National Park Service
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Natural Resource Program Center

Lake Clark National Park and Preserve Land Cover Mapping Project User's Guide

Natural Resource Report NPS/LACL/NRTR—1998/001

ON THE COVER
View from a ridge just south of The Tusk, looking upstream on the Neacola River.
Photograph by: Page Spencer, National Park Service.

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September 1998

U.S. Department of the Interior
National Park Service
Natural Resource Program Center
Fort Collins, Colorado

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Please cite this publication as:

Golden, M., and P. Spencer. 1998. Lake Clark National Park and Preserve land cover mapping project user's guide. Natural Resource Technical Report NPS/LACL/NRTR—1998/001. National Park Service, Fort Collins, Colorado.

NPS D-38, September 1998

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Introduction and Project Background

I.A. Introduction.

In August, 1996, the Alaska System Support Office of the National Park Service (NPS) joined with Pacific Meridian Resources to develop and produce a digital landcover map of the lands encompassing and surrounding Lake Clark National Park and Preserve. This report documents this project, the resulting raster land cover map, and the methods and procedures used. In addition to this report, a digital user's guide (in html format) has been produced for the Alaska System Support Office.

I.B. Project Background

The Alaska Support Office (AKSO) initiated a program to develop landcover maps of Alaska's National Parks in the early 1980's. The need of fire management professionals for fire fuels information, which can be derived from landcover maps, was the initial impetus for developing the program. In 1983, the NPS Fire Management Program (FirePro) and the AKSO (then called the Alaska Regional Office) initiated pilot projects in Denali and Wrangell-St. Elias National Parks to collect field-based data in support of landcover mapping. FirePro crews have continued collecting data through the present in Denali and Wrangell-St. Elias, and expanded to include the other "FirePro" parks of Gates of the Arctic, Bering Land Bridge, Noatuak, Kobuk Valley, Cape Krusenstern, Yukon-Charley Rivers, Lake Clark, and Katmai. Satellite multispectral imagery (Landsat Thematic Mapper and SPOT) has been purchased, from the mid-1980's through 1996. These field and imagery data comprise the major source of information from which the landcover maps are derived. Through in-house efforts, interagency partnerships and contracts, the Alaska NPS has completed maps for 7 of the 15 units in the state. This report describes the work completed for Lake Clark through a teaming effort with Pacific Meridian Resources.

Since the early years, the program has grown to support a wide variety of resources management needs in addition to fire management. Most recently, the Alaska NPS program has received support from the national NPS Inventory and Monitoring Program. This program's purpose is to provide baseline inventory information for several "nominal" data themes, of which vegetation is one. The vegetation inventory information will be used by scientists, managers, interpreters, park rangers, and planners in better managing the resources under NPS care as well as in better serving the public's information needs. The Inventory and Monitoring Program's goal is that information will be applicable at the local level, while being aggregatable for national reporting by using consistent classification schemes and methods. Toward that end, the Alaska NPS initiated projects with Pacific Meridian Resources in 1995 to accomplish the following tasks:

1. Evaluate the National Vegetation Classification System, developed by The Nature Conservancy for use in the lower-48, and expand it for mapping Alaska vegetation types.
2. Automate much of the FirePro field-based data,
3. Conduct a landcover mapping project in Wrangell-St. Elias National Park and Preserve,
4. Conduct a landcover mapping project of Lake Clark National Park and Preserve.

This report will focus on documenting Task 4.

II. Project Area

A. General Description

Lake Clark National Park and Preserve is a four million acre area in the heart of the Chigmit Mountains on the Alaskan Peninsular. The area is a composite of ecosystems representative of many diverse regions throughout Alaska. The area encompasses a wide range of biological diversity because it lies at the intersection of four different Alaskan bio-geographic regions (Pacific coastal, Interior Alaska, Aleutian, and Alaskan arctic-alpine). Also, the climate and microclimate vary greatly within the area due to terrain variation and the relative differences of coastal and continental influences. The climate along the eastern side of the project (along Cook Inlet) is mild with high precipitation, while to the west more continental climates prevail with relatively cold winters, hot summers and low rainfall.

Most of Lake Clark National Park falls within Gallant's Alaska Range ecoregion (Gallant, et.al., 1995). Two areas are transitional to the Interior Forest ecoregion. These are the areas west of Telaquana Lake and the southwestern half of Lake Clark and out the Newhalen River. Racine and Young (1978) describe five physiographic-biogeographic regions within Lake Clark National Park and Preserve (see Figure II-1). The following paragraphs are taken from their descriptions.

The Coastal Zone bordering Cook Inlet in the southeast corner of the proposal includes the lowlands between the inlet and the ice and snow of the Aleutian Range. Snowline occurs here between 1220 m (4000 ft) and 1520 m (5000 ft). Pacific coastal forests of Sitka spruce occur here near their northwestern limit in North America. Alder thickets cover most of the uplands. Large tidal fluctuations in deep bays (Tuxedni and Chinitna Bays) and glacial outwash result in well-developed estuarine salt marsh. Coastal beach vegetation is also present as are intertidal communities. Permafrost is rare or absent in the Coastal Zone and the climate is warmer and wetter (150-200) cm annual precipitation) than on the west side of the park.

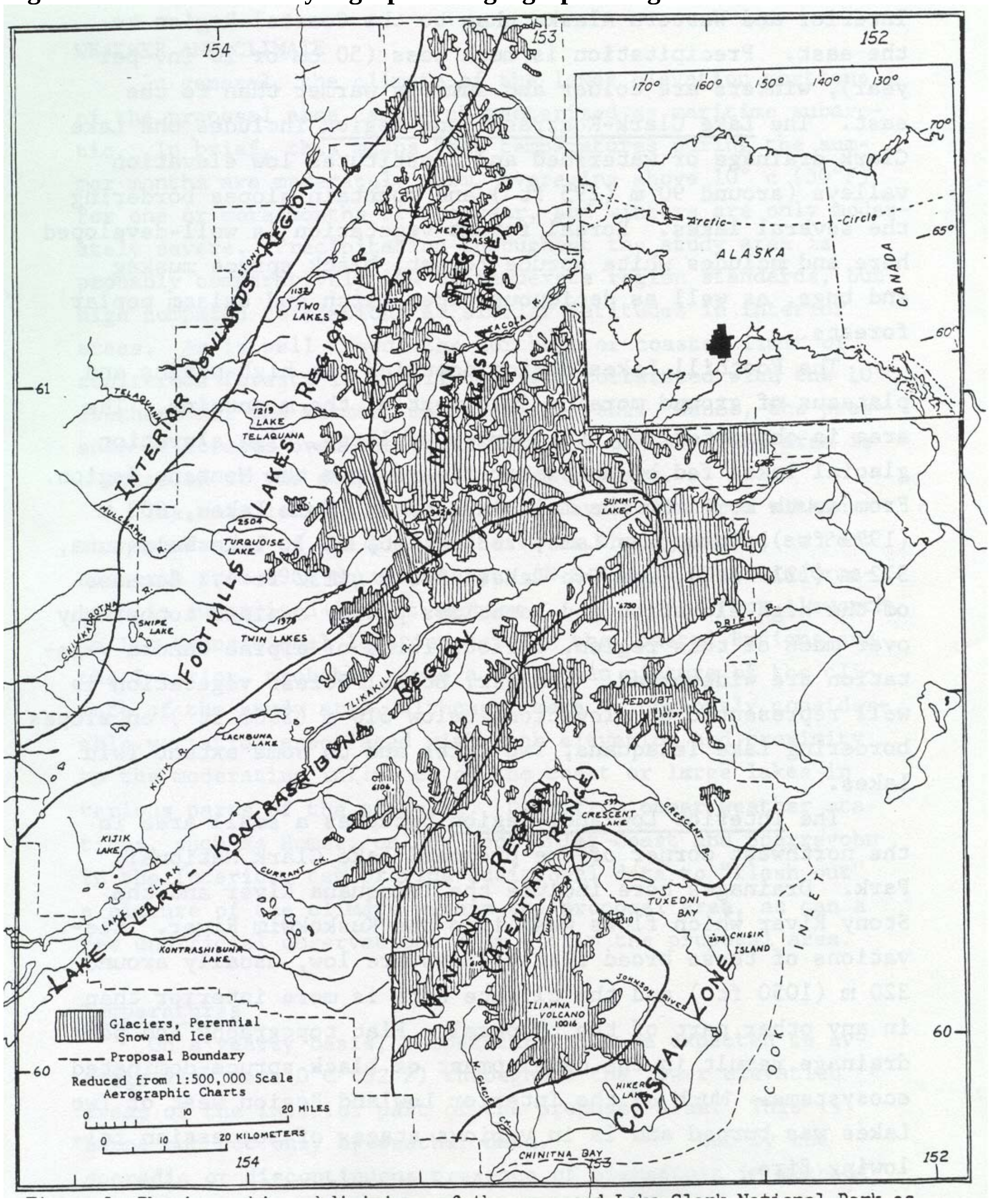
The Montane Region includes parts of the Alaska and Aleutian Ranges and represents a vast upland of alpine tundra, glaciers, permanent snow, ice and rock. Except for a few passes that penetrate the mountains where there are forests (Merrill and Lake Clark Passes), the vegetation is sparse and represented mainly by alpine tundra and shrub thicket.

Immediately west of the Montane Region (Alaska and Aleutian Ranges) and penetrating these ranges in places along their west side are the Lake Clark-Kontrashibuna and Foothill Lakes Regions. These areas are more closely related to Interior and Western Alaska than to the Coastal Region to the east. Precipitation is much less (50 cm or 20 in. per year), winters are colder and summers warmer than to the east. The Lake Clark-Kontrashibuna Region includes the Lake Clark drainage or watershed and constitutes low elevation valleys (around 90 m (295 ft) and mountain slopes bordering the several lakes. Boreal forest vegetation is well-developed here and includes white spruce forest, black spruce muskeg and bogs, as well as deciduous paper birch and balsam poplar forests.

