than 4 inches thick over silt or sand. Organic-humic layers up to 8 inches thick (pH of 4.5 to 5.5) were found in the wetter stands. The pH of the mineral layer ranges from 5.5 to 7.0. Horizon development occurred in most of the soil profiles. Gleying was not found, but mottling was noted in most profiles, although absent on all dune sites. Salinity was low in all stands.

Succession—This is an early-successional type. On outwash plains, it is a primary colonizer of new alluvial deposits, on dunes it invades the early-successional herbaceous types, and on the uplifted marsh it invades the newly uplifted levees. On all landscapes, this community is seral to other *Picea sitchensis* types and, eventually, *Tsuga heterophylla* community types.

Other studies—This type is similar to the *Picea sitchensis/*seral (Sitka spruce/seral) c.t. described by Shephard (1995) for the Yakutat Forelands.

Picea sitchensis/ **Bryophyte Community Type**
Sitka Spruce/ Bryophyte Community Type
PICSIT/BRYOPH
G4; S4

Vegetation—Stands are composed of moderately dense mature *Picea sitchensis* and a scattering of *Populus trichocarpa* (black cottonwood) trees (fig. 16). Other shrub, forb (except *Equisetum arvense* [meadow horsetail]), graminoid, and fern species have consistently low cover values. Tree height of an average-sized tree ranges from 35 to 90 feet, and their age ranges from 37 to 125 years. The stands are typically a single cohort. Dead *Alnus crispa* subsp. *sinuata* (Sitka alder) occurs as a major component in most stands. *Equisetum arvense* occasionally dominates the herbaceous understory. In all stands, bryophytes form a carpet consisting of *Hylocomium splendens* (feather moss), *Rhytidiadelphus loreus, Rhytidiadelphus squarrosus*, and other moss species.

The following tabulation lists the species that occur in more than 50 percent of the sites (50 percent constancy) and gives the percentage of constancy, average percentage of canopy cover for sites in which they occur, and range of cover values (number of sites sampled = 11; species richness = 48):

Species	Constancy	Average	Range
	- - - - - - - - - - - -	*Percent*	- - - - - - - - - - - -
Trees:			
Picea sitchensis	100	72	60-80
Populus trichocarpa	55	11	0-30
Shrubs:			
Alnus crispa subsp. *sinuata*	82	5	0-10
Forbs:			
Moneses uniflora	64	1	0-1
Pyrola secunda	55	1	0-3
Mosses and lichens:			
Hylocomium splendens	91	26	0-50

Figure 16—*Picea sitchensis*/bryophyte c.t. on a beach ridge near Cape Suckling.

Environmental characteristics—The *Picea sitchensis*/bryophyte c.t. (fig. 16) is a minor, yet widespread, type on terraces of floodplains and outwash plains (except the Copper River outwash where it does not occur), on the higher positions of stabilized dunes of beaches and spits, and on moraines. On outwash plains and floodplains, the sites are well drained, although during high riverflows, they may be inundated. The surface topography differs from level to pitted with hummocks.

On coastal dunes, the sites are well drained and have an undulating surface topography. Site shape is usually linear. Vegetation zones, moving from dunes of increasing stability, elevation, and distance from the ocean, typically change from *Elymus arenarius* (beach rye) types to various herbaceous types to forested types.

Soils—The soils are variable, classified as either Spodic Cryopsamments, Typic Cryumbrepts, or Typic Cryorthents. In general, they are characterized by a litter layer 2 to 4 inches thick over sand. The pH of the litter layer ranges from 4.5 to 5.4, and the mineral layer pH ranges from 5.4 to 6.5. Horizon development in the soil profiles was uncommon. Gleying was not found, and mottling was noted in one profile. Salinity was low in all stands.

Succession—This is a mid-successional type that follows the *Picea sitchensis/Alnus crispa* (Sitka spruce/Sitka alder) c.t. or *Populus trichocarpa*/young (black cottonwood/young) c.t. On all landscapes, this community is seral to other *Picea sitchensis* types and, eventually, *Tsuga heterophylla* (western hemlock) communities.

Picea sitchensis/ Echinopanax horridum
Community Type
Sitka Spruce/ Devil's Club
Community Type
PICSIT/ECHHOR
G5; S5

Other studies—This type is similar to the plant associations *Picea sitchensis/ Echinopanax horridum* (Sitka spruce/devil's club) and *Picea sitchensis/Echinopanax horridum-Rubus spectabilis* (Sitka spruce/devil's club-salmonberry) described by DeMeo and others (1992), Martin and others (1995), and Pawuk and Kissinger (1989) for the Tongass National Forest. Worley (1977) described a related type for the outer coast of Glacier Bay National Park. Borchers and others (1989) and DeVelice and others (1994) described a *Picea sitchensis/Vaccinium ovalifolium-Echinopanax horridum* (Sitka spruce/ tall blueberry-devil's club) c.t. for the Chugach National Forest that is also similar to this community type.

Vegetation—This type is dominated by large *Picea sitchensis* (Sitka spruce) surrounded by *Echinopanax horridum* (devil's club). Mature *Tsuga heterophylla* (western hemlock) trees occur in 50 percent of the stands. The trees tend to be taller on uplifted beach ridges and shorter on other landscapes. *Echinopanax horridum* dominates the understory with scattered amounts of *Vaccinium* (blueberry) species and *Rubus spectabilis* (salmonberry) occurring in many stands. *Echinopanax horridum* and *Rubus spectabilis* cover increases in tree canopy gaps. *Rubus pedatus* (five-leaf bramble) and *Tiarella trifoliata* (foam flower) are common forbs. *Dryopteris dilatata* (shield fern), and *Gymnocarpium dryopteris* (oak fern) are common ferns.

The following tabulation lists the percentage of constancy, average percentage of canopy cover for sites in which they occur, and range of cover values for the common plants (number of sites sampled = 4):

Species	Constancy	Average	Range
	- - - - - - - - - -	*Percent*	- - - - - - - - - -
Trees:			
Picea sitchensis	100	54	28-90
Shrubs:			
Alnus crispa sinuata	75	4	1-8
Echinopanax horridum	100	50	40-60
Vaccinium ovalifolium or *V. alaskensis*	75	3	2-4
Forbs:			
Rubus pedatus	100	6	1-10
Streptopus amplexifolius	100	1	1-1
Tiarella trifoliata	100	9	3-20
Ferns:			
Dryopteris dilatata	100	13	3-35
Gymnocarpium dryopteris	100	13	4-30
Mosses and lichens:			
Hylocomium splendens	75	17	10-30
Rhizomnium glabrescens	75	22	20-26
Rhytidiadelphus loreus	75	21	12-35
Moss unknown	100	40	1-80

Environmental characteristics—This community type is found primarily on well-drained sand or gravel on uplifted beach ridges, floodplains, moraines, and proximal outwash. The water table occasionally rises into the surface horizons in the floodplain stands, whereas in most other stands, the water table is typically 3 feet or more below the surface (Shephard 1995).

Soils—The soils are usually classified as Oxyaquic Haplocryods in the floodplains and as Typic Haplocryods in the other landscapes (Shephard 1995).

Succession—This community may be a mid-seral type that eventually will be replaced by a (*Tsuga heterophylla-Picea sitchensis*) western hemlock-Sitka spruce-dominated forest type. Additional study is needed.

***Picea sitchensis/ Rubus spectabilis* Community Type**
Sitka Spruce/ Salmonberry Community Type
PICSIT/RUBSPE
G3-4; S3-4

Other studies—This type has been previously described in south-central Alaska by DeVelice and others (1994) and southeast Alaska by DeMeo and others (1992).

Vegetation—The stands consist of moderately open uneven-aged *Picea sitchensis* (Sitka spruce). *Rubus spectabilis* (salmonberry), the diagnostic understory species, dominates the tall shrub layer, and *Alnus crispa* subsp. *sinuata* (Sitka alder) forms a significant component in some stands. Species composition and cover are highly variable in the forb, graminoid, and fern layers. In many stands, bryophytes form a carpet consisting mainly of *Hylocomium splendens* (feather moss), *Rhizomnium glabrescens*, and *Rhytidiadelphus loreus*.

The following tabulation lists the species that occur in more than 50 percent of the sites (50 percent constancy) and gives the percentage of constancy, average percentage of canopy cover for sites in which they occur, and range of cover values (number of sites sampled = 7; species richness = 22):

Species	Constancy	Average	Range
	- - - - - - - - - -	*Percent*	- - - - - - - - - -
Trees:			
Picea sitchensis	100	41	29-53
Shrubs:			
Echinopanax horridum	100	20	2-35
Rubus spectabilis	100	41	30-55
Vaccinium alaskensis or *V. ovalifolium*	100	10	2-25
Forbs:			
Rubus pedatus	100	6	1-10
Streptopus amplexifolius	100	2	1-4
Tiarella trifoliata	100	3	1-5
Ferns:			
Dryopteris austriaca	100	18	4-40
Gymnocarpium dryopteris	100	13	2-25
Mosses and lichens:			
Hylocomium splendens	86	14	1-40
Rhizomnium glabrescens	86	22	0-40
Rhytidiadelphus loreus	86	19	0-40
Sphagnum spp.	57	12	0-25

Environmental characteristics—The *Picea sitchensis/Rubus spectabilis* (Sitka spruce/salmonberry) c.t. is a major type occurring on alluvial surfaces, formed on outwash plains, and on coastal dune crests or uplifted dunes. It occurs as stringers, broad expanses of forest, or inclusions within forests. The sites are typically well drained although on outwash plains during high riverflows, they may be inundated. Some sites may be sufficiently elevated above the river to avoid flooding. The surface topography is typically level on outwash plains and undulating on dune systems.

Soils—The soils on the outwash plains are deep, well-drained alluvium. They are characterized by a thin to thick humic layer and weakly developed mineral horizons. Mottling was noted in most of the soil profiles. The soils on dunes are deep, well-drained aeolian sand.

Succession—This is a mid-successional type that follows the *Picea sitchensis/Alnus crispa* (Sitka spruce/Sitka alder) c.t. or *Populus trichocarpa*/young (black cottonwood/young) c.t. On all landscapes, this community may be seral to other *Picea sitchensis* types and, eventually, *Tsuga heterophylla* (western hemlock) communities.

Other studies—This type also is reported from Dixon Harbor in Glacier Bay National Park (Worley 1977).

Picea sitchensis/ Sphagnum
Community Type
Sitka Spruce/ Peat Moss
Community Type
PICSIT/SPHAGN
G2-3; S2-3

Vegetation—One site was sampled. Vegetation is composed of dwarf *Picea sitchensis* (Sitka spruce) and *Tsuga heterophylla* (western hemlock), with a cover of less than 25 percent. Limited regeneration is common for both conifer species. Downed logs are uncommon. The shrub layer is dominated by *Myrica gale* (sweetgale), *Empetrum nigrum* (crowberry), and *Oxycoccus microcarpus* (bog cranberry). Typical forbs are *Cornus canadensis* (bunchberry) and *Rubus arcticus* (nagoonberry). The two most common graminoids are *Carex sitchensis* (Sitka sedge) and *Eriophorum angustifolium* (cotton grass). Bryophytes, including *Sphagnum* (peat moss) species, blanket the ground.

Environmental characteristics—This minor type occupies old undisturbed sites of distal outwash plains, floodplains, and uplifted marshes. These are ombrotrophic fens, or bogs, typically dominated by *Sphagnum* (peat moss) species. The water table is close to the surface most of the year, and the surface topography is level with minor hummock formation.

Soils—Shephard (1995) states the soils usually are classified as Histic Cryaquepts and Terric Cryofibrists and have an average organic matter depth of 16 inches over the mineral horizon (fine gravel to silt).

Other studies—This type occurs throughout southeast and south-central Alaska, and is similar to the *Picea sitchensis/Vaccinium ovalifolium* (Sitka spruce/tall blueberry) c.t. described by Borchers and others (1989) and DeVelice and others (1994) for the Chugach National Forest, and DeMeo and others (1992), Martin and others (1995), and Shephard (1995) for the Tongass National Forest. Worley (1977) describes a related type for the outer coast of Glacier Bay National Park.

Picea sitchensis/ Vaccinium ovalifolium
Community Type
Sitka Spruce/ Tall Blueberry
Community Type
PICSIT/VACCIN
G5; S5

Vegetation—Stands consist of moderately dense uneven-aged *Picea sitchensis* (Sitka spruce; fig. 17). *Tsuga heterophylla* (western hemlock) is often a minor component in the overstory and understory. Tree height ranges from 75 to 105 feet, and tree age

Figure 17—*Picea sitchensis/Vaccinium ovalifolium* c.t. on the glacial outwash of Saddlebag Glacier.

ranges up to 205 years. *Vaccinium alaskensis* (Alaska blueberry) or *V. ovalifolium* (tall blueberry), the diagnostic understory species, dominate the shrub layer; *Echinopanax horridum* (devil's club) and *Rubus spectabilis* (salmonberry) occur in most stands as a minor component. *Rubus pedatus* (five-fingered bramble) and *Gymnocarpium dryopteris* (oak fern) have high coverage values in most stands. Other forb, graminoid, and fern species have highly variable cover values. In many stands, bryophytes form a carpet consisting mainly of *Hylocomium splendens* (feather moss) and *Rhytidiadelphus loreus*.

The following tabulation lists the species that occur in more than 50 percent of the sites (50 percent constancy) and gives the percentage of constancy, average percentage of canopy cover for sites in which they occur, and range of cover values (number of sites sampled = 7; species richness = 31):

Species	**Constancy**	**Average**	**Range**
	- - - - - - - - - -	*Percent*	- - - - - - - - - -
Trees:			
Picea sitchensis	100	64	40-80
Tsuga heterophylla	71	6	0-20
Shrubs:			
Echinopanax horridum	86	3	0-4
Menziesia ferruginea	57	5	0-10
Rubus spectabilis	71	7	0-20
Vaccinium alaskensis or *V. ovalifolium*	100	27	5-60

(tabulation continues on page 93)

Species	Constancy	Average	Range
	- - - - - - - - - - *Percent*	- - - - - - - - - -	
Forbs:			
Cornus canadensis	100	6	1-20
Rubus pedatus	100	12	4-20
Streptopus amplexifolius	86	1	0-1
Tiarella trifoliata	86	5	0-20
Ferns:			
Dryopteris dilatata	57	4	0-10
Gymnocarpium dryopteris	86	14	0-30
Mosses and lichens:			
Hylocomium splendens	86	30	0-60
Rhytidiadelphus loreus	57	23	0-30

Environmental characteristics—The *Picea sitchensis/Vaccinium ovalifolium* c.t. is a minor type occurring on floodplains, proximal outwash, beach ridges, and spits. It occurs as stringers, broad expanses of forest, or inclusions within forests. Sites occur on alluvial surfaces formed on outwash plains, and on coastal dune crests or uplifted dunes. They are typically well drained, although on the outwash plains and floodplains, during high riverflows, they may be inundated. Some sites are sufficiently elevated above the river to avoid flooding. The surface topography is typically level on outwash plains, and undulating on dune systems.

Soils—On outwash plains and floodplains the soils are deep, well-drained alluvium, and on dunes they are deep, well-drained aeolian sand. Soils are variable, classified as either Typic Cryorthents or Typic Cryochrept. In general, they are characterized by a humus layer less than 4 inches thick over silt or sand. The pH of the humus layer ranges from 4.5 to 5.1, and the mineral layer pH ranges from 5.4 to 6.4. Horizon development was noted for all soil profiles. Gleying and mottling were not observed, and soil salinity was low.

Succession—This is a mid- to late-successional type that follows the *Picea sitchensis/Alnus crispa* (Sitka spruce/Sitka alder) c.t. or *Populus trichocarpa*/young (black cottonwood/young) c.t. On all landscapes, this community may be seral to other *Picea sitchensis* types and, eventually, *Tsuga heterophylla* communities.

Picea sitchensis/Vaccinium ovalifolium-Echinopanax horridum Community Type
Sitka Spruce/Tall Blueberry-Devil's Club Community Type
PICSIT/VACCIN/ECHHOR
G5; S5

Other studies—This type is similar to a *Picea sitchensis/Vaccinium ovalifolium-Echinopanax horridum* (Sitka spruce/tall blueberry-devil's club) c.t. previously described for south-central Alaska by Borchers and others (1989) and DeVelice and others (1994) and for southeast Alaska by DeMeo and others (1992) and Martin and others (1995).

Vegetation—Stands are dominated by uneven-aged *Picea sitchensis* (Sitka spruce) and often have a significant *Tsuga heterophylla* (western hemlock) component in the overstory and understory. Tree height ranges up to 115 feet, and tree age ranges up to 180 years. *Vaccinium ovalifolium* (tall blueberry), *V. alaskensis* (Alaska blueberry) or *Echinopanax horridum* (devil's club), the diagnostic understory species, dominate the shrub layer along with *Menziesia ferruginea* (rusty menziesia). *Rubus pedatus* (five-fingered bramble) and *Tiarella trifoliata* (foam flower) have high coverage values in most stands; other forb, graminoid, and fern species have highly variable cover values.

The following tabulation lists the species that occur in more than 50 percent of the stands (50 percent constancy) and gives the percentage of constancy, average percentage of canopy cover for stands in which they occur, and range of cover values (number of sites sampled = 8; species richness = 27):

Species	Constancy	Average	Range
	- - - - - - - - -	*Percent*	- - - - - - - - -
Trees:			
Picea sitchensis	100	61	35-80
Tsuga heterophylla	88	15	0-18
Shrubs:			
Echinopanax horridum	100	12	8-25
Menziesia ferruginea	50	16	0-1
Rubus spectabilis	63	5	0-20
Vaccinium ovalifolium or *V. alaskensis*	100	35	5-60
Forbs:			
Cornus canadensis	88	2	0-3
Rubus pedatus	100	11	3-20
Streptopus amplexifolius	100	1	1-1
Tiarella trifoliata	100	4	1-20
Ferns:			
Athyrium filix-femina	63	3	0-4
Gymnocarpium dryopteris	100	12	2-20
Lycopodium annotinum	75	1	0-1

Environmental characteristics—The *Picea sitchensis/Vaccinium ovalifolium-Echinopanax horridum* c.t. is a minor type occurring on floodplains, proximal outwash, beach ridges, and spits. It occurs as stringers, broad expanses of forest, or inclusions within forests. Sites occur on alluvial surfaces formed on outwash plains or floodplains, and on coastal dune crests or uplifted dunes. They are typically well drained, although on the outwash plains and floodplains, during high riverflows they may be inundated. Often sites are sufficiently elevated above the river to avoid flooding. The surface topography is typically level on outwash plains and undulating on dune systems.

Soils—On outwash plains and floodplains the soils are deep, well-drained alluvium, and on dunes they are deep, well-drained aeolian sand. Soils are classified as either Typic Haplocryorthods or Typic Cryorthod. In general, they are characterized by a humus layer less than 3 inches thick over silt, sand, or gravel. The pH of the mineral layer ranges from 4.8 to 6.5. Horizon development was noted in all the soil profiles. Gleying and mottling were not observed, and soil salinity was low.

Succession—This is a mid- to late-successional type, that follows the *Picea sitchensis/Alnus crispa* (Sitka spruce/Sitka alder) c.t. or *Populus trichocarpa*/young (black cottonwood/young) c.t. On all landscapes, this community may be seral to other *Picea sitchensis* types and, eventually, *Tsuga heterophylla* communities.

Picea sitchensis/Vaccinium ovalifolium/Lysichiton americanum
Community Type
Sitka Spruce/Tall Blueberry/Yellow Skunk Cabbage Community Type
PICSIT/VACCIN/LYSAME
G5; S5

Other studies—This type is similar to the plant association *Picea sitchensis/Vaccinium ovalifolium/Lysichiton americanum* (Sitka spruce/tall blueberry/yellow skunk-cabbage) described by Martin and others (1995), and DeMeo and others (1992) for the Tongass National Forest and Borchers and others (1989) and DeVelice and others (1994) for the Chugach National Forest.

Vegetation—The relatively open *Picea sitchensis* (Sitka spruce) overstory is uneven aged. *Lysichiton americanum* (yellow skunk-cabbage), the diagnostic undergrowth species, grows from the wetter microsites including standing water. Species composition on the drier hummocks is variable and includes *Vaccinium ovalifolium* (tall blueberry) or *V. alaskensis* (Alaska blueberry), *Cornus canadensis* (bunchberry), *Alnus crispa* subsp. *sinuata* (Sitka alder), *Hylocomium splendens* (feather moss), *Rhytidiadelphus loreus*, and *Sphagnum* (peat moss) species.