The Foothill Lakes Region occupies the high plains and plateaus of ground moraine just west of the mountains. The area is characterized by a series of large, high elevation glacial lakes fed by meltwater rivers from the Montane Region. From south to north the main lakes are: Twin Lakes, 603 m (1979 ft), Turquoise Lake, 763m (2504 ft), Lake Telaquana, 372 m (1219 ft), and Two Lakes, 345 m (1132 ft). Because of the high elevations and sometimes poorly drained topography over much of this region, various forms of alpine tundra vegetation are widespread. However, Boreal Forest vegetation is well represented at elevations below 610 m (2000 ft) on slopes bordering Lake Telaquana, Two Lake and to some extent Twin Lakes.

The Interior Lowlands Region occupies a small area in the northwest corner of Lake Clark National Park and Preserve. Drainages here include the Telaquana River and the Stony River which flow west into the Kuskokwim River. Elevations of these broad flat valleys are low, usually around 320 m (1050 ft) and the climate here is more interior than in any other part of the Park. Flat topography and poor drainage result in the development of black spruce-dominated ecosystems. Much of the Interior Lowland Region west of Two Lakes was burned and is in various stages of succession following fire.

Figure II-1 Lake Clark Physiographic-Biogeographic Regions



(from Racine and Young, 1978)

II.B. Mapping Extent

A total of eleven SPOT scenes cover Lake Clark National Park and Preserve. (see Section IV.C for scene id's). Initially, the entire extent of the scenes were classified. Figure II-2 presents the extent of the scenes, their location within Alaska, and the park and preserve boundary. Aerial photo coverage was very limited outside the park boundary. Therefore, review of the classification and subsequent photo based reprocessing were limited outside the park and preserve boundary; and accuracy assessment sites (which had been delineated on the photography) were non-existent outside the photo coverage. Pacific Meridian Resources and NPS felt the classification was much less reliable outside photo coverage. Therefore, after processing, the mapping extent boundary was clipped to just outside the park and preserve boundary (Figure II-3).

Figure II-2. Lake Clark SPOT Scene Locations.

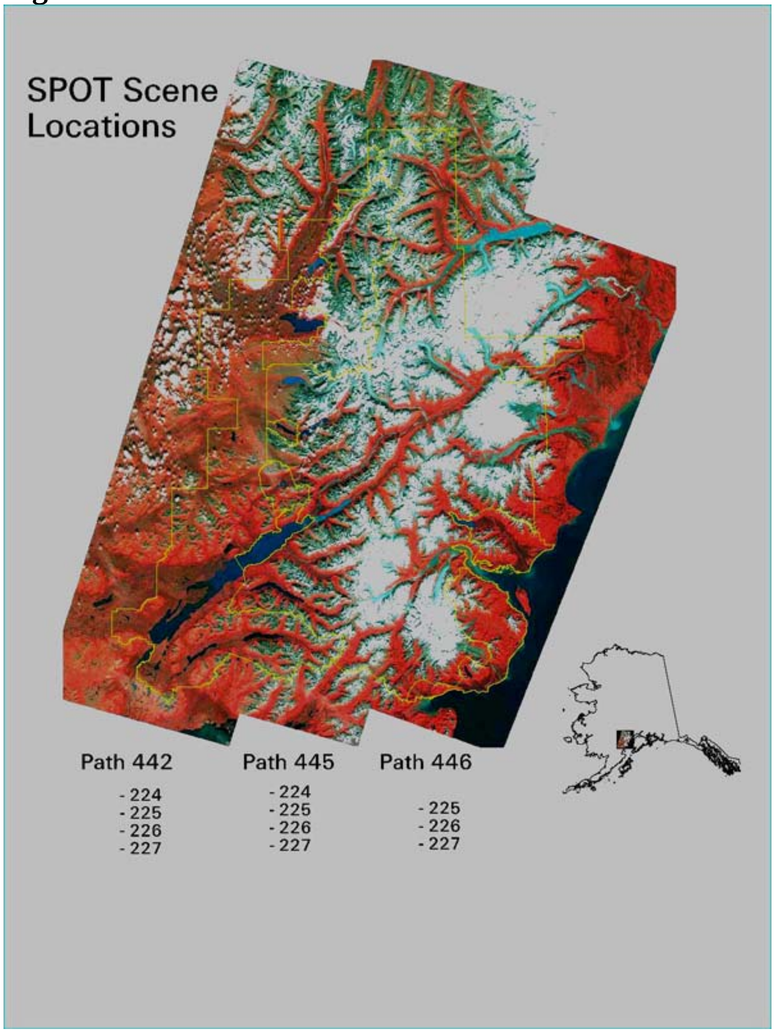
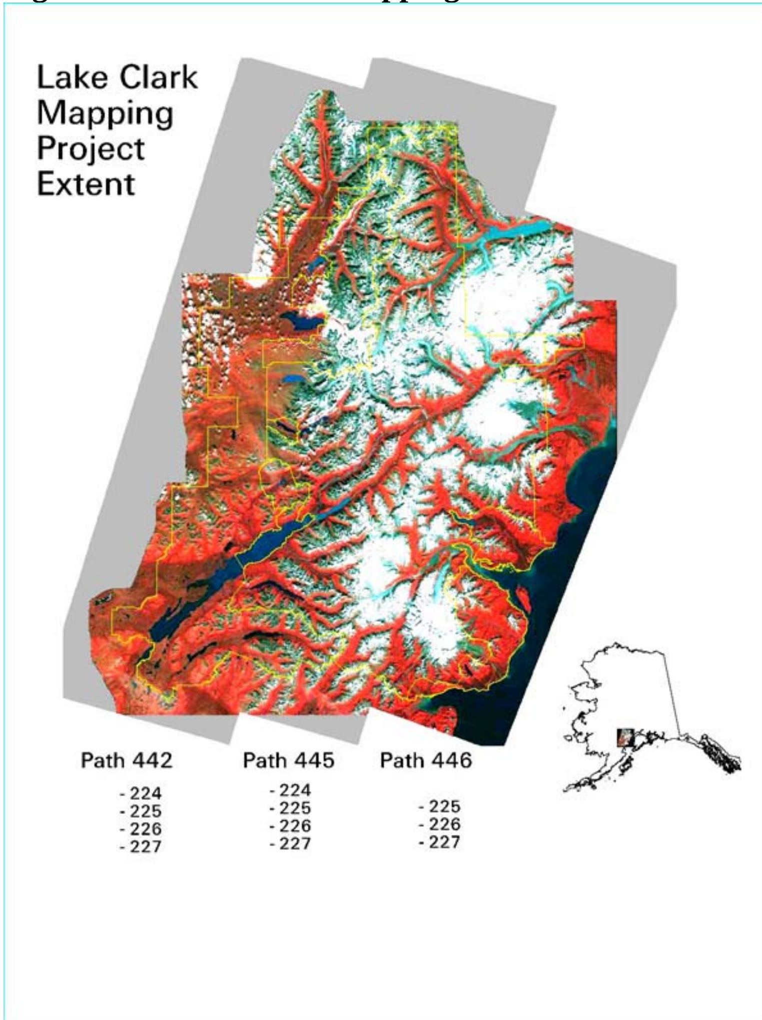


Figure II-3. Lake Clark Mapping Extent.



III Classification Scheme

A. Classification Scheme Development

As a starting point, the Draft National Vegetation Classification System (NVCS) as modified for Alaska (prepared under Task Order 2 of this contract) was reviewed for identifying the classification scheme and defining the individual mapping classes. However, the NVCS classes are not mappable directly from remotely sensed data and so modifications were allowed. The vegetation notes taken during the field reconnaissance in 1996 (see Section VI.C.3) and NPS Ecologist Page Spencer's knowledge of vegetation conditions in and around Lake Clark National Park and Preserve were relied on heavily. Dr. Spencer developed an initial list of mapping classes that was reviewed by Page, Sara Wesser, Alan Bennett, and Laurel Bennett from NPS and Pacific Meridian Resources. A tentative list of classes was developed. Some class definitions were modified during mapping and one class (beetle infested spruce) was dropped due to insufficient field data and the inability of the imagery to consistently identify the class. Example photographs and descriptions of each class are presented in the next section. he final mapping classes are as follows:

1. Closed Coastal Spruce
2. Closed Interior Spruce
3. Closed Birch Forest
4. Closed *Populus* Forest
5. Closed Mixed Forest
6. Open Spruce
7. Spruce Woodland
8. Open Mix Forest
9. Open *Populus* Forest
10. Open Birch Forest
11. Closed Alder
12. Open Alder
13. Willow Shrub
14. Low Shrub
15. Dwarf Shrub Tundra
16. Prostrate Shrub Tundra
17. Fellfield
18. Lichen Tundra
19. Sedge and Shrub Bog Meadow
20. Wet Sedge Meadow
22. Emergent Marsh
23. Sedge Dominated Mesic Tundra
24. Grasslands
25. Gravel and Sparsely Vegetated
26. Bedrock
27. Ice and Snow
28. Clear and Deep Water
29. Silty or Shallow/Murky Water
30. Marine Water
31. Marine Mudflats
33. Cloud and Cloud Shadow

B. Class List and Descriptions

1. Closed Coastal Spruce

Closed coastal spruce indicates stands of conifer with total crown cover generally greater than 60% on the coastal side of the Alaska Range. Sitka and white spruce (*Picea sitchensis* and *P. glauca*) are the dominant species, with a deciduous component less than 25% of total crown cover. Sitka spruce is more predominant south of Tuxedni Bay, with white spruce becoming predominant north of Tuxedni Bay. The deciduous species are balsam poplar south of the Big River, and a mixture of balsam poplar and paper birch from the Big River north. The understory consists of alder, devil's club, salmonberry, and a ground cover of mosses with scattered grasses and forbs.