The following tabulation lists the species that occur in more than 50 percent of the sites (50 percent constancy) and gives the percentage of constancy, average percentage of canopy cover for sites in which they occur, and range of cover values (number of sites sampled = 3):

Species	**Constancy**	**Average**	**Range**
	- - - - - - - - - -	*Percent*	- - - - - - - - - -
Trees:			
Picea sitchensis	100	39	24-63
Picea sitchensis-understory	67	3	0-5
Shrubs:			
Alnus crispa var. *sinuata*	100	2	2-3
Echinopanax horridum	67	2	0-2
Rubus spectabilis	67	2	0-2
Vaccinium ovalifolium or *V. alaskensis*	100	6	4-10
Viburnum edule	67	1	0-1
Forbs:			
Cornus canadensis	100	6	1-10
Fauria crista-galli	67	6	0-10
Lysichiton americanum	100	37	10-50
Moneses uniflora	67	3	0-4
Rubus pedatus	100	4	3-4
Streptopus amplexifolius	67	1	0-1
Tiarella trifoliata	100	2	1-5
Ferns:			
Dryopteris austriaca	67	1	0-1
Gymnocarpium dryopteris	100	2	1-2
Mosses and lichens:			
Hylocomium splendens	67	15	0-20
Rhizomnium glabrescens	67	28	0-50
Rhytidiadelphus loreus	100	14	6-25
Sphagnum spp.	67	6	0-10

Environmental characteristics—The *Picea sitchensis/Vaccinium ovalifolium/Lysichiton americanum* c.t. is a minor type occurring on outwash plains, floodplains, or dune edges. It often forms a mosaic within or at the edge of larger sites composed of drier *Picea sitchensis* or *Tsuga heterophylla* types (DeMeo and others 1992). The surface topography typically consist of hummocks interspersed with small depressions containing standing water.

Soils—The hummocks are either deep and somewhat poorly drained mineral soils or decaying logs and tree bases (Borchers and others 1989, DeMeo and others 1992, Shephard 1995). The soils in the depressions are deep, poorly drained with moderate to thick organic layers; sites are often complexes of two or more soils.

Succession—Two hypotheses are proposed for the development of the site and vegetation characteristics of this community. (1) On moist (possibly wet) sites, hummocks form from either alluvial deposition or root wads. The hummocks eventually support *Picea sitchensis*. (2) The other hypothesis is that well-drained sites supporting *Picea sitchensis* are flooded because of a general elevation in the water table level, as often occurs with beaver activity. The understory vegetation composition will then change from mesic-tolerant species to wetland species, such as *Lysichiton americanum*. This type is seral to the *Tsuga heterophylla/Vaccinium ovalifolium/Lysichiton americanum* (western hemlock/tall blueberry/yellow skunk cabbage) c.t.

Other studies—This type is similar to the *Populus trichocarpa/Salix* (black cottonwood/willow), *Populus trichocarpa/Rubus spectabilis* (black cottonwood/salmonberry), and *Populus trichocarpa/Echinopanax horridum* (black cottonwood/devil's club) c.t.'s described by Shephard (1995) for the Yakutat Foreland, Tongass National Forest.

Populus trichocarpa/ Aruncus sylvester **Community Type**
Black Cottonwood/ Goatsbeard Community Type
POPTRI/ARUSYL
G3; S3

Vegetation—This type forms large expanses of widely spaced mature *Populus trichocarpa* (black cottonwood) over a dense understory of shrubs including *Echinopanax horridum* (devil's club) and *Rubus spectabilis* (salmonberry). Tree height ranges from 40 to 85 feet, and tree age ranges from 50 to more than 100 years. The trees within the stands are typically a single cohort, suggesting little or no *Populus trichocarpa* regeneration. *Aruncus sylvester* (goatsbeard) is the diagnostic understory species and typically has high cover values. Species composition and cover of the forb, graminoid, and fern layer is variable. Bryophytes are uncommon.

The following tabulation lists the species that occur in more than 50 percent of the sites (50 percent constancy) and gives the percentage of constancy, average percentage of canopy cover for sites in which they occur, and range of cover values (number of sites sampled = 3):

Species	Constancy	Average	Range
	- - - - - - - - - - -	*Percent*	- - - - - - - - - - - -
Trees:			
Populus trichocarpa	100	43	10-60
Shrubs:			
Alnus crispa subsp. *sinuata*	100	12	5-20
Echinopanax horridum	100	20	1-50
Rubus spectabilis	67	25	0-40
Salix alaxensis	67	10	0-10
Viburnum edule	100	5	1-10

(tabulation continues on page 97)

Species	Constancy	Average	Range
	- - - - - - - - - - - *Percent*	- - - - - - - - - - - -	
Forbs:			
Artemisia tilesii	67	6	0-10
Aruncus sylvester	100	52	5-80
Equisetum arvense	100	4	1-10
Calamagrostis canadensis	67	15	0-20

Environmental characteristics—The *Populus trichocarpa/Aruncus sylvester* c.t. predominantly occurs as a minor type on linear dunes at the mouth of the Copper River. It also is found as a minor type on outwash plains and floodplains of the region. It occurs on well-drained alluvial or aeolian surfaces; some sites are inundated during high riverflows. The surface topography is typically level on outwash plains and undulating on dune systems. Slope values on dunes range from 5 to 65 percent.

Soils—On outwash plains and floodplains, the soils are deep, well-drained alluvium, and on dunes they are deep, well-drained aeolian sand. Soils on dunes are classified as Coarse-Silty Typic Cryaquent. In general, they are characterized by a litter layer less than 1 inch thick over silt or sand. The pH of the mineral layer ranges from 7.1 to 7.8. Horizon development, gleying, and mottling were not observed, and soil salinity was low.

Succession—Succession on linear dunes moves from herbaceous communities establishing on recently disturbed surfaces, to shrub or cottonwood types. The cottonwood types, however, are likely not stable and, consequently, are not considered late successional. On outwash plains and floodplains, this type is mid successional, following various early-seral shrub types and the *Populus trichocarpa*/young (black cottonwood/young) c.t. On the floodplain of the Copper River, this community is seral to alder types, whereas on the other floodplains and outwash plains of the region, it is seral to *Picea sitchensis* (Sitka spruce) types and, eventually, *Tsuga heterophylla* (western hemlock) communities.

Other studies—This type is similar to the *Populus trichocarpa/Salix* (black cottonwood/willow) c.t., *Populus trichocarpa/Rubus spectabilis* (black cottonwood/salmonberry) c.t., and *Populus trichocarpa/Echinopanax horridum* (black cottonwood/devil's club) c.t. described by Shephard (1995) for the Yakutat Foreland, Tongass National Forest.

Populus trichocarpa/ Alnus crispa **Community Type Black Cottonwood/ Sitka Alder Community Type POPTRI/ALNCRI G3; S3**

Vegetation—This type forms large expanses of widely spaced mature *Populus trichocarpa* (black cottonwood) over a dense understory of shrubs including *Alnus crispa* var. *sinuata* (Sitka alder), *Echinopanax horridum* (devil's club), and *Rubus spectabilis* (salmonberry; fig. 18). Tree height ranges from 35 (crowns broken) to 90 feet, and tree age ranges from 50 to more than 100 years. The trees within the stands are often a single cohort, suggesting little or no *Populus trichocarpa* (black cottonwood) regeneration.

Alnus crispa subsp. *sinuata* (Sitka alder) are large and sprawling, their bases often covered with wind or fluvial transported sand and silt. Alder height ranges from 15 to 25 feet, stem base diameter ranges up to 7 inches, and stem age ranges up to 43 years. Species composition and cover or the forb, graminoid, and fern layer is typically low. *Athyrium filix-femina* (lady-fern) cover, however, is often high. Bryophytes are uncommon.

Figure 18—A mixture of communities on the Bering River: early-seral herbaceous communities invading sandbars, followed by shrub communities, and the *Populus trichocarpa/Alnus crispa* c.t. in the background.

The following tabulation lists the species that occur in more than 50 percent of the sites (50 percent constancy) and gives the percentage of constancy, average percentage of canopy cover for sites in which they occur, and range of cover values (number of sites sampled = 7; species richness = 35):

Species	**Constancy**	**Average**	**Range**
	- - - - - - - - - - -	*Percent*	- - - - - - - - - - - -
Trees:			
Populus trichocarpa	100	29	20-40
Shrubs:			
Alnus crispa var. *sinuata*	100	62	25-70
Echinopanax horridum	86	39	0-80
Rubus spectabilis	71	34	0-60
Sambucus racemosa	71	15	0-50
Forbs:			
Equisetum arvense	71	3	0-10
Streptopus amplexifolius	86	3	0-10
Ferns:			
Athyrium filix-femina	86	22	0-70

Environmental characteristics—The *Populus trichocarpa/Alnus crispa* (black cottonwood/Sitka alder) c.t. is a major type dominating the outwash plain of the Copper River. It also occurs as a minor component on other outwash plains and floodplains of the region, and as a minor type on the linear dunes found along the Copper River. It occurs on well-drained alluvial or aeolian surfaces; some sites are inundated during high riverflows. The surface topography is typically level on outwash plains and floodplains, and undulating on dune systems. Slope values on dunes range from 5 to 30 percent.

Soils—On outwash plains and floodplains the soils are deep, well-drained alluvium, and on dunes they are deep, well-drained aeolian sand. In general, they are characterized by an organic layer less than 1 inch thick over silt or sand. The pH of the mineral layer ranges from 5.1 to 7.2. Horizon development was observed in a minority of the stands; the lower pH values were associated with horizon development. Gleying and mottling were not observed, and soil salinity was low.

Succession—On outwash plains and floodplains, this type is mid successional, following various early-seral shrub types and the *Populus trichocarpa*/young (black cottonwood/young) c.t. On the floodplain of the Copper River, this community is seral to alder types, whereas on the other floodplains and outwash plains of the region, it is seral to *Picea sitchensis* (Sitka spruce) types and, eventually, *Tsuga heterophylla* (western hemlock) types. Succession on linear dunes moves from herbaceous communities establishing on recently disturbed surfaces to shrub or cottonwood types. The cottonwood types, however, are likely not stable and, consequently, are not considered late successional.

Populus trichocarpa-Picea sitchensis **Community Type**
Black Cottonwood-Sitka Spruce Community Type
POPTRI-PICSIT G4; S4

Other studies—This *Populus trichocarpa-Picea sitchensis* (black cottonwood-Sitka spruce) c.t. has similarities to a *Picea sitchensis-Populus trichocarpa*/seral (Sitka spruce-black cottonwood/seral) c.t. reported for the Yakutat Foreland by Shephard (1995). The latter type also has been described from Dixon Harbor in Glacier Bay National Park (Worley 1977).

Vegetation—This type is composed of sparse to dense stands of mature *Populus trichocarpa* (black cottonwood) and *Picea sitchensis* (Sitka spruce), over a dense understory of *Alnus crispa* subsp. *sinuata* (Sitka alder) and *Echinopanax horridum* (devil's club). Cottonwood height ranges from 10 to 55 feet, and age ranges up to 61 years. Spruce height ranges up to 50 feet, and age ranges up to 90 years. The cottonwood trees within the stands are typically a single cohort, suggesting little or no cottonwood regeneration; whereas, spruce regeneration is present. Species composition and cover within the forb, graminoid, and fern layers are highly variable. Bryophyte cover ranges from 3 to 40 percent.

The following tabulation lists the species that occur in more than 50 percent of the sites (50 percent constancy) and gives the percentage of constancy, average percentage of canopy cover for sites in which they occur, and range of cover values (number of sites sampled = 3):

Species	Constancy	Average	Range
	- - - - - - - - - - - *Percent*	- - - - - - - - - - -	
Trees:			
Picea sitchensis	100	20	10-30
Populus trichocarpa	100	43	20-70
Shrubs:			
Alnus crispa var. *sinuata*	100	67	50-90
Echinopanax horridum	100	17	1-30
Salix sitchensis	67	2	0-3
Sambucus racemosa	67	7	0-10
Forbs:			
Circaea alpina	100	8	1-20
Galium triflorum	67	1	0-1
Pyrola asarifolia	67	2	1-3
Pyrola secunda	67	2	0-3
Rubus pedatus	67	11	0-20
Stellaria crassifolia	67	1	0-1
Stellaria crispa	67	1	0-1
Streptopus amplexifolius	100	1	1-1
Tiarella trifoliata	67	2	0-3
Viola epipsila	100	1	1-1
Ferns:			
Athyrium filix-femina	67	55	0-90
Dryopteris dilatata	100	5	1-10

Environmental characteristics—The *Populus trichocarpa-Picea sitchensis* (black cottonwood-Sitka spruce) c.t. is a minor type on all the major outwash plains and floodplains of the region. It does not occur on the outwash of the Copper River. The sites are well-drained alluvium; some sites are inundated during high riverflows. The surface topography is typically level to uneven because of meander scrolls and levee formation.

Soils—The soils are deep, well-drained alluvium characterized by an organic layer less than 1 inch thick over silt, sand, or cobble. Horizon development was observed in a minority of the stands. Gleying was not observed, but mottling was noted; soil salinity was low.

Succession—This type is mid successional, following various early-seral shrub types and the *Populus trichocarpa*/young (black cottonwood/young) c.t. It is seral to *Picea sitchensis* (Sitka spruce) types and, eventually, *Tsuga heterophylla* (western hemlock) types.

Other studies—This type is similar to the younger stands within the *Populus trichocarpa/Salix* (black cottonwood/willow) c.t., *Populus trichocarpa/Rubus spectabilis* (black cottonwood/salmonberry) c.t., and *Populus trichocarpa/Echinopanax horridum* (black cottonwood/devil's club) c.t. described by Shephard (1995) for the Yakutat Foreland, Tongass National Forest.

Populus trichocarpa/**Young Community Type**
Black Cottonwood/Young Community Type
POPTRI/Young
Not Ranked

Vegetation—Sampled stands are composed of relatively open, sapling to pole size (less than 9 inches d.b.h.) *Populus trichocarpa* (black cottonwood). *Picea sitchensis* (Sitka spruce) commonly occurs and may codominate, although it is not present in stands along the Copper River. Cottonwood height ranges from 20 to 30 feet, and the ages range up to 30 years. Spruce height ranges from 15 to 18 feet, and age ranges up to 25 years. Younger stands with lower tree heights occur. *Alnus crispa* subsp. *sinuata* (Sitka alder) and *Salix sitchensis* (Sitka willow) form a dense and tall (commonly up to 15 feet in height) shrub layer. *Epilobium angustifolium* (fireweed), *Rubus arcticus* (nagoonberry), and *Calamagrostis canadensis* (bluejoint) dominate the herbaceous layer. In the sampled stands, bryophytes formed a dense carpet, typically exceeding 90 percent canopy cover.

The following tabulation lists the species that occur in more than 50 percent of the sites (50 percent constancy) and gives the percentage of constancy, average percentage of canopy cover for sites in which they occur, and range of cover values (number of sites sampled = 4):

Species	Constancy	Average	Range
	- - - - - - - - - - -	*Percent*	- - - - - - - - - - -
Trees:			
Picea sitchensis	75	11	0-20
Populus trichocarpa	100	25	10-40
Tsuga heterophylla	25	1	0-1
Shrubs:			
Alnus crispa var. *sinuata*	100	48	30-80
Salix barclayi	75	5	0-10
Salix sitchensis	100	23	3-30
Forbs:			
Epilobium angustifolium	50	12	0-20
Moneses uniflora	50	1	0-1
Pyrola asarifolia	75	4	0-10
Pyrola secunda	75	7	0-10
Rubus arcticus	75	12	0-30
Stellaria crassifolia	75	11	0-30
Trientalis europaea	50	2	0-3
Graminoids:			
Agrostis alaskana	75	2	0-3
Calamagrostis canadensis	75	20	0-30
Ferns:			
Athyrium filix-femina	75	1	0-1

Environmental characteristics—The *Populus trichocarpa*/young (black cottonwood/young) c.t. is a minor, yet widespread, type on the outwash plains and floodplains of the rivers of the delta. Along with various community types, it occurs on recently disturbed lands including ice-scoured islands, new alluvial deposits along the edge of a river, and abandoned river channels. On the Copper River outwash plain, it often dominates wide expanses of exposed abandoned river channels. The sites are typically well drained although during high riverflows, they are nearly always inundated. Surface topography differs from level to uneven. Site shape is often a stringer or small patch.

Soils—The soils generally are characterized by a thin organic layer over silt or sand. Horizon development was not observed, and mottling was noted in most profiles.

Succession—This is an early-successional type. On outwash plains and floodplains, it is a primary colonizer of ice-scoured islands, new alluvial deposits along the edge of a river, and abandoned river channels. It is seral to either *Alnus crispa* subsp. *sinuata* (Sitka alder) on the outwash of the Copper River, or *Picea sitchensis* (Sitka spruce) types and, eventually, *Tsuga heterophylla* (western hemlock) community types on the other floodplains and outwash of the region.

Tsuga heterophylla/ Vaccinium ovalifolium **Community Type**
Western Hemlock/ Tall Blueberry Community Type
TSUHET/VACCIN
G5; S5

Other studies—This type is closely related to *Tsuga heterophylla/Vaccinium ovalifolium* c.t. described for south-central Alaska by Borchers and others (1989), DeVelice and others (1994), and Fox (1983). It is common throughout southeast Alaska and has been described for the outer coast of Glacier Bay National Park (Worley 1977) and the Yakutat Foreland (Shephard 1995), Chatham (Martin and others 1995), Stikine (Pawuk and Kissinger 1989), and Ketchikan Areas (DeMeo and others 1992) of the Tongass National Forest.

Vegetation—The moderate to dense tree overstory is uneven aged and dominated by *Tsuga heterophylla* (western hemlock), although *Picea sitchensis* (Sitka spruce) may codominate in some stands. Western hemlock ranges up to 100 feet tall (Shephard 1995). The characteristic shrub layer is dominated by a moderate cover of *Vaccinium ovalifolium* (tall blueberry) or *V. alaskensis* (Alaska blueberry). The forb, graminoid, and fern layers are typically sparse. In many stands, bryophytes form a dense carpet consisting mainly of *Sphagnum* (peat moss) species, *Rhizomnium glabrescens*, and *Rhytidiadelphus loreus*.

The following tabulation lists the common species and gives their percentage of constancy, average percentage of canopy cover for sites in which they occur, and range of cover values (number of sites sampled = 4):

Species	Constancy	Average	Range
	- - - - - - - - -	*Percent*	- - - - - - - - -
Trees:			
Picea sitchensis	100	9	6-15
Picea sitchensis-understory	50	1	0-1
Tsuga heterophylla	100	61	35-80
Tsuga heterophylla-understory	100	10	1-30
Shrubs:			
Echinopanax horridum	100	1	1-2
Rubus spectabilis	75	2	0-3
Vaccinium ovalifolium or *V. alaskensis*	100	30	20-60
Forbs:			
Cornus canadensis	100	2	1-4
Listera cordata	75	1	0-1
Moneses uniflora	75	1	0-1
Rubus pedatus	100	8	2-10
Tiarella trifoliata	75	1	0-1

(tabulation continues on page 103)

Species	Constancy	Average	Range
	- - - - - - - - -	*Percent*	- - - - - - - - -
Ferns:			
Dryopteris austriaca	75	7	0-10
Gymnocarpium dryopteris	100	5	2-10
Mosses and lichens:			
Dicranum scoparium	50	8	0-8
Hylocomium splendens	75	9	0-10
Rhizomnium glabrescens	75	27	0-55
Rhytidiadelphus loreus	75	20	0-25
Sphagnum spp.	100	49	10-70

Environmental characteristics—The *Tsuga heterophylla/Vaccinium ovalifolium* (western hemlock/tall blueberry) c.t. is a minor type occurring on floodplains, proximal outwash, beach ridges, and spits. It occurs as stringers, broad expanses of forest, or inclusions within forests. Sites occur on alluvial surfaces formed on outwash plains and on coastal dune crests or uplifted dunes. They are typically well drained, although on the outwash plains and floodplains, during high riverflows, they may be inundated. The surface topography is typically level on outwash plains and undulating on dune systems.

Soils—On outwash plains and floodplains the soils are deep, well-drained alluvium, and on dunes they are deep, well-drained aeolian sand. Soils are mostly classified as Spodosols (Shephard 1995).

Succession—This is a late-successional type that follows various *Picea sitchensis* (Sitka spruce) communities.

Other studies—This type is common throughout Prince William Sound and southeast Alaska. It is described for the Chugach National Forest by Borchers and others (1989) and DeVelice and others (1994) and has been reported from the Yakutat Foreland (Shephard 1995), the outer coast of Glacier Bay National Park (Worley 1977), and the Tongass National Forest (DeMeo and others 1992, Martin and others 1995, Pawuk and Kissinger 1989). Each regional classification uses separate canopy cover breaks to define the type; consequently, a direct correlation between types is not possible.