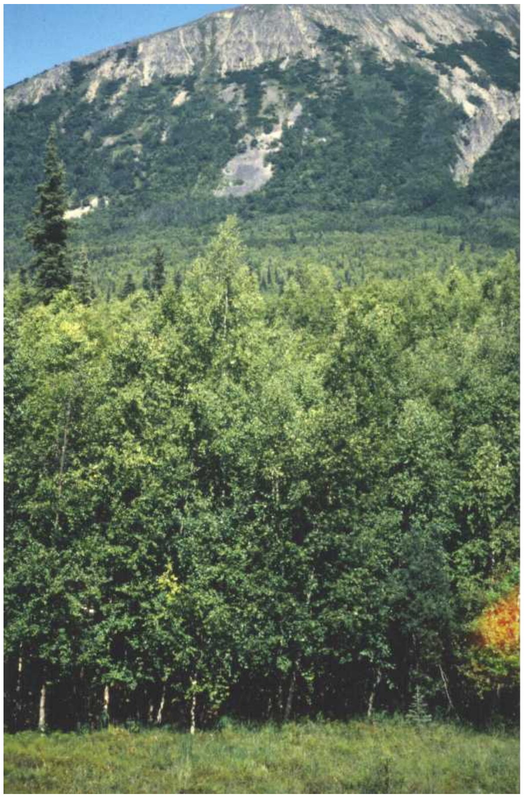
These rich and productive forests are distributed in the major valleys and along the coastal plain of the east side of Lake Clark National Park and Preserve. Large closed conifer stands grow on the old outwash plain east of Crescent Lake, and scattered throughout the valley downstream, and along the coastal plain between the Red River and East Glacier Creek, and along the floodplain of West Glacier Creek. Stands of dense white spruce along Tuxedni Bay and north are becoming infested with spruce bark beetle.

2. Closed Interior Spruce

Closed Interior Spruce indicates dense spruce stands on the west side of the Alaska Range. Closed spruce stands generally run from 60% to 80% crown closure of tree species. White spruce is the predominant overstory in this type, with some scattered black spruce near boggy margins, and balsam poplar and birch making up less than 25% of the total crown cover. Understory consists of scattered alder, ferns and forbs, and ground cover is a layer of mosses.

Closed spruce forests occur in small patches along the north shore of Lake Clark, especially at the mouths of Kijik River and along Chulitna Bay, up Currant Creek on the south side of Lake Clark, some unburned riparian remnant stands along the Stony River, and scattered patches in the Necons River floodplain northeast of Two Lakes. This type may be spatially confused with open spruce stands, especially on steeper north facing slopes, and may have some spectral confusion with cloud shadows in the northwest portion of the classification.

3. Closed Birch Forest



The closed birch forest type are dense stands of Kenai birch with crown closures of 60-100%. Balsam poplar is often mixed with birch, especially near upper altitudinal limits around Lake Clark and along riparian zones. Alder often fills in canopy openings and is a major component of the understory. Rose, highbush cranberry, grasses and forbs are common in the understory. Ground cover is sparse mosses and litter. Scattered white spruce make up less than 25% of the tree canopy.

Closed birch stands are most commonly found along the shores and associated valleys of Lake Clark, and on the southeast facing slopes above the Stony River. Scattered stands of closed birch may occur at the east entrance to Lake Clark Pass, and down in the valley of West Glacier Creek. Birch seems to be rare to absent along the Cook Inlet coast between the Big River and the West Glacier Creek.

4. Closed *Populus* Forest

Closed *Populus* forests are primarily balsam poplar stands, with scattered aspen clones included in this class. Balsam poplar grows in riparian zones and in chutes with surface or subsurface water flow along upper mountain sides, and occasionally forms timberline stands on southerly facing steep slopes. Crown closure ranges from 60 to nearly 100%. Birch may be included in these stands, especially on upper slopes. Alder is a major component of these stands, filling in canopy openings and extending into the understory. White spruce may form up to 25% of the forest canopy, especially in mature riparian stands. Understory in dense balsam poplar stands is mostly alder, with scattered rose, some highbush cranberry, grasses, Forbs and ferns, and a ground cover primarily litter with scattered mosses.

Closed balsam poplar forests are primarily on the south facing slopes of Copper Mountain above Kontrashibuna Lake, the south facing slopes at the upper end of Lake Clark and the valleys of Miller Creek, the lower Tlikakila River, and the lower Kijik River. Small aspen clones occur in the valley of the Stony River, and very rarely, along the terraces above Lake Clark west of Port Alsworth.

5. Closed Mixed Forest

Closed mixed forest are stands of primarily white spruce mixed with birch and/or balsam poplar, so that the total tree component is 60 to 100% crown closure. Mixes range from 25/75% proportions of deciduous to conifer, to the reverse at 25/75% conifer to deciduous species. Openings in the overstory are often filled with alder, which extends to the understory of the stand. A wide variety of understory and ground cover communities are present, depending on the proportion of tree species and total crown closure.

Closed (and open) mixed forests are dominant along the shores of Lake Clark and the associated valleys of Miller Creek, Kijik River, Tlikakila and Chokotonk Rivers, Current Creek and the Tazimina and Kontrashibuna Lakes. Mix forest in the northern section of the park are in the upper reaches of the Stony River, around Tequaluana Lake, the floodplain of the Neacola River, and on the east side in the broad valleys of the North Fork and Big Rivers, lower Drift River and Crescent River and the north shore of Tuxedni Bay.

6. Open Spruce


Open Spruce forests cover a wide variety of conifer communities with tree crown closure ranging from 25 to 60%. Deciduous trees (not considering alder), make up less than 25% of the total tree canopy. Open spruce is a dominant class in the lower elevations of Lake Clark National Park and Preserve. On the eastern Cook Inlet side of the Alaska Range, Sitka and white spruce form open stands, with alder understories and associated grass and forb ground cover. Extensive stands of open Sitka spruce are on the slopes above Cook Inlet from the valley of East Glacier Creek north to the Red River/Saddle Mountain. In the old floodplain of East Glacier Creek, open spruce stands are interspersed with small sedge and *Sphagnum* bogs. Open white spruce stands occur in the Crescent River valley and the north side of Tuxedni Bay. These stands have a more open understory of alder and willow, with forb and moss ground cover.

Open spruce in the Stony River valley and west of Telaquana Lake are predominately black spruce regrowth from wildfires in the early 1950's. As this area is the southern extent of the interior taiga, some white spruce may mix into these stands. However, these conifers are often slow growing and stunted. Understory is dwarf birch, willow and ericaceous shrubs, with openings of sedge and *Sphagnum* bog. Discontinuous permafrost may be present under these stands. Open spruce in the Chilikadrotna and Little Mulchatna drainages west of Snipe and Fishtrap Lakes is primarily "black spruce-like" trees with an understory of low shrub and ericaceous shrubs.

Open spruce stands in Lake Clark Pass are primarily white spruce with alder understory. The easternmost stands in this area are experiencing spruce bark beetle infestations. Open white spruce also grows around Lake Clark east of Port Alsworth/Kijik Lake and associated valleys. Current Creek, Ospook Creek and upper Tazimina River support open white spruce riparian stands. Extensive open black spruce stands grow on the flatter country of Keyes Point and Chulitna River on the north and western shore of Lake Clark, and on the north facing slopes above Tazimina and Kontrashibuna Lakes. These stands have an understory of willow, ericecaous shrubs, sedges and mosses.

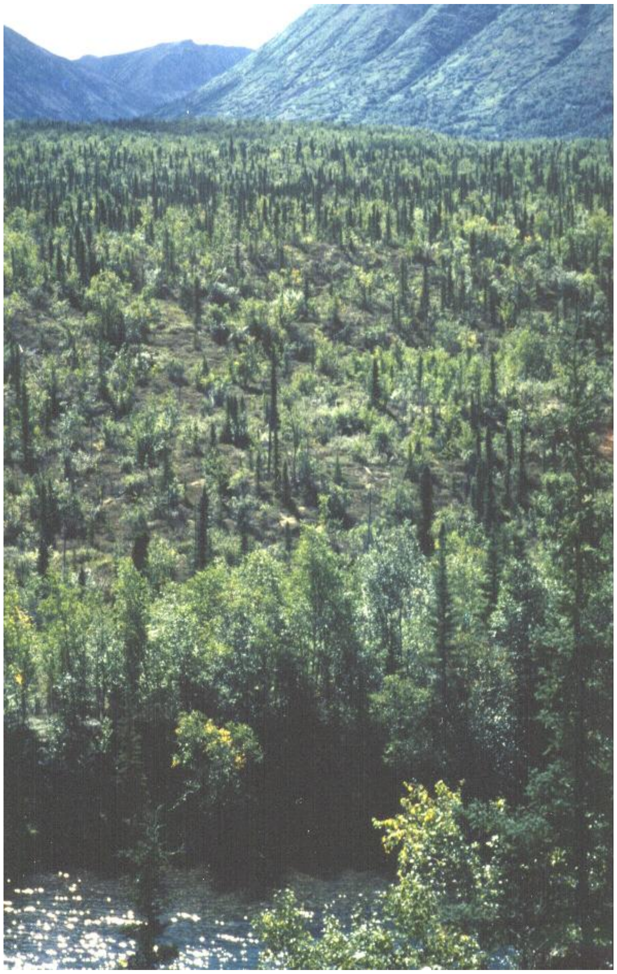
7. Spruce Woodland


Spruce woodlands are very sparse conifer stands with total tree cover 10-25%. Some deciduous trees, particularly mature birch may be present in some stands. Spruce woodlands are intermixed with open spruce and their corresponding understory types, such as low shrub, alder or sedge and shrub bog meadow.

Spruce woodlands in the Stony River and Telaquana Lack country are usually black spruce with wetland and some low shrub understories. In the Mulchatna and Chilkadrotna drainages, stunted spruce stands have dwarf birch and willow understories with ericaceous shrubs and fruticose lichen/moss ground cover. Black spruce woodland in the Chulitna River country have sedge and shrub bog understories and frequent openings. Spruce woodland on the south and west shores of Lake Clark are growing on well-drained lateral moraines and glacial outwash plains. Here they are white spruce with lichen and ericaceous ground cover, interspersed with birch stands and small sedge and shrub bog meadows.