Tsuga heterophylla/Vaccinium ovalifolium-Echinopanax horridum Community Type Western Hemlock/Tall Blueberry-Devil's Club Community Type TSUHET/VACCIN-ECH-HOR G5; S5

Vegetation—The moderate to dense tree overstory is uneven aged and dominated by *Tsuga heterophylla* (western hemlock), although *Picea sitchensis* (Sitka spruce) may codominate in some stands. Western hemlock ranges up to 95 feet in height (Shephard 1995). The characteristic shrub layer is dominated by a moderate cover of *Echinopanax horridum* (devil's club), *Vaccinium ovalifolium* (tall blueberry), and *V. alaskensis* (Alaska blueberry). The forb, graminoid, and fern layers are typically sparse. In many stands, bryophytes form a dense carpet consisting mainly of *Sphagnum* (peat moss) species, *Hylocomium splendens*, and *Rhytidiadelphus loreus*.

The following tabulation lists the species that occur in more than 50 percent of the sites (50 percent constancy) and gives the percentage of constancy, average percentage of canopy cover for sites in which they occur, and range of cover values (number of sites sampled = 6; species richness = 20):

Species	Constancy	Average	Range
	- - - - - - - - - -	*Percent*	- - - - - - - - - -
Trees:			
Picea sitchensis	100	22	8-35
Tsuga heterophylla	100	46	37-55
Shrubs:			
Echinopanax horridum	100	15	6-25
Menziesia ferruginea	67	1	0-2
Rubus spectabilis	100	4	1-8
Vaccinium ovalifolium or *V. alaskensis*	100	25	15-40
Forbs:			
Cornus canadensis	100	1	1-2
Listera cordata	67	1	0-2
Moneses uniflora	50	1	0-1
Rubus pedatus	100	6	3-8
Streptopus amplexifolius	83	1	0-1
Tiarella trifoliata	100	1	1-2
Ferns:			
Athyrium filix-femina	50	1	0-1
Dryopteris austriaca	100	9	2-20
Gymnocarpium dryopteris	100	10	2-30
Mosses and lichens:			
Dicranum scoparium	83	8	0-15
Hylocomium splendens	100	10	4-20
Rhizomnium glabrescens	100	9	4-15
Rhytidiadelphus loreus	100	16	4-35
Sphagnum spp.	100	29	2-65

Environmental characteristics—The *Tsuga heterophylla/Vaccinium ovalifolium-Echinopanax horridum* (western hemlock/tall blueberry-devil's club) c.t. is a minor type occurring on floodplains, proximal outwash, beach ridges, and spits. It occurs as stringers, broad expanses of forest, or inclusions within forests. Sites occur on alluvial surfaces formed on outwash plains, and on coastal dune crests or uplifted dunes. They are typically well drained, although on the outwash plains and floodplains, during high riverflows they may be inundated. The surface topography is typically level on outwash plains and undulating on dune systems.

Soils—On outwash plains and floodplains, the soils are deep, well-drained alluvium, and on dunes, they are deep, well-drained aeolian sand.

Succession—This is a late-successional type that follows various *Picea sitchensis* (Sitka spruce) communities.

Figure 19—*Tsuga heterophylla/Vaccinium ovalifolium* c.t. on a mature outwash plain (photo courtesy of Michael Shephard, USDA, Sitka, Alaska).

Tsuga heterophylla/ Vaccinium ovalifolium/ Lysichiton americanum **Community Type Western Hemlock/ Tall Blueberry/ Yellow Skunk Cabbage Community Type TSUHET/VACOVA/ LYSAME G5; S5**

Other studies—This type has been described for the Tongass National Forest (DeMeo and others 1992, Martin and others 1995, Pawuk and Kissinger 1989), and the Chugach National Forest by Borchers and others (1989) and DeVelice and others (1994).

Vegetation—One site was sampled (fig. 19). The relatively open *Tsuga heterophylla* (western hemlock) and *Picea sitchensis* (Sitka spruce) overstory is uneven aged. *Lysichiton americanum* (yellow skunk-cabbage) grows from the wetter microsites including standing water. Species composition on the drier hummocks includes *Vaccinium ovalifolium* (tall blueberry), *Cornus canadensis* (bunchberry), *Hylocomium splendens* (feather moss), and *Sphagnum* (peat moss) species.

Environmental characteristics—This is an incidental type occurring on outwash plains, floodplains, or dune edges. It often forms a mosaic within or at the edge of larger sites composed of drier *Picea sitchensis* (Sitka spruce) or *Tsuga heterophylla* (western hemlock) types (DeMeo and others 1992). The surface topography typically consist of hummocks interspersed with small depressions containing standing water. The hummocks are formed by mineral soil, downed logs, or tree bases.

Shrub Community Type Descriptions

***Alnus crispa/ Calamagrostis canadensis* Community Type**
Sitka Alder/ Bluejoint Community Type
ALNCRI/CALCAN
G5; S5

Other studies—The *Alnus crispa/ Calamagrostis canadensis* (Sitka alder/bluejoint) c.t. is closely related to the *Alnus sinuata*/graminoid (Sitka alder/graminoid) c.t., described by Shephard (1995) for the Yakutat Foreland, Tongass National Forest. A drier-site c.t. was previously described for the Copper River Delta by Crow (1968), and DeVelice and others (1994) report this latter community type from other parts of the Chugach National Forest. Various other *Alnus crispa/ Calamagrostis canadensis* (Sitka alder/ bluejoint) types are reported by Viereck and others (1992) for other parts of the state.

Vegetation—This community is dominated by *Alnus crispa* var. *sinuata* (Sitka alder), although *Salix barclayi* (Barclay willow) may be a strong codominant in some sites. Alder age ranges up to 20 years, and its height ranges from 10 to 17 feet. *Carex sitchensis* (Sitka sedge), *Calamagrostis canadensis* (bluejoint), and *Equisetum arvense* (meadow horsetail) dominate the understory. Composition and cover of other herbaceous species are highly variable. Bryophyte cover is typically low.

The following tabulation lists the species that occur in more than 50 percent of the sites (50 percent constancy) and gives the percentage of constancy, average percentage of canopy cover for sites in which they occur, and range of cover values (number of sites sampled = 5; species richness = 47):

Species	Constancy	Average	Range
	- - - - - - - - - -	*Percent*	- - - - - - - - - -
Shrubs:			
Alnus crispa subsp. *sinuata*	100	74	60-80
Salix barclayi	60	21	0-30
Forbs:			
Equisetum arvense	80	29	0-90
Potentilla palustris	60	4	0-10
Rubus arcticus	80	3	0-3
Trientalis europaea	60	1	0-1
Viola epipsila	60	1	0-1
Graminoids:			
Calamagrostis canadensis	100	52	20-90
Carex sitchensis	60	40	0-70
Ferns:			
Athyrium filix-femina	60	3	0-3

Environmental characteristics—The *Alnus crispa/Calamagrostis canadensis* (Sitka alder/bluejoint) c.t. is a widely occurring shrub type on the outwash plains and flood-plains of the smaller rivers, and on slough levees of the uplifted marsh. It typically forms discontinuous stringers along the rivers, sloughs, recently disturbed areas, or pond edges. The sites occur on alluvial surfaces and are typically well drained, although during high riverflows, they may be inundated. The surface topography is level to rounded on the levee banks.

Soils—The soils are characterized by an organic layer 1 inch thick over silt or sand, although one site had a histic epipedon. The pH of the mineral layer ranges from 5.2 to 5.6. Horizon development in the soil profiles is common. Gleying was not found, and mottling was noted in a minority of the profiles. Salinity is low in all stands.

Figure 20—*Alnus crispa/Equisetum arvense* c.t. on a levee of the uplifted marsh landscape near Government Slough.

Succession—This is an early- to mid-successional type that follows various pioneer communities on new alluvial surfaces and uplifted marsh levees. The drier sites are likely seral to various *Picea sitchensis* (Sitka spruce) communities, although the dense graminoid cover may retard tree establishment. Wetter sites with histic epipedons will develop into peatlands.

***Alnus crispa/ Equisetum arvense* Community Type**
Sitka Alder/Meadow Horsetail Community Type
ALNCRI/EQUARV
G5; S5

Other studies—No other studies refer to the *Alnus crispa/Equisetum arvense* (Sitka alder/meadow horsetail) c.t. for south-central or southeast Alaska. Viereck and others (1992), however, cite studies with *Alnus crispa/Equisetum arvense* c.t.s. for northwestern Alaska.

Vegetation—The dense overstory is dominated by *Alnus crispa* var. *sinuata* (Sitka alder), although *Salix* (willow) may be a strong codominant at some sites (fig. 20). Alder age ranges up to 25 years, and its height ranges from 3 to 24 feet. *Populus trichocarpa* (black cottonwood) and *Picea sitchensis* (Sitka spruce) were recorded in several sites. *Equisetum arvense* or *Equisetum variegatum* (northern horsetail) dominate the understory. Typically, *Equisetum arvense* is the dominant understory component within this type except at sites on the Copper River floodplain where *Equisetum variegatum* dominates. Composition and cover of other herbaceous species are highly variable. Bryophyte cover is sparse to moderate.

The following tabulation lists the common species and gives their percentage of constancy, average percentage of canopy cover for sites in which they occur, and range of cover values (number of sites sampled = 13; species richness = 57):

Species	Constancy	Average	Range
	- - - - - - - - - - *Percent*	- - - - - - - - - -	
Shrubs:			
Alnus crispa subsp. *sinuata*	100	80	40-90
Salix alaxensis	46	5	0-10
Salix barclayi	46	14	0-30
Salix sitchensis	54	19	0-60
Forbs:			
Equisetum arvense	92	59	0-90
Equisetum variegatum	38	25	0-70
Pyrola asarifolia	46	12	0-30
Graminoids:			
Calamagrostis canadensis	77	3	0-10

Environmental characteristics—The *Alnus crispa/Equisetum arvense* (Sitka alder/ meadow horsetail) c.t. is a major type widely distributed throughout much of the Copper River Delta, including floodplains, outwash plains, uplifted marshes, linear dunes, and nontidal extensions of the mudflats. This community occurs on various surfaces including new alluvial deposits or dry channels formed on outwash plains and floodplains; dry to moist levees within the uplifted marshes; and nontidal, well-drained (sandy) portions of the mudflats that were uplifted in the 1964 earthquake. It typically forms discontinuous stringers. Surface topography is level or sloping (< 5 percent).

Soils—The soils are characterized by an organic layer ranging from 0 to 2 inches thick over silt or sand. The pH of the mineral layer ranges from 5.9 to 7.8. Horizon development in the soil profiles is uncommon. Gleying is rare and found only in the deeper (> 9 inches) layers. Mottling was noted in most of the profiles. Salinity is low in all stands.

Succession —Its seral status is unclear on linear dunes. On new alluvial surfaces and uplifted marsh levees, it is an early- to mid-successional type that follows various pioneer communities. It is seral to various *Picea sitchensis* (Sitka spruce) communities, as indicated by the presence of *Picea sitchensis* (Sitka spruce) and *Populus trichocarpa* (black cottonwood) at several of the sites.

Alnus crispa/Rubus spectabilis Community Type Sitka Alder/ Salmonberry Community Type ALNCRI/RUBSPE G5; S5

Other studies—This type is similar to the *Alnus sinuata/Rubus spectabilis* (Sitka alder/ salmonberry) c.t. described for the outer coast of Glacier Bay (Streveler and Paige 1971, Worley 1977), Yakutat Foreland (Shephard 1995), and Prince William Sound region (DeVelice and others 1994, Heusser 1960, Isleib and Kessel 1973). It has been described for several other locations in the state (Viereck and others 1992).

Vegetation—On terraces of the Copper River, this community is often dominated by huge, layered *Alnus crispa* var. *sinuata* (Sitka alder; fig. 21). Their bases are typically buried in sand-silt and are 5 to 9 inches in diameter. Alder age ranges up to 71 years, and its height ranges from 12 to 18 feet. Alder regeneration appears to all be by suckering from downed branches. On other landscapes, alder is younger and smaller. *Rubus spectabilis* (salmonberry) and *Athyrium filix-femina* (lady-fern) dominate the understory, and bryophyte cover is low.

Figure 21—The *Alnus crispa/Rubus spectabilis* c.t. on linear dunes at the mouth of the Copper River.

The following tabulation lists the species that occur in more than 50 percent of the sites (50 percent constancy) and gives the percentage of constancy, average percentage of canopy cover for sites in which they occur, and range of cover values (number of sites sampled = 8; species richness = 50):

Species	**Constancy**	**Average**	**Range**
	- - - - - - - - - -	*Percent*	- - - - - - - - - -
Shrubs:			
Alnus crispa subsp. *sinuata*	100	79	50-90
Rubus spectabilis	100	41	10-70
Sambucus racemosa	75	14	0-30
Forbs:			
Equisetum arvense	88	4	0-20
Heracleum lanatum	50	6	0-10
Ferns:			
Athyrium filix-femina	63	18	0-40

Environmental characteristics—The *Alnus crispa/Rubus spectabilis* (Sitka alder/salmonberry) c.t. is a major type on the linear dunes and outwash of the Copper River and is an incidental type on levees of the uplifted marsh. On outwash deposits, it occurs as broad expanses of shrubland or wide stringers between stands of the *Populus trichocarpa/Alnus crispa* (black cottonwood/Sitka alder) c.t. The surface topography varies from level to uneven on outwash and undulating on dunes with slopes up to 35 percent. The sites are typically well drained, although some are inundated during high riverflows.

Soils—The soils are characterized by an organic layer ranging from 0 to 1 inch thick over sand or gravel. The pH of the mineral layer ranges from 5.0 to 6.0 (pH 8.0 on uplifted marsh levee). Horizon development in the soil profiles is common. Gleying was not observed, but mottling was noted in most of the profiles. Salinity is low in all stands.

Succession—This is a late-successional type on the outwash of the Copper River and a mid-successional type on linear dunes and levees of the uplifted marsh. On outwash, new alluvial deposits are colonized by various herbaceous or woody communities. Sites without *Populus trichocarpa* (black cottonwood) develop into the *Alnus crispa/Rubus spectabilis* (Sitka alder/salmonberry) c.t. Sites with *Populus trichocarpa* (black cottonwood) develop into the *Populus trichocarpa/Alnus crispa* (black cottonwood/Sitka alder) community. *Populus trichocarpa* (black cottonwood) apparently only regenerates on the early alluvial deposits and consequently dies out, probably within 150 years. The next and oldest community identified is the *Alnus crispa/Rubus spectabilis* (Sitka alder/salmonberry) c.t. The outwash of the Copper River is relatively young and may, in time, support other late-seral communities.

Alnus crispa/Salix **Community Type**
Sitka Alder/Willow Community Type
ALNCRI/SALIX G4; S4

Other studies—Two sites were sampled. This type is similar to the *Alnus crispa/Salix sitchensis* (Sitka alder/Sitka willow) c.t. described by Shephard (1995) and DeVelice and others (1994) and an alder thicket type described by Batten and others (1978) for the Softuk Lagoon area. Both types are dominated by *Salix sitchensis* (Sitka willow).

Vegetation—The thick overstory is dominated by *Alnus crispa* subsp. *sinuata* (Sitka alder) in combination with *Salix barclayi* (Barclay willow), *Salix sitchensis* (Sitka willow), or *Salix commutata* (undergreen willow). The height of the tallest shrub layer ranges from 10 to 12 feet. *Populus trichocarpa* (black cottonwood) and *Picea sitchensis* (Sitka spruce) seedlings are often present. Composition and cover of herbaceous species are highly variable. Bryophyte cover is sparse to moderate.

Environmental characteristics—This is an incidental type distributed throughout much of the Copper River Delta. It occurs on various surfaces including levees on outwash plains and floodplains, relatively dry levees within the uplifted marshes, and upper dune slopes of coastal dunes. It typically forms discontinuous stringers. The sites range from well to poorly drained and surface topography ranges from level to undulating.

Soils—Soils are characterized by an organic layer ranging from 1 to 12 inches thick over silt or sand. The pH ranges from 5.4 to 6.6. Mottling was observed in the mineral soil, and salinity was low.

Succession—This is an early- to mid-successional type that follows various pioneer communities on uplifted marsh levees, dunes, and new alluvial surfaces. It is seral to various *Picea sitchensis* (Sitka spruce) communities, as indicated by the presence of *Picea sitchensis* and *Populus trichocarpa* (black cottonwood).

Empetrum nigrum-Carex pluriflora **Community Type**
Crowberry-Several-Flowered Sedge Community Type
EMPNIG-CARPLU G5; S5

Other studies—This community type is described for the Yakutat Foreland by Shephard (1995); an *Empetrum nigrum-Vaccinium uliginosum/Eriophorum angustifolium* c.t. is reported for the Chugach National Forest by DeVelice and others (1994). The *Empetrum nigrum-Carex pluriflora* (crowberry-several flowered sedge) may be similar to Neiland's (1971) *Empetrum nigrum-Vaccinium uliginosum/Eriophorum angustifolium-Carex pluriflora/Sphagnum recurvum-Pleurozium schreberi* c.t. for southeast Alaska. Other related types include *Empetrum nigrum/Carex pluriflora-Carex pauciflora/*

Sphagnum (Batten and others 1978, Dachnowski-Stokes 1941, Heusser 1960, and Scheirel and Meyer 1977), and *Empetrum nigrum-Eriophorum angustifolium/Sphagnum magellanicum-Sphagnum warnstorfii* (Reiners and others 1971, Streveler and others 1973). Ericaceous shrub types such as the *Empetrum nigrum/Carex pluriflora* c.t. are common in the maritime climate of southeastern and south-central Alaska and the Aleutian Islands (Viereck and others 1992).

Vegetation—The shrub layer is dominated by *Empetrum nigrum* (Crowberry). *Vaccinium uliginosum* (bog blueberry) and *Kalmia polifolia* (bog laurel) are often strong codominants. *Eriophorum angustifolium* (cotton grass) and *Drosera rotundifolia* (sundew) are common herbaceous species. Bryophytes, primarily *Sphagnum* (peat moss) species, blanket the ground.

The following tabulation lists the common species and gives their percentage of constancy, average percentage of canopy cover for sites in which they occur, and range of cover values (number of sites sampled = 4):

Species	Constancy	Average	Range
	- - - - - - - - - -	*Percent*	- - - - - - - - - -
Trees:			
Picea sitchensis	50	3	0-3
Shrubs:			
Empetrum nigrum	100	40	10-80
Kalmia polifolia	50	10	0-10
Oxycoccus microcarpus	50	2	0-3
Vaccinium uliginosum	100	7	3-10
Vaccinium vitis-idaea	50	7	0-10
Forbs:			
Drosera rotundifolia	75	8	0-10
Graminoids:			
Trichophorum caespitosum	50	12	0-20
Carex pluriflora	50	10	0-10
Carex sitchensis	75	20	0-40
Eriophorum angustifolium	75	40	0-80
Mosses and lichens:			
Aulocomnium palustre	25	20	0-20
Hylocomium splendens	25	20	0-20
Oncophorus wahlenbergii	25	20	0-20
Pleurozium schreberi	75	17	0-20
Ptilium crista-castrensis	25	40	0-40
Sphagnum fuscum	25	10	0-10
Sphagnum lindbergii	25	40	0-40
Sphagnum spp.	25	90	0-90

Environmental characteristics—This minor type occupies old undisturbed sites of distal outwash plains, floodplains, and uplifted marshes. These are bogs, or ombrotrophic fens, typically dominated by *Sphagnum* (peat moss) species. The sites are nutrient poor and acidic with the water table at or close to the surface most of the year. Surface topography is level with minor hummock formation. Consistent vegetation zonation patterns are found within peatlands. Near water tracts or streams, herbaceous types such as *Carex sitchensis* (Sitka sedge) or *Calamagrostis canadensis* (bluejoint) dominate. Moving to higher, and presumably drier sites, the vegetation changes to herbaceous-dwarf shrub, to shrub and dwarf tree communities. Where peatlands abut the upland forests, the ecozone consists of mature, typically slow-growing, needleleaf trees growing on a thin peat layer overlaying mineral soil.

Soils—The soils are characterized by an organic layer, ranging from 14 to more than 40 inches thick, over silt or sand. The pH ranges from 4.2 to 5.7, and salinity is low. The soil is likely saturated throughout much of the growing season. The water table depth, however, can drop in excess of 12 inches during dry spells.

Succession—This is a late-seral type. To develop, it requires saturated soils or depressions in level areas that once supported ponds but are now filled with organic material.

Myrica gale/Carex lyngbyaei **Community Type**
Sweetgale/Lyngby's Sedge Community Type
MYRGAL/CARLYN
G?; S2

Other studies—Various investigations describe many *Myrica gale* (sweetgale) c.t.'s for south-central and southeast Alaska (Viereck and others 1992); a *Myrica gale/Carex lyngbyaei* (sweet gale/Lyngby's sedge) type, however, has not been previously recognized in the literature.