Spruce woodlands on the Cook Inlet side of the Alaska Range are concentrated in the outwash fans of the Red River, below Hickerson Lake, and the timberline reaches of the North Fork of the Crescent River. These are well drained Sitka and white spruce stands with alder understory.

8. Open Mix Forest



Open mixed forest stands are very similar to closed mix stands, except the crown closure of tree species ranges from 25-60%. Mixes range from 25/75% proportions of deciduous to conifer, to the reverse at 25/75% conifer to deciduous species. Open mix stands are intermingled with closed mix stands in broad swaths through the open slopes and valley bottoms of the study area. As in closed mix, the dominant conifer species is white spruce, and the deciduous species are birch and balsam poplar. Alder is a major component in the understory and canopy openings. Spruce mixes will have a understory with more moss and ericaceous ground cover, while deciduous mixes will have a wider variety of shrubs such as rose and highbush cranberry, with ferns, forbs and litter for ground cover.

Open mix is a common cover type throughout the country around Lake Clark and the valleys flowing into it. Stands higher on the slopes, especially north facing areas, have a little bare rock cliffs and stringers of white spruce in the narrow drainages. An unusual community is the open mix regrowth in the fire around Port Alsworth, which has a understory heavy in Labrador tea. Birch in these regrowth areas seem to be major moose browse. Open mix on the Cook Inlet side is concentrated in the valley of Crescent Lake and River, especially at the juncture of the North Fork and Lake Fork, Crescent River. Understory in this area is willow and alder, with sparse grass and forb and litter ground cover.

9. Open *Populus* Forest

Open *Populus* Forest is almost exclusively balsam poplar, as most of the aspen clones seem to be mapped as Closed *Populus* Forest. *Populus balsamiferia* has forest cover ranging from 25-60%, with less than 25% of the tree cover in conifer. Alder is a common understory and interstial species for this type. Open *Populus* grows primarily on floodplains and outwash fans, or occasionally, near timberline in areas with surface or subsurface drainages. Mature birch or white spruce may be mixed with balsam poplar. Often the large sparsely spaced trees are used as nest sites by eagles and other large raptors.

Open *Populus* forests are scarce on the western side of the Alaska Range in Lake Clark National Park and Preserve. Some stands occur at the mouth of the Kijik River and around Kijik Lake, on fans from streams draining into Tazimina and Kontrashibuna Lakes, scattered along the Stony River. Open *Populus* stands are more common on the eastern side of the study area in the large glacial valleys draining into Cook Inlet.

10. Open Birch Forest

Open birch is dominated with Kenai birch with tree crown closures from 25% to 60%. Balsam poplar and white spruce may be minor components of the tree cover in this type. Open birch is heavily infested with alder in most locations, although dwarf shrub tundra may be the ground cover in the timberline ecotone. Open birch is intermingled with closed birch and mixed forest throughout the study area.

Open and closed birch forest on the north-facing slopes of Tanalian Mountain near Port Alsworth, are regrowth stands from a wildfire in the early 1950's. Other open birch stands are the upper limits of forest on many slopes around Lake Clark and valleys draining into it. Open birch stands also grow on south facing slopes above the Stony River floodplain. Open birch is uncommon on the Cook Inlet side of the Alaska Range. Scattered birch stands grow in the West Glacier Creek valley, then skip most of the coastline northward until the east entrance to Lake Clark Pass near Big River Lakes.

11. Closed Alder


The closed alder type is a dense community with crown cover greater than 75% and generally 100%. Layers of alder overlap each other in impenetrable thickets, with occasional mountain ash or cow parsnip in the less dense spaces. Ground cover is primarily alder leaf litter with scattered grasses. The parasitic plant broomrape grows on alder roots. Alder thickets may form large patches surrounded by grassland or dwarf shrub tundra, or blanket the mountainsides for miles. Comparisons with historical records indicate that alder is spreading down across mountain valleys and closing off previous travel routes.

Alder is a nitrogen fixing species and is an early pioneer on recently exposed soils such as de-glaciated till. Alder grown on moderately drained to rocky sites from just about sea level to around 3500'. Open and closed alder together are the most extensive vegetated type in Lake Clark National Park and Preserve (second only to ice and snow). Even forested areas could be viewed as a dense alder layer with a few trees. This community pretty much rings the mountain regions from water to ice with openings for rivers and rocky cliffs, especially on the coastal side. On the western slope of the Alaska Range, closed alder grades from timberline deciduous forest to tundra types above 3500'.

12. Open Alder

Open alder is basically smaller patches of *Alnus viridis* in a matrix of grassland or dwarf shrub tundra. Open alder is mapped in areas where the crown cover of alder is 25-75%. As in closed alder, the understory is sparse grasses and forbs with leaf litter for ground cover. The grassland component is primarily *Calmagrostis* with rich variety of forbs: fireweed, *Veratrum*, *Valeriana*, monkshood and ferns. Open alder on the Cook Inlet side and some slopes in the extreme western part of the study area are mixed with grasslands. Open alder on the western side of the mountains down through the big lake country is usually mixed with dwarf shrub tundra. This has low growing dwarf birch, blueberry, cranberry, mossberry (crowberry), Labrador tea, and has a ground cover of mosses and lichens.

Open alder generally occurs at the upper edges of the alder zone where shrubs are grading into tundra types. As such, it is on most of the upper mountain slopes throughout the park and preserve. The only vegetated areas of the study area without substantial alder are the Stony River valley south over the Telaquana Highlands into the Fishtrap Lake valley, and the Chulitna lowlands.

13. Willow Shrub

Willow communities make up a small proportion of the vegetated classes, but are important as moose habitat, especially in the western mountain valleys of the park. These predominately alpine and riparian stands have been hand edited to separate them from the willow stands which are part of the low shrub type.

Willow stands are dominated by Salix alaxensis and S. glauca growing one to over two meters high. They commonly grow on recently deglaciated moraines such as those in upper Currant Creeks or on active floodplains of flashy mountain streams. Scattered alder are often mixed with these willow stands. Ground cover is primarily rocks and dry habitat mosses. In some areas these stands are also important habitat for beaver.

14. Low Shrub

Low shrub communities are dominated by a mixture of dwarf birch and several willow species .5-1.5 meters high. Crown closures range from a low of 25% to densest stands about 80%. Some alder may be mixed in with the dwarf birch and willow in this community. A low growing ericaceous layer Labrador tea, blueberry, cranberry, and mossberry lies under the taller shrubs and in openings between patches. Ground cover is mosses with patches of fruticose lichens on dryer locations.

The low shrub type is concentrated in the center of the western lake country; west of Telaquana and south to the Lachbuna lake valley, along the southwestern coast of Lake Clark and Lower Tazamina Lake.

15. Dwarf Shrub Tundra

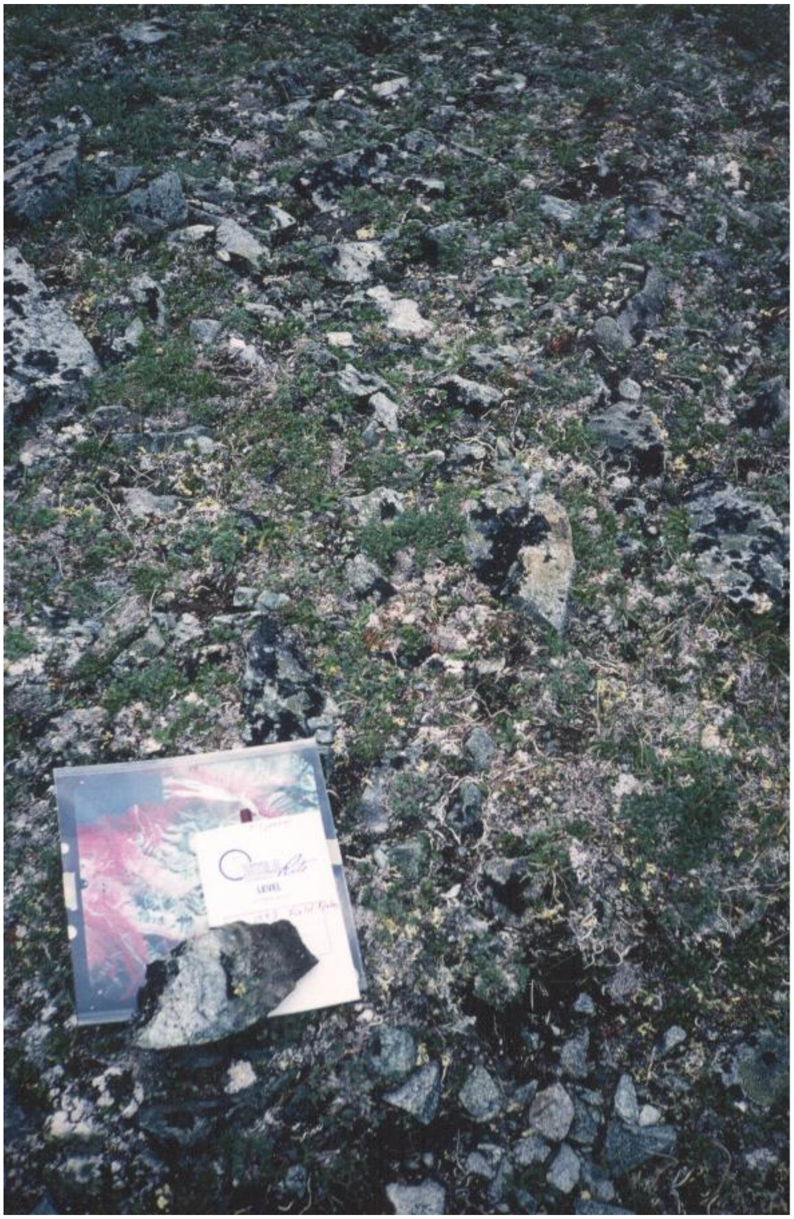
Dwarf shrub tundra is often understory to types such as low shrub, open alder or spruce woodland. When no overstory is present, this community is mapped as dwarf shrub tundra. This type is dominated by low growing ericaceous shrubs, dwarf birch and occasionally willow; all less than .33 meter high. Dwarf shrub tundra has a minimum vegetative cover of 25%, but more commonly has vegetative cover of 50-90%. This type is often a good berry producer for blueberries, cranberries and mossberries, thus providing fall and winter food for bears, ptarmigan and voles. Ground cover is mosses and lichens, mostly fruticose lichen species commonly called reindeer moss, and foliose *Peltigeras*.