Vegetation—The overstory is dominated by *Myrica gale* (sweetgale). *Carex lyngbyaei*, the diagnostic understory species, dominates the herbaceous layer. *Equisetum arvense* (meadow horsetail), *Potentilla palustris* (marsh fivefinger), and *Calamagrostis canadensis* (bluejoint) are common understory species. Bryophyte cover ranges from sparse to dense.

The following tabulation lists the species that occur in more than 50 percent of the sites (50 percent constancy) and gives the percentage of constancy, average percentage of canopy cover for sites in which they occur, and range of cover values (number of sites sampled = 7; species richness = 57):

Species	Constancy	Average	Range
		Percent	
Shrubs:			
Alnus crispa var. *sinuata*	57	4	0-10
Myrica gale	100	59	20-80
Salix barclayi	86	6	0-10
Salix commutata	71	2	0-3
Salix hookeriana	71	5	0-10
Salix sitchensis	57	3	0-3
Forbs:			
Equisetum arvense	86	7	0-20
Galium triflorum	57	1	0-1
Iris setosa	57	4	0-10
Potentilla egedii	57	9	0-10
Potentilla palustris	100	7	1-20

(tabulation continues on page 113)

Species	Constancy	Average	Range
	- - - - - - - - - -	*Percent*	- - - - - - - - - -
Graminoids:			
Agrostis alaskana	57	11	0-40
Calamagrostis canadensis	86	5	0-10
Carex lyngbyaei	100	50	30-70
Festuca rubra	57	1	0-1

Environmental characteristics—The *Myrica gale/Carex lyngbyaei* (sweet gale/Lyngby's sedge) c.t. is a major type found on uplifted marshes and tidal marshes of the Copper River Delta. On uplifted marshes, this type occurs on various surfaces, including saturated peat between levees and ponds, wet levees, and raised peat. It also is found on the drier extensions of the tideflats with tidal influence. All the sampled sites were poorly drained. The surface topography is hummocky because of the raised root wads of *Myrica gale* (sweetgale). Consistent vegetation zonation patterns are associated with different water depths. Vegetation zones, moving from wet (standing water) to dry, typically change from emergent vegetation, to herbaceous wet meadow, to shrub-dominated wetland, to forest on levees.

Soils—Uplifted marsh sites have soils characterized by an organic mat ranging from 3 to more than 16 inches thick overlaying saturated silt. The pH ranges from 3.8 to 6.4, and salinity is low. Sites within the tidal marsh have soils characterized by an organic mat less than 1 inch thick overlaying saturated silt. The soil is likely saturated throughout much of the growing season. The water table depth, however, can drop in excess of 16 inches during dry spells.

Succession—On the uplifted marsh landscape, this type is early to mid seral. Before the 1964 uplift, these sites were either dominated by *Carex lyngbyaei* (Lyngby's sedge) or *Myrica gale* (sweetgale) and *Carex lyngbyaei* together. Subsequent to the uplift, *Myrica gale* invaded sites dominated by *Carex lyngbyaei*; *Carex lyngbyaei,* however, has persisted and continues to dominate the herbaceous canopy. As the organic mat continues to thicken and *Sphagnum* invades, these sites eventually will develop into extensive peatlands.

Within the tidal marsh landscape, this type develops on sites at the edge of the tidal zone. *Carex lyngbyaei* (Lyngby's sedge) first invades the saturated soils, and *Myrica gale* (sweetgale) soon follows. As the marsh landforms mature, the species composition on these sites may change dramatically.

Other studies—A *Myrica gale/Carex sitchensis* (sweetgale/Sitka sedge) c.t. is described for the Yakutat Foreland by Shephard (1995). Various other *Myrica gale* c.t.'s are documented in the literature (Viereck and others 1992); no sources list *Carex sitchensis,* however, as an associated species.

Myrica gale/Carex sitchensis **Community Type**
Sweetgale/ Sitka Sedge Community Type
MYRGAL/CARSIT
G4; S4

Vegetation—The overstory is dominated by *Myrica gale* (sweetgale) from 1 to 3 feet tall (fig. 22). *Menyanthes trifoliata* (buckbean), *Potentilla palustris* (marsh fivefinger), and *Carex sitchensis* (Sitka sedge) are common understory species. Bryophyte cover ranges from sparse to dense.

Figure 22—*Myrica gale/Carex sitchensis* c.t. on a peatland where outwash grades into uplifted marsh.

The following tabulation lists the species that occur in more than 50 percent of the sites (50 percent constancy) and gives the percentage of constancy, average percentage of canopy cover for sites in which they occur, and range of cover values (number of sites sampled = 7; species richness = 41):

Species	**Constancy**	**Average**	**Range**
	- - - - - - - - - -	*Percent*	- - - - - - - - - -
Shrubs:			
Myrica gale	100	70	20-90
Salix barclayi	86	3	0-10
Salix hookeriana	57	7	0-10
Forbs:			
Equisetum fluviatile	86	9	0-10
Menyanthes trifoliata	57	25	0-50
Potentilla palustris	100	24	1-70
Graminoids:			
Calamagrostis canadensis	100	9	1-30
Carex sitchensis	43	20	0-60
Mosses and lichens:			
Sphagnum spp.	57	30	0-90

Environmental characteristics—The *Myrica gale/Carex sitchensis* (sweetgale/Sitka sedge) c.t. is a major type found on old undisturbed portions of uplifted marshes, floodplains, and outwash plains of the Copper River Delta. It occurs on late-successional peatland sites, the wet zone between levees and ponds, and on wet levees.

These are fens, or ombrotrophic fens, often dominated by *Sphagnum* (peat moss) species. Precipitation and ground-water flow are both water sources; consequently, nutrient availability, pH values, and biomass productivity are all higher than in bogs. The sites are poorly drained. Surface topography is often hummocky because of the raised root wads of *Myrica gale* (sweetgale). Consistent vegetation zonation patterns are found within peatlands. Near water tracts or streams, herbaceous types such as *Carex sitchensis* (Sitka sedge) or *Calamagrostis canadensis* (bluejoint) dominate. Moving to higher, and presumably drier sites, the vegetation changes to herbaceous-dwarf shrub, shrub, and dwarf tree communities. Where peatlands abut the upland forests, the ecozone consists of mature, typically slow-growing, needleleaf trees growing on a thin peat layer overlaying mineral soil.

Soils—The soils are characterized by an organic mat ranging from 1 to 22 inches thick overlaying saturated silt or sand. The pH ranges from 5.0 to 6.1, and salinity is low. The soil is likely saturated throughout much of the growing season; the water table depth, however, can drop in excess of 16 inches during dry spells.

Succession—This type ranges from mid seral on the uplifted marsh, to mid to late seral on outwash and floodplains. It may have occurred before the 1964 uplift within the uplifted marsh. On mid-seral sites, the organic mat will continue to thicken, *Sphagnum* (peat moss) will invade, and the site eventually will develop into extensive peatlands. To develop, peatlands require saturated soils or depressions in level areas that once supported ponds but are now filling with organic matter.

Myrica gale/ Empetrum nigrum **Community Type**
Sweetgale/Crowberry Community Type
MYRGAL/EMPNIG
G4; S4

Other studies—Neiland (1976, personnal communication to Viereck and others 1992) has documented a *Myrica gale/Empetrum nigrum-Eriophorum angustifolium-Carex pluriflora/Sphagnum recurvum-Pleurozium schreberi* type for southeast Alaska.

Vegetation—The overstory is dominated by *Myrica gale* (sweetgale) from 1 to 2 feet tall. Common subshrubs are *Empetrum nigrum* (crowberry) and *Andromeda polifolia* (bog rosemary). The two most common sedges are *Carex sitchensis* (Sitka sedge) and *Eriophorum angustifolium* (cotton grass). Bryophytes, predominantly *Sphagnum* (peat moss) species, blanket the ground.

The following tabulation lists the common species, and gives their percentage of constancy, average percentage of canopy cover for sites in which they occur, and range of cover values (number of sites sampled = 3):

Species	Constancy	Average	Range
	- - - - - - - - - -	*Percent*	- - - - - - - - - -
Trees:			
Picea sitchensis	100	1	1-1
Shrubs:			
Andromeda polifolia	100	10	10-10
Empetrum nigrum	100	27	1-40
Myrica gale	100	30	30-30
Oxycoccus microcarpus	100	7	1-20
Graminoids:			
Carex pluriflora	100	14	1-20
Carex sitchensis	100	21	3-50
Eriophorum angustifolium	100	67	60-80
Mosses and lichens:			
Sphagnum fuscum	67	40	0-50
Sphagnum papillosum	33	50	0-50
Sphagnum spp.	67	75	0-90

Environmental characteristics—This incidental type is found on old undisturbed portions of floodplains and outwash plains of the Copper River Delta. These are bogs, typically dominated by *Sphagnum* (peat moss) species. Precipitation is the primary water source, with little or no ground-water flow; consequently the sites are nutrient poor and acidic. The sites are poorly drained. Surface topography is often hummocky because of the raised root wads of *Myrica gale* (sweetgale). Consistent vegetation zonation patterns are found within peatlands. Near water tracts or streams, herbaceous types such as *Carex sitchensis* (Sitka sedge) or *Calamagrostis canadensis* (bluejoint) dominate. Moving to higher, and presumably drier sites, the vegetation changes to herbaceous-dwarf shrub, to shrub and dwarf tree communities. Where peatlands abut the upland forests, the ecozone consists of mature, typically slow-growing, needleleaf trees growing on a thin peat layer overlaying mineral soil.

Soils—The soils are classified as Hydric Borohemists or Sphagnic Borofibrists. They are characterized by an organic mat, in excess of 16 inches, overlaying saturated silt or sand. The pH ranges from 4.3 to 4.8, and salinity is low. The soil is likely saturated throughout much of the growing season; however, the water table depth can drop in excess of 16 inches during dry spells.

Succession—This is a late-seral type. To develop, it requires saturated soils or depressions in level areas that once supported ponds but are now filled with organic material.

Myrica gale/Epilobium angustifolium **Community Type**
Sweetgale/Fireweed Community Type
MYRGAL/EPIANG
G?; S2a

Other studies—A *Myrica gale/Epilobium angustifolium* (sweetgale/fireweed) c.t. has not been previously described in the literature.

Vegetation—The overstory is dominated by *Myrica gale* (sweetgale) 1 to 3 feet in height. *Equisetum arvense* (meadow horsetail), *Epilobium angustifolium* (fireweed), and *Festuca rubra* (red fescue) are common herbaceous species. Fireweed ranges up to 6 feet in height. Bryophyte cover ranges from sparse to moderate.