Most of the dwarf shrub tundra is distributed in association with low shrub tundra and spruce woodland in the central lake country on the west side of the Alaska Range. Dwarf shrub tundra is common in the valley east of Fishtrap Lake, the upper reaches of what would be the south fork of the Chilikadrotna River, the drainages west of Twin Lakes and Turquoise Lake, and mixed with mesic sedge tundra on the Telaquana Highlands. Dwarf shrub tundra is widely scattered throughout the remainder of the study area, mostly in patches on mountain slopes above the alder community and grading into rock and talus. As the terrain becomes more extreme and unstable, this type grades into prostrate shrub tundra.

16. Prostrate Shrub Tundra

Prostrate shrub tundra is a shorter, rockier community than dwarf shrub tundra. Vegetation is generally less than 6" high and often grows on very well drained, unstable substrates such as active talus, and niches on bedrock. Prostrate shrub tundra is a micro-patchy community with tundra patches consisting of at least 50% cover throughout the unit. Actual tundra patches have more than 70% vegetative cover, usually mountain avens, dwarf species willow, mossberry, buleberry, cranberry, several species of heather, and fruticose lichens like *Cladinas* and *Cladonias*. Prostrate shrub tundra is the predominant tundra type in the alpine zone of the study area. It is distributed through the mountains and rolling uplands above the alder and dwarf shrub tundra, and into the rock and talus and glacier regions over 4000'.

17. Fellfield



Fellfields are very dry rocky tundra communities dominated by mat and cushion plants and lichens. Fellfield usually grows on exposed wind-blasted ridges with little snow cover. Vegetation cover ranges from 30-70% with broken rock the remainder. Common species are mountain avens, moss campion, *Diapensia* and prostrate growing Labrador tea, blueberry, cranberry, dwarf willows, and mossberry. Lichen flora is rich in crustose lichens on the rocks, with *Allectoria* spp, *Cetrarias*, and some *Cladinas* woven into the prostrate vegetation. These areas form a micro-mosaic of communities with pockets of frost fracturing and snowbank accumulation zones.

Fellfield is concentrated on the exposed moraines on the south side of the Telaquana Highlands and the corresponding moraines that wrap around the mountain to the south of Turquoise Lake.

18. Lichen Tundra

Lichen tundra is alpine tundra that is dominated by a rich fruticose lichen flora. Total vegetation cover is greater than 70%, of which 50-70% is lichen cover. Vascular plants are ericaceous shrubs and dwarf birch, generally less than 6" high. Lichens are mats of *Cetrarias* (*C. Islandica, nivalis, cucullata*), *Thamnolia, Cladonias* and *Cladinas* with some *Stereocaulon* on unstable sites. Lichen tundra grows on gentle to moderately steep, well drained slopes. As these areas do not accumulate deep snow, they are available for winter caribou forage.

Lichen tundra is sparsely distributed in the mostly unglaciated mountains in the southwestern part of Lake Clark Park and Preserve, and in the mountains north of Neacola River/Telaquana Lake. Lichen tundra is nearly absent in alpine regions on the eastern side of the study area.

19. Sedge and Shrub Bog Meadow

Sedge and shrub bog meadows are a complex of perched wetlands in succession toward forested types. Sedge tussocks and higher shrub hummocks are interspersed with little pools or streams. Often black spruce is encroaching around the edges. Sedge tussocks are cottongrass in wetter sites, and *Carex* on higher locations with cloudberry, horsetails, sundew and bog rosemary. Shrub hummocks have willow, shrubby cinquefoil or *Myrica gale* with sedges and various forbs. Ground cover in these wetlands is mosses, usually *Sphagnum* spp. and litter. Soils are wet to saturated peat.

Sedge and shrub bog meadows are intermixed with open and woodland black spruce in the lowlands on the western side of the park and preserve. These bogs are common in the Stony and Necons River valleys, scattered in the poorly drained morainal pockets in the Chilikadrotna Mulchatna drainages, then are common further south in the Chulitna River drainage and lower Lake Clark and Tazimina drainages. Sedge and shrub bog meadows on the east side of the mapping area are on large river valleys of West Glacier Creek, outwash of Red River, old beaver pond complexes in the Johnson River, and large open wetlands in the Crescent River and Polly Creek drainages. Extensive patches of this type are mapped in the outwash fans of the Drift, Big, Kustatan, McArthur, and Chakachamna, but the description may not be appropriate for these extensive wetlands outside the park and preserve boundary.

20. Wet Sedge Meadow

Wet sedge meadows are rich wetlands which are usually located along the sides of large floodplains. They are intermittently flooded with fresh water, and usually have some standing water. Wed sedge meadows are dominated by *Carex utriculata* and *C. aquatalis*, and marsh fivefinger with willow in the slightly better drained areas. Although not widespread or extensive, these areas are very rich wildlife habitat zones, especially for moose, bear, swans and other water fowl and beaver.

Moderately large wet sedge meadows are found on the large rivers draining the east side of the study area: the outwash fan of the Tuxedni Glacier in the Tuxedni River floodplain, in the maze of drainages and beaver ponds at the upper end of Crescent Lake and upper North Fork Crescent River, and along the Neacola River and depositional area of Kenibuna Lake. On the western side, wet sedge meadows are smaller and scattered in areas with wet micro topography. Wet sedge meadows are scattered throughout the lower Chulitna River, west of Snipe Lake, Stony River valley, as pocket wetlands west of Twin Lakes, and perched in the old moraines on the south side of the Telaquana Highlands.

21. Salt Marsh

Salt marsh refers to a complex of wetland communities under tidal or marine influence along the Cook Inlet coast of the park and preserve. These marshes are dominated by *Carex lyngbyaie* and *C. ramenskii*, with other sedges, forbs and grasses. See work by Jerry Tande and Alan Bennett (Tande, 1996) for more detailed community descriptions and mapping detail of the salt marshes along the Cook Inlet coast. The salt marshes are vital habitat for brown bears, especially in the spring before salmon and berries are available.

Prominent salt marsh areas are the heads and side shores of Tuxedni and Chinitna Bays and the lagoons behind coastal beaches at Spring Point, the fan of the Red River, and along the coast between Silver Salmon Creek and the mouth of the Johnson River.

22. Emergent Marsh

Emergent marshes are small fresh water wetlands which are flooded throughout the growing season. They are usually interspersed with wet sedge meadows in large floodplains. Emergent vegetation growing in these marshes includes horsetail, bog buckbean, aquatic sedges, and water lilies. These marshes are also rich wildlife habitat, especially for moose and nesting sites for waterfowl.

Emergent marshes are mapped in the lower Tuxedni River, and as scattered pockets at the mouth of Silver Salmon Creek and along the sides of West Glacier Creek. Emergent marshes fill the old river sloughs of the Stony River.

23. Sedge Dominated Mesic Tundra

Sedge dominated mesic tundra is a hummocky tundra of sedges and forbs which spreads across the gentle rolling slopes of the Telaquana Highlands. Vegetation is dominated by *Carex* spp and forbs including colts foot, *Sedum*, *Arnica* sp., dwarf monkshood, and *Selaginella* and foliose lichen *Peltiergia* spp. Some dwarf shrubs are present, including blueberry, dwarf birch and dwarf willows. Subtle drainages in the area are slightly wetter with cottongrass as the sedge component. Mosses and litter make up the ground cover.

The primary location of sedge dominated mesic tundra is on the rolling uplands between Telaquana and Turquoise Lakes, named the Telaquana Highlands. This type is probably under mapped in the region due to clouds and shadows in the area. Other mesic tundra patches are scattered in valley bottoms throughout the mountains on the western side of the Alaska Range divide.

24. Grasslands

Grasslands are diverse herbaceous communities of grasses and forbs. *Calmagrostis* grasslands grow in large patches within the alder zone and in even larger extents near the upper extents of alder, grading into rock and tundra types above 4000'. These communities are dominated by *Calmagrostis* with many large forbs. Primary forb species are fireweed, *Veratrum*, monkshood, *Valeriana*, *Angelica* and ferns. Scattered mountain ash or highbush cranberry may be present. *Calmagrostis* grasslands grow in association with open alder at the upper ends of large mountain valleys, especially the Tuxedni, Crescent, Drift and Tlikakila River drainages. Smaller patches of grasslands ring the mountains north of Lake Clark.

Another important grassland type is the *Elymus* community that grows along the marine shore just above the high tide line. *Elymus* grows in sand and is subject of occasional salt water flooding or splashing. It is crucial for holding beach lands against wave and tidal erosion. *Elymus* is the dominant species, with cow parsnip, beach pea, *Honckenya* and scattered composites. *Elymus* grasslands grow along the Cook Inlet beaches on the east side of the park and preserve.

A minor but unusual component of the grassland type is a late snowbank forb community which grows in small patches on valley slopes of avalanche runout zones and snowbank pockets. Prominent species are *Veratrum*, geranium, dogwood, saxifrage and buttercup, with *Cassiope tetragona* as ground cover.

25. Gravel and Sparsely Vegetated

Gravel and sparsely vegetated is widely distributed through the study area in a variety of forms. Unstable talus forms debris cones off steep bedrock ridges. Around glaciers the gravel is unsorted till in a variety of moraines on the ice and in recently deglaciated areas. These areas may have patches of prostrate shrub tundra attempting to colonize the constantly moving surfaces. Active streams and rivers have large areas of alluvially deposited gravel. Balsam poplar and willow seedlings are sparse on portions of the floodplains which have not been subject to recent severe flooding. Coastal beach sands may be mapped as gravel on the Cook Inlet shore. And finally, volcanic ash deposits from recent eruptions of Mts Redoubt, Spurr and older Iliamna ash deposits are mapped as sparse vegetation where the shrub and tundra communities are colonizing the downwind ashfall areas.


26. Bedrock

The bedrock class indicates barren rock which forms the spine of the Chigmit mountains and various outcrops throughout the park and preserve. Small patches of vegetation colonize bedrock fractures and sheltered niches at elevations below about 4000’. At higher elevations, bedrock is inhabited by howling winds and dancing waterfalls.

27. Ice and Snow


This class maps glacier ice and areas of late lying snow. Functionally, nothing grows there except algae forming watermelon snow and ice worms. Large expanses of ice and snow blanket the Alaska Range mountains down the center of the study area. Occasional bedrock nunataks, moraines and volcanic vents penetrate the ice, but otherwise, ice and snow dominate the landscape above 4000' or so, and make large glacial excursions into lower elevations.

28. Fresh Water - Clear (Clear and Deep Water)

Clear water maps fresh waters in the park and preserve that are unsedimented, or lightly silty from glacial flour. These lakes and ponds are generally rich habitats for aquatic vegetation and native fish species. Most small lakes deeper than about one meter, and many large lakes are mapped as clear water. Such lakes include Lake Clark, the Taziminas, Kontrashibuna, both Twins and Telaquana Lakes. Clear water streams generally did not get mapped in this classification.

29. Water - Silty and/or Shallow (Silty or Shallow/Murky Water)

This class maps rivers and lakes with high sediment load from glacial runoff, and shallow lakes which generally freeze to the bottom during winter and thus are not good aquatic habitat. Lakes mapped as silty or shallow include Little Lake Clark, Turquoise and Two Lakes, shallow portions of the Caribou Lakes and Crescent Lake. Large braided glacial rivers were also mapped as silty waters, including Tuxedni, Tlikakila, Drift, North Fork Big, and Neacola Rivers. Sedimented plumes at the mouths of these rivers into Cook Inlet are also mapped as extra silty.

30. Marine Waters (Marine Water)

Marine water refers to salt water of Cook Inlet. It is mapped exclusively on the eastern shore of the park and preserve. Important marine bays to Lake Clark habitats include Chinitna and Tuxedni Bays.

31. Marine Mudflats

Marine Mudflats are those silt and clay flats subject to diurnal tidal flooding. The tide stage during image acquisition shows Mudflats at the heads of Chinitna, Tuxedni Bays and Squarehead Cove. These area are rich clam beds which are used by bears during low tides in spring

32. Beetle infested spruce

This class was not mapped in the final classification due to lack of field support data and the rapidly moving infestation between image date of 1995 and field work in 1997. Spruce bark beetles are primarily infesting closed and open spruce stands along the Cook Inlet coast and associated valleys from the south shore of Tuxedni Bay and north, and are moving west through Lake Clark Pass. As of summer 1997, spruce bark beetle infested trees were evident several miles west of the North Fork and Tlikakila River junction, and about half way down the Chokotonk River which flows into Little Lake Clark.

33. Cloud and Cloud Shadow

This class accounts for both clouds and cloud shadows present over the study area during data collection on August 20 and 21, 1995. There is a flotilla of cumulus clouds in the northwest part of the study area in the Stony River valley west of Telaquana and Turquoise Lakes, scattered cumulus in the upper valleys of Current Creek, Tlikakila River, upper Kijik River, and both sides of upper Twin Lake. A dense valley-filling fog clogs the entire drainage of the Telaquana River between the lake and Telaquana Pass, and lays along the front of the mountain slope between Telaquana and Turquoise Lakes. Several con trails and their associated shadows traversed the southwest portion of the study area, but have been largely edited out and remapped to their appropriate landcover type.

Despite rigorous hand-editing, some confusion may remain with prostrate shrub tundra, talus/sparsely vegetated and wetland classes.

C. List of Common Plants

Common Name or term used in Class Descriptions	Scientific Name (Caswell, 1998) terms in ( ) are as used in Hultén (1968)
Sitka spruce	*Picea sitchensis*
white spruce	*Picea glauca*
black spruce	*Picea mariana*
Kenai birch	*Betula kenaica*
balsam poplar	*Populus balsamifera*
aspen	*Populus tremuloides*
alder	*Alnus viridis (Alnus crispa)*
mountain ash	*Sorbus scopulina, S. sitchensis*
dwarf birch	*Betula glandulosa, B. nana*
riparian willow (in Willow shrub class)	*Salix alaxensis, S. pulchra, S. barclayi*
alpine willow (in Willow shrub class)	*Salix brachycarpa, S. glauca*
low shrub willow (in low shrub & open/woodland conifer)	*Salix fuscescen, S. pulchra*
dwarf willows (in tundra classes)	*Salix arctica, S. reticulata*
moss campion	*Silene acaulis*
Honckenya	*Honckenya peploides*
Arnica	*Arnica frigida*
colts foot	*Petasites frigidus*
Diapensia	*Diapensia lapponica*
dogwood	*Cornus canadensis*
mossberry (crowberry)	*Empetrum nigrum*
Labrador tea	*Ledum palustre, L. groenlandicum*
heathers	*Cassiope spp, Arctostaphylos spp. Luetkea pectinata, Phyllodoce aleutica, Harrimanella stelleriana*
Casiope	*Cassiope tetragona Cassiope tetragona*
Ericaceous shrubs	*Vaccinium spp., Arctostaphylos spp, Ledum, Emptrum*
bog rosemary	*Andromeda polifolia*
blueberry	*Vaccinium uliginosum*
cranberry	*Vaccinium vitis-idaea*
bog buckbean	*Menyanthes trifoliata*
geranium	*Geranium erianthum*
devil's club	*Oplopanax horridus (Echinopanax horridum)*
Calamagrostis	*Calamagrostis canadensis*
Elymus	*Leymus mollis (Elymus arenarius)*
highbush cranberry	*Viburnum edule*
Veratrum	*Veratrum viride*
fireweed	*Epilobium angustifolium*
broomrape	*Boschniakia rossica*
beach pea	*Lathyrus japonicus (L. maritimus)*
buttercup	*Ranunculus sp.*
monkshood	*Aconitum delphinifolium*
rose	*Rosa acicularis*
mountain avens	*Dryas octopetala*
cloud berry	*Rubus chamaemorous*
shrubby cinquefoil	*Pentaphylloides floribunda (Potentilla fruticosa)*
marsh fivefinger	*Comarum palustre (Potentilla palustris)*
Salmonberry	*Rubus spectabilis*
Sedum	*Sedum integrifolium (S. rosea)*
saxifrage	*Saxifraga sp.*
cottongrass	*Eriophorum spp.*
sedges	*Carex spp.*
sundew	*Drosera rotundifolia*
Angelica	*Angelica lucida*

cow parsnip	*Heracleum maximum (H. lanatum)*
Valeriana	*Valeriana capitata*
water lily	*Nuphar polysepala*
Myrica gale	*Myrica gale*
Selaginella	*Selaginella sibirica*
horsetails	*Equisetum arvense*
Peltigerias	
fruticose lichens	*Cladinas, Cladonias, Alectoria, Thamnolia, Sterocaulon, Cetrarias (C. islandica, C. nivalis, C. cucullata)*
crustose lichens	*Umbilarica spp. and many others*
Sphagnum	*Sphagnum spp*.

IV Mapping Methods

A Overview

The Lake Clark Mapping Project was a joint endeavor between the National Park Service and Pacific Meridian Resources. The primary data sources were SPOT multispectral images, Alaska NHAP color infra-red photography, and extensive field data. All digital processing was conducted using ERDAS Imagine software on a SUN Unix workstation. All image processing was conducted by Mike Golden from Pacific Meridian Resources.