The following tabulation lists the species that occur in more than 50 percent of the sites (50 percent constancy) and gives the percentage of constancy, average percentage of canopy cover for sites in which they occur, and range of cover values (number of sites sampled = 4):

Species	Constancy	Average	Range
	- - - - - - - - - -	*Percent*	- - - - - - - - - -
Shrubs:			
Myrica gale	100	60	40-80
Forbs:			
Achillea borealis	100	9	1-30
Angelica genuflexa	50	10	0-10
Angelica lucida	50	12	0-20
Circaea alpina	50	2	0-3
Epilobium angustifolium	100	50	20-70
Equisetum arvense	50	65	0-70
Iris setosa	50	1	0-1
Lathyrus palustris	50	6	0-10
Potentilla egedii	50	1	0-1
Rubus arcticus	50	2	0-3
Sanguisorba stipulata	75	4	0-10
Graminoids:			
Festuca rubra	50	20	0-30
Hordeum brachyantherum	50	2	0-3
Ferns:			
Athyrium filix-femina	100	9	1-30

Environmental characteristics—This is an incidental type found on uplifted marshes and slacks of coastal dunes. It occurs on poorly drained levees. Surface topography is hummocky because of the raised root wads of *Myrica gale* (sweetgale). Consistent vegetation zonation patterns are associated with different water depths. Vegetation zones on uplifted marsh ponds, moving from wet (standing water) to dry, typically change from emergent vegetation, to herbaceous wet meadow, to shrub-dominated wetland and to forest. The forested portions usually are associated with levees.

Soils—The soils are characterized by an organic mat less than 2 inches thick overlaying silt or sand. The pH ranges from 5.0 to 5.9, and salinity is low. Depth to the water table is likely shallow for portions of the growing season; however, it can drop in excess of 11 inches during dry spells.

Succession—On the uplifted marsh landscape, this type is early to mid seral. Before the 1964 uplift, these sites probably were dominated by *Carex lyngbyaei* (Lyngby's sedge). Subsequent to the uplift, *Myrica gale* (sweetgale) and *Epilobium angustifolium* (fireweed) invaded and now dominate the sites. It is unclear what the next stage of succession is. Peatland types eventually will dominate. On slacks (level areas between or fronting beach dunes), this type is mid seral, following various herbaceous communities that colonize the sites.

***Myrica gale/Equisetum variegatum*
Community Type
Sweetgale/Northern Horsetail
Community Type
MYRGAL/EQUVAR
G4; S4**

Other studies—This type is similar to a *Myrica gale/Equisetum variegatum* (sweetgale/northern horsetail) c.t. reported by Shephard (1995) for the Yakutat Foreland, Tongass National Forest.

Vegetation—The overstory is dominated by *Myrica gale* (sweetgale) 2 to 3 feet tall. *Salix barclayi* (Barclay willow) and *Salix commutata* (undergreen willow) are common shrub associates. *Equisetum variegatum* (northern horsetail) dominates the herbaceous layer. Bryophyte cover ranges from moderate to dense.

The following tabulation lists the common species and gives their percentage of constancy, average percentage of canopy cover for sites in which they occur, and range of cover values (number of sites sampled = 3):

Species	Constancy	Average	Range
	- - - - - - - - - -	*Percent*	- - - - - - - - - -
Shrubs:			
Myrica gale	100	53	30-70
Salix barclayi	67	8	0-10
Salix commutata	67	13	0-20
Forbs:			
Equisetum arvense	100	8	1-20
Equisetum variegatum	100	36	1-97
Lupinus nootkatensis	33	1	0-1
Potentilla egedii	100	5	1-10
Sanguisorba stipulata	33	3	0-3
Graminoids:			
*Carex lyngbyae*i	67	2	0-3
Festuca rubra	100	2	1-5
Mosses and lichens:			
Conocephalum conicum	33	50	0-50
Sphagnum squarrosum	33	30	0-30

Environmental characteristics—This is an incidental type found on the high tide edge of newly developing tidal marshes and slacks of coastal dunes. The surface topography is hummocky because of the raised root wads of *Myrica gale* (sweetgale).

Soils—The soils are classified as Typic Cryaquents, characterized by an organic mat ranging from 0 to 15 inches thick overlaying silt or sand. The pH ranges from 6.5 to 7.0. Salinity ranges from that of fresh water to ocean water. The sites are poorly drained; however, mottles in one soil profile indicate a fluctuating water table.

Succession—Within the tidal marsh and coastal dune (slack) landscapes, this community develops on sites at the edge of the tidal zone. The *Carex lyngbyaei/Ranunculus cymbalaria* (Lyngby's sedge/seaside buttercup) or other primary successional tidal community first invades the sites, and *Myrica gale* (sweetgale) soon follows. As the marsh landforms mature, the species composition on these sites may change dramatically.

Undersampled *Myrica gale* (Sweetgale) Community Types

Myrica gale/Carex pluriflora **(Sweetgale/several-flowered sedge) c.t.—**This community is an incidental type (one site sampled) on the Copper River Delta. According to Shephard (1995), and the one plot sampled on the delta, it is dominated by *Myrica gale* (sweetgale) and *Carex pluriflora* (several-flowered sedge). It is a mid-seral community following *Carex lyngbyaei* (Lyngby's sedge) after tectonic uplifts or isostatic rebound of tidal marshes; the only landscapes where it was identified in Yakutat or the Copper River was uplifted marsh. The soils are characterized by peat averaging 22 inches thick. Not ranked.

Rubus spectabilis-Echinopanax horridum
Community Type
Salmonberry-Devil's Club Community Type
RUBSPE-ECHHOR
G5; S5

Other studies—DeVelice and others (1994) described a similar *Rubus spectabilis* (salmonberry) c.t. for other portions of the Chugach National Forest. This type also seems to be a modification of a closed tall *Alnus* (alder) type previously described by Heusser (1960), Isleib and Kessel (1973), and Streveler and Paige (1971).

Vegetation—One site was sampled. The thick shrub layer is dominated by *Rubus spectabilis* (salmonberry) in combination with *Echinopanax horridum* (devil's club). The mean height of the tallest shrub layer is 5 feet. *Aruncus sylvester* (goatsbeard) is a common understory species. Bryophyte cover is sparse.

Environmental characteristics—This community type is an incidental type on the linear dunes at the mouth of the Copper River. It typically forms patches on level sand-silt deposits adjacent to dunes or on dune crests. The sites are well to moderately well drained.

Soils—Soils are characterized by a thin organic layer over silt or sand.

Salix alaxensis
Community Type
Feltleaf Willow Community Type
SALALA
Not Ranked

Other studies—No other studies have described a *Salix alaxensis* (feltleaf willow) c.t. On the Yakutat Foreland, *Salix alaxensis* is commonly found in newly vegetated areas such as well-drained outwash gravels, but no community type is reported (Shephard 1995).

Vegetation—Two sites were sampled. The overstory is open and dominated by *Salix alaxensis* ranging in height up to 10 feet; species richness is low and cover is sparse. No bryophytes were recorded.

Environmental characteristics—The *Salix alaxensis* c.t. is an incidental type on dunes of the Copper River. The sites are unstable because of wind-transported sand and slumping sand deposits, creating an environment inhospitable to seedling establishment. Sites are typically well drained on level to steep slopes.

Soils—The soils are characterized by a thin litter layer over sand with no horizon development. Mottles and gleying were not encountered.

Salix arctica/Carex lyngbyaei
Community Type
Arctic Willow/ Lyngby's Sedge Community Type
SALARC/CARLYN
G?; S1

Other studies—A *Salix arctica/Carex lyngbyaei* (arctic willow/Lyngby's sedge) c.t. has not been previously described in the literature.

Vegetation—*Salix arctica* (arctic willow) and *Carex lyngbyaei* (Lyngby's sedge) codominate the community. The canopy cover of *Carex lyngbyaei* (Lyngby's sedge) is variable, partially because of intense grazing by waterfowl (primarily Canada geese) on some sites. *Iris setosa* (wild iris) and *Parnassia palustris* (grass of parnassus) are common herbaceous associates. Composition and cover of other herbaceous species are variable. Bryophyte cover ranges from moderate to high.

The following tabulation lists the species that occur in more than 50 percent of the sites (50 percent constancy) and gives the percentage of constancy, average percentage of canopy cover for sites in which they occur, and range of cover values (number of sites sampled = 4):

Species	Constancy	Average	Range
	- - - - - - - - - -	*Percent*	- - - - - - - - - -
Shrubs:			
Alnus crispa subsp. *sinuata*	75	1	0-1
Salix arctica	100	28	10-50
Forbs:			
Equisetum variegatum	50	1	0-1
Hedysarum alpinum	50	1	0-1
Iris setosa	100	7	1-20
Parnassia palustris	100	2	1-3
Potentilla egedii	75	7	0-10
Potentilla palustris	75	1	0-1
Rhinanthus minor	75	2	0-3
Graminoids:			
Carex lyngbyaei	100	35	1-90

Environmental characteristics—This is an incidental type found on the uplifted marshes at the mouth of the Copper River. It is located on moist levees or the edge of ponds. The water table ranges from greater than 16 inches to right at the soil surface; species composition suggests that the water table is near the soil surface for at least part of the growing season.

Soils—The soils are characterized by a mat of roots and organic matter 0 to 2 inches thick over silt or sand. No horizon development was observed. The pH ranges from 7.2 to 7.6, and salinity is low.

Succession—This is an early- to mid-seral type; successional pathways are unclear.

Salix barclayi/ Carex pluriflora **Community Type Barclay Willow/ Several- Flowered Sedge Community Type SALBAR/CARPLU G3; S3**

Other studies—This type is similar to the *Salix barclayi/Carex pluriflora* (Barclay willow/ several-flowered sedge) c.t. described by Shephard (1995) from the Yakutat Foreland. Additional *Salix barclayi* plant communities are described for south-central (Ritchie and others 1981) and southeast Alaska (del Moral and Watson 1978).

Vegetation—Two sites were sampled. The overstory is dominated by *Myrica gale* (sweetgale), *Salix barclayi* (Barclay willow), and *Salix sitchensis* (Sitka willow). Various herbaceous species dominate the understory, including *Carex lyngbyaei* (Lyngby's sedge), *Carex pluriflora* (several-flowered sedge), *Calamagrostis canadensis* (bluejoint), and *Eriophorum russeolum*. Bryophyte cover is moderate.

Environmental characteristics—This is an incidental type found on the uplifted marshes of the Copper River, typically near tidal marshes.

Soils—The soils are poorly drained and are characterized by a mat of roots and organic matter 0 to 2 inches thick over silt. The pH ranges from 5.5 to 7.5, and salinity is low.