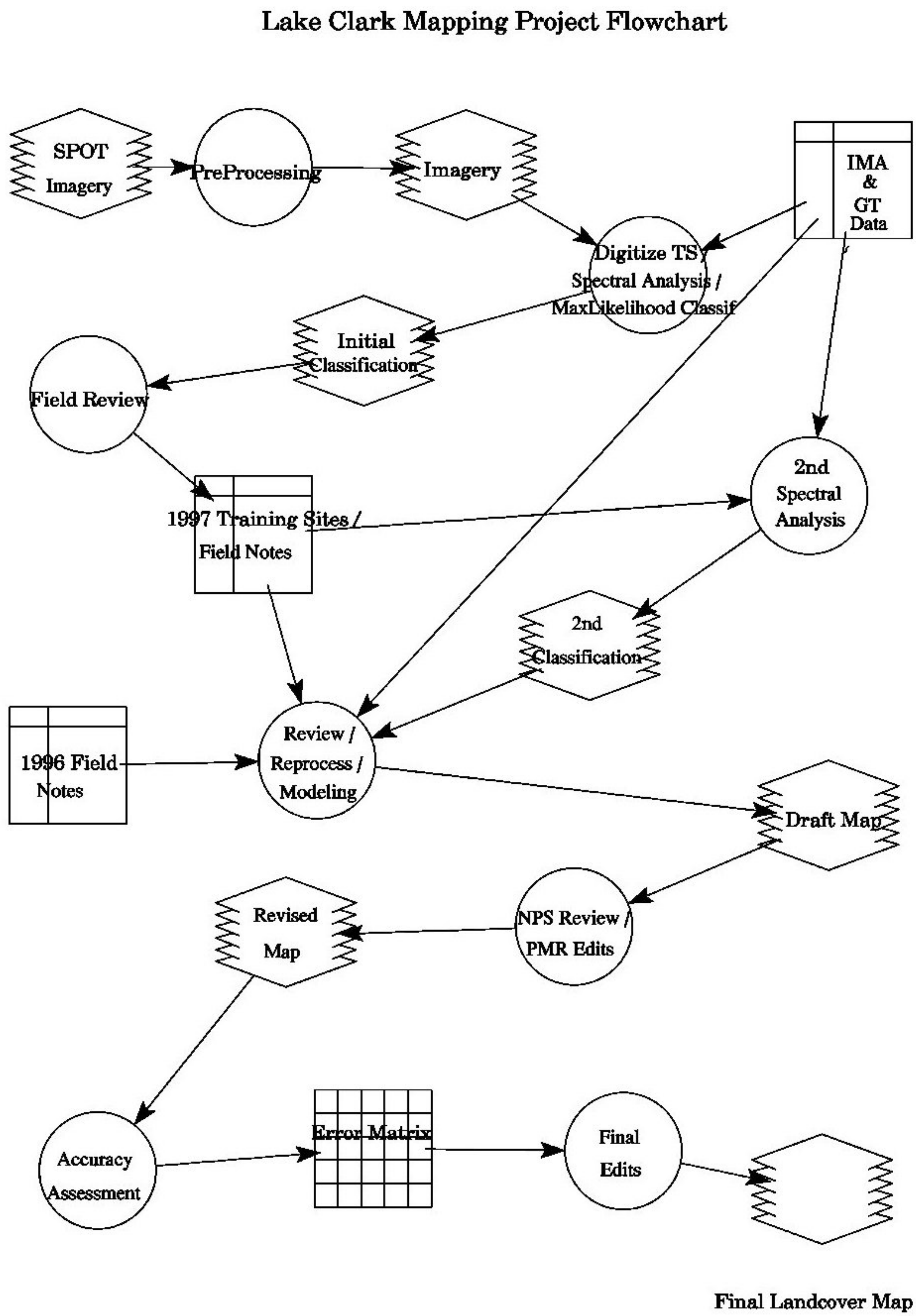
A total of 31 land cover classes (plus cloud cover) were identified for the Lake Clark mapping project. This project integrated digital image classification, photointerpretation, ground-based vegetation data, and knowledge of the vegetation of the park by NPS and Pacific Meridian Resources personnel. Initial mapping was accomplished using automated computer classification of the SPOT imagery. Subsequent iterations used the imagery as a geographic base and relied on photointerpretation and ground based vegetation data. The map was further improved by the use of spatial models developed by the NPS and Pacific Meridian Resources. A flowchart of the steps involved in producing the land cover map is presented in Figure IV-1. Detailed descriptions of the steps involved in producing the land cover map are presented in the sections that follow.

A discussion of general image processing for land cover mapping is presented in Appendix A.

B. Scoping Meeting.

On December 3 and 4, 1996, Pacific Meridian Resources met with The National Park Service for a project kick-off and scoping meeting. Present at the meeting were Jeff Campbell and Mike Golden from Pacific Meridian Resources; George Dickison, Sara Wesser, Page Spencer, Joel Cusick, and Beth Koltun from the NPS Alaska Support Office in Anchorage; and Alan Bennett from Lake Clark National Park. The purpose of the meeting was to provide Pacific Meridian Resources with background information on Lake Clark NP and the Park's data needs, discuss available ancillary data sets, begin organizing communication and logistics for field work, and refine the list of mapping classes for the project.

Figure IV-1. Lake Clark Mapping Project Flowchart.



C. Imagery and Ancillary Data Sets

C.1. SPOT imagery data. The primary data source used to produce the land cover map was SPOT multispectral imagery. A total of eleven scenes, spanning three satellite paths were purchased by the NPS (see Figure II-2). Table VI-1 lists the scene identification numbers for each scene by path. Paths 442 and 445 were acquired on Aug. 20, 1995; scenes from path 446 were acquired on Aug. 21, 1995.

Table IV-1 SPOT Scene Identification

Path	Scene Number	Scene ID
Path 442	442-224	34422249508212137142X
	442-225	34422259508212137212X
	442-226	34422269508212137292X
	442-227	34422279508212137372X
Path 445	445-224	34452249508212137121X
	445-225	34452259508212137201X
	445-226	34452269508212137281X
	445-227	34452279508212137351X
Path 446	446-225	34462259508202156351X
	446-226	34462269508202156431X
	446-227	34462279508202156511X

The scenes were terrain corrected and projected to Albers (Alaska) projection using the following parameters and NAD27 datum:

Projection Albers
Units METER Spheroid CLARK1866
Parameters:
1st standard parallel 55 0 0.000
2nd standard parallel 65 0 0.000
central meridian 154 0 0.000
latitude of projection's origin 50 0 0.000
false easting (meters) 0.00000
false northing (meters) 0.00000.

Because paths 442 and 445 were collected at the same time (same satellite overpass, different sensors aboard the satellite), all parameters (sun angle, atmospheric conditions, satellite orientation, etc.) are identical except for sensor calibration. Therefore, the eight scenes in the two paths could be calibrated and merged into a single data set. Because the satellite orientation was identical, the registration between the two paths was nearly perfect. Path 442 was calibrated to path 445. Using the overlap between the paths, for each reflectance value in path 445, a histogram of corresponding reflectance values in path 442 was generated. This was done for each of the three spectral bands (up to 255 histograms for each spectral band). The histograms were examined and found to be normally distributed. It was hypothesized that the variance was due to within-path mis-calibration between individual detectors. A difference image for the overlap area was produced to examine this hypothesis. The difference image had distinct stripping in the path direction, verifying that various detectors were consistently brighter or darker than other detectors on the sensor. From the histograms, a "look-up" table was generated and applied to path 442. The resulting scene was merged with path 445 to produce a single image file from the original 8 scenes. This file was initially processed as a single file. The three scenes in path 446 were joined and processed as a second image file.

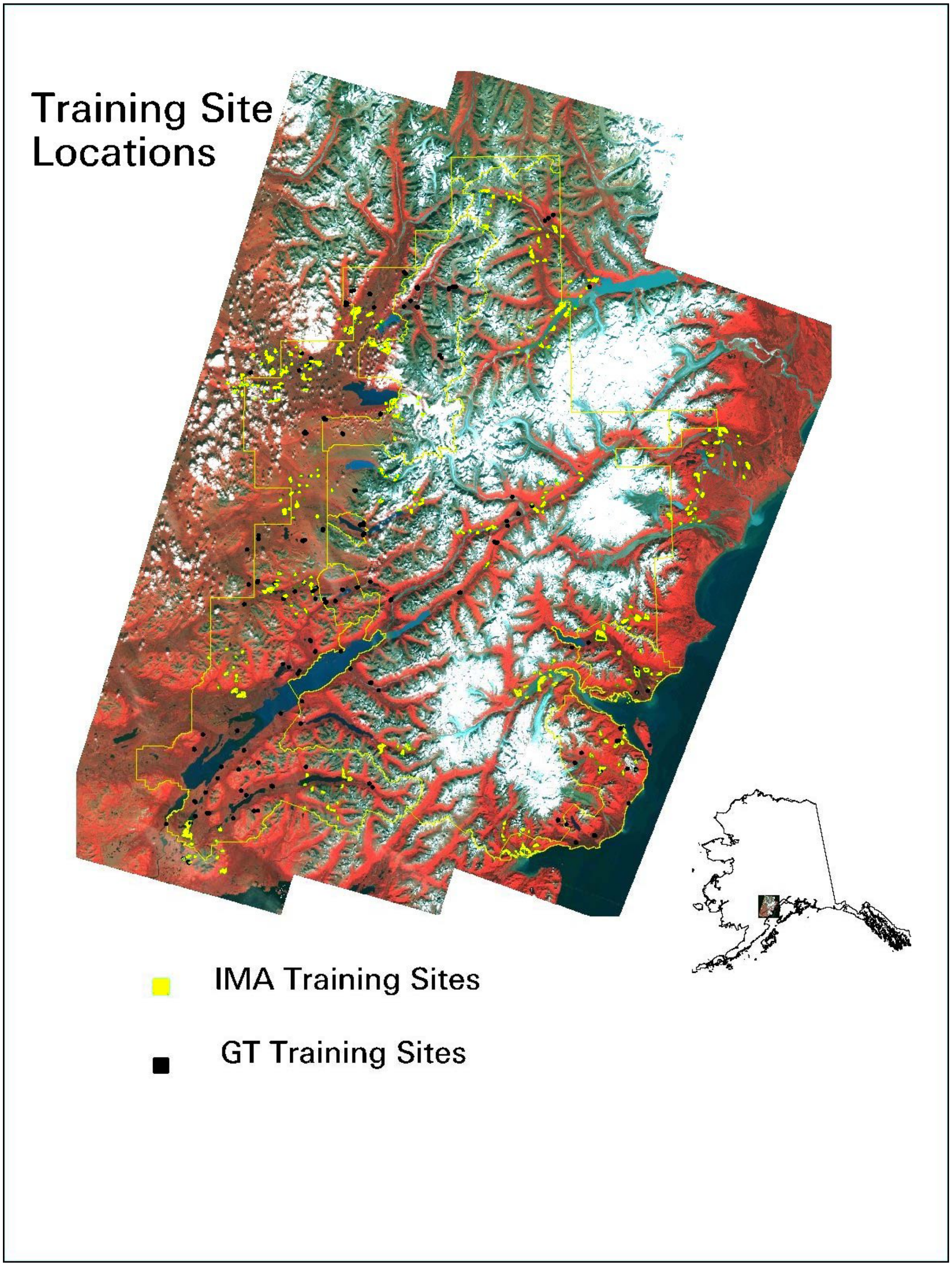
Close inspection of the registration between path 445 and path 446 identified a mistregistration of these data relative to several other data layers in the Lake Clark digital data set (particularly 1:65000 hydrography). The misregistration was not consistent across the SPOT scenes so a simple shift would not correct the misregistration. Pacific Meridian Resources and NPS agreed that requesting SPOT to re-terrain correct the images would probably not solve the problem, since the DEM data used was of too coarse a scale (1:250,000). Instead, Pacific Meridian Resources performed a precision correction using ground control points (gcp) selected on screen. These points were converted to an ArcInfo link coverage, and the images were "rubber-sheeted" in GRID using the ADJUST command. Three iterations of slecting gcp's/ adjusting/reviewing were performed. This work was conducted concurrently with image classification, so the classified image files were adjusted along with the original image files. The final files could then be mosaiced without an obvious stitchline, and registered well with the hydology layer.

In addition to the three spectral bands of SPOT multispectral imagery, two derrived bands were generated. A ratio band was created by ratioing band 2 (red visible) by band 3 (near infra-red) and scaled within the range of 8-bit data (0-255). This particular band combination has been shown to assist in minimizing the impact of shadowing in satellite image classification. A texture band was generated using Image Processing Workbench (IPW) software (Woodcock, et.al., 1993). IPW's texture algorythm (3x3, adaptive window) was used to produce the texture band. It was anticipated that the texture band would help discriminate between low density forested sites (particularly low density spruce) and non-forested sites. The two derived bands were added to the original three spectral bands to produce images with 5 bands.

C.2. 1:65,000 Color Infra-red Photography. Color infra-red photography (1,60,000) from the Alaska High Altitude Photography (AHAP) program was the secondary data set used to produce the classified image map. Nine-by-nine inch prints covering the Park and Preserve were available.

C.3. FirePro data. Two sets of FirePro data were available for the Lake Clark Mapping Project. Twenty-four photos had been selected by NPS as Intensive Measurement Areas (IMA). On each of the photos, IMA polygons were delineated and vegetation data was collected for 499 polygons in the field by FirePro crews during the summers of 1983, 1984, 1986,and 1991**.** These IMA polygons were the primary source of training site data for classifying the imagery. Accuracy assessment polygons were also selected from the IMA polygons. Additionally, NPS had selected 200 Ground Truth (GT) points which were pin-pricked on photos and vegetation information collected in the field throughout the Park and Preserve. Both the IMA and GT data were entered into a FoxPro database as part of Task 3 of this contract. ArcInfo polygon and point coverages of the locations of IMA polygons and GT points were also generated as part of Task 3 and were used extensively in this project. The locations of IMA and GT sites are presented in Figure IV-2. An example of the IMA field form and the GT field form is presented in Appendix B.

Figure IV-2. IMA and GT field data locations.



VI. Mapping Methods (cont.)

C.4. Field '96 notes. During the summer of 1996, Page Spencer conducted aerial reconnaissance of the Park and Preserve. She recorded extensive field notes on hard copy image plots and field notebooks. The purpose was twofold; 1) to gather basic vegetation information to help define mapping classes, and 2) to gather site specific vegetation data for use in the mapping. The site specific notes were later transferred to ArcView shape files and plotted over the imagery and later over interim draft map products. These notes were also used extensively in the mapping project. Mike Golden joined Page for two days of reconnaissance August 20 and 21, 1996.

C.5. Arcview project coverages. The NPS supplied an Arcview 2 project for Lake Clark containing numerous physical, cultural, and baseline data sets. Of particular use to this project were:

> 1:63360 park, preserve, and wilderness boundary – used for orientation on screen and hard copy map outputs.
> 1:63360 photorevised hydrography for the park – used for orientation and hard copy map outputs. Used to refine the terrain correction of the SPOT imagery.
> 1:25000 digital elevation models – used to produce raster coverages of slope, aspect, and elevation. These coverages were used in post classification modeling.
> 1:63360 quads of National Wetlands Inventory for part of the park – used to review the classification of wetland classes.

D. Initial Classification

The first step in the classification of the imagery involved reviewing and labeling all the available training sites. For each IMA polygon and GT site, the field data and field photo were examined. Sites were labeled according to the classification scheme described in Section III. Sites were flagged as unacceptable as training sites or accuracy assessment sites if the vegetation amounts fell near class breaks in the classification scheme (generally within 10% of the defining covertype percent). For example, for the break between open spruce (<60% cover) and closed spruce (>60%), sites between 50% and 70% would not be used. Sites were also eliminated if they did not appear homogenous (in terms of class) across the entire training site or were too narrow or too small to generate acceptable training site statistics. After labeling, the IMA polygons were stratified by class and one-half of each class was randomly selected as accuracy assessment sites (see Sec. VI.A). These sites were not used in the classification or reprocessing of the imagery.

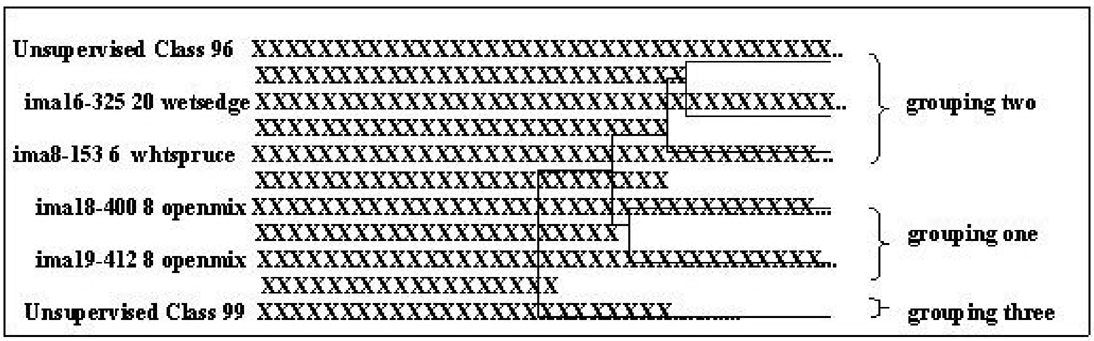
Image classification was performed separately on the two image files (mosaiced paths 442 and 445, referred to as the "interior image" throughout the remainder of this document; and path 446, referred to as the "coast image"). The same procedures were performed on each image. An initial unsupervised classification with 100 clusters was performed on each image. Visual assessment of this classification identified several spectral classes representing single classes (e.g., snow, or marine water, or rock, etc). These classes were masked out into a separate file and were not considered in subsequent classification iterations.

Next, the remaining IMA polygons (those not chosen for accuracy assessment or eliminated as unacceptable) were used as supervised training sites, and the location and spectral signature of each site was digitized on the imagery using the aerial photography as a guide. To accomplish this task, the image analyst located a "seed" pixel within each IMA polygon using Erdas Imagine's region growing tool. The seed pixel was allowed to "grow" into adjacent spectrally similar pixels based on thresholding parameters established by the analyst. The goal in "seeding" training sites is to produce a distribution of pixel digital number (dn) values that adequately cover the spatial extent of the site and are normally distributed with a fairly small standard deviation (typically 3 dn). The final group of spectrally similar pixels grown within each IMA polygon represented the supervised training site for the polygon. Spectral signatures for each site were then saved and labeled according to the mapping class definition. Site labels included the site identification and the mapping class number and text label. Additional information deemed useful by the analyst was often also attached to the training site label. For example, if the training site had a high standard deviation in a particular spectral band this information could be added to the site label.

A second unsupervised classification (200 clusters for the interior image, 150 clusters for the coast image) was performed on the portions of the image that had not previously been labeled from the initial unsupervised classification. The unsupervised signatures were combined with the supervised signatures into a single signature set. The spectral means of the signatures were then exported into a SAS data set and multivariate clustering of the means was performed (the parameters used were Euclidean distance, complete linkage, normalization). Results were plotted in a tree diagram. Figure IV-3 presents a small portion of the spectral clustering for the interior image. The clustering produced three possible groupings of classes:

1. groups of informationally similar supervised signatures and unsupervised signatures;
2. groups of informationally dissimilar supervised signatures.
3. groups of unsupervised signatures (with no supervised signatures).

Figure IV-3 Portion of Spectral Clustering of Means



Grouping one represents classes which are informationaly consistent and spectrally homogeneous. We would anticipate that these signatures would consistantly classify pixels correctly. The second grouping (informationally dissimilar signatures) present the biggest challenge to the image analyst. These signatures are spectrally similar but represent different mapping classes. We would anticipate that these signatures would produce class confusion if used in a computer classifcation. These classes need additional spectral analysis, further clustering, or ancillary information to separate the classified pixels into the appropriate class. Some signatures from this second grouping need to be re-seeded or discarded as unusable signatures. The third grouping represents spectral classes which were not accounted for by the supervised signatures. These signatures must be identified and labeled through photointerpretation and/or field verification.

The clustering of supervised and unsupervised signatures is a very useful tool for examining spectral signatures. However, it does not definitively identify which signatures should be used in subsequent classification iterations. It is best used to identify, and focus attention on, those signatures that need additional analysis. The final decision on which signatures to use, which to eliminate, and which classification technique to use must be based on the analyst’s knowledge and expert judgement.

After identifying "problem" signatures (grouping 2) from the spectral signature clustering, scatter diagrams and ellipse plots were used to assess the signatures. Scatter diagrams plot the dn values of the signatures in two dimensional plots (multiple plots of two-band combinations). Over these plots the standard deviation values are plotted, forming an ellipse. Recall that the spectral clustering described above used the spectral mean of each band. Signatures could have spectral means which were similar, but have multivariate distributions which did not overlap. These signatures would not necessary cause class confusion in computer classifications and ellipse plots would identify those signatures. On the other hand, signatures whose ellipses overlap are truly spectrally confused. Another analysis tool used was Imagine’s quick alarm tool. Single or multiple signatures can be used in a parallel-piped classification on screen to quickly identify which pixels would be classified by that signature. After examining scatter diagrams, ellipse plots, and quick alarms, numerous signatures were identified as truly "problem" signatures. These signatures were dropped from the signature set, but kept in a list of sites for future processing.

From the spectral analysis described above, a single set of supervised and unsupervised training site was used in a maximum likelihood classification. The supervised training sites were assigned a color based on their class label; the unsupervised training sites were assigned colors to match their appearance on a false color infra-red image. The resulting classified image was visually reviewed for accuracy using the training sites, GT sites, and the field notes. The next step was to determine the appropriate label (or labels) for the unsupervised signatures. Using the classified image on screen, areas of homogeneous unsupervised class pixels were identified and transferred to the aerial photography These areas would then become supervised training sites by visiting them in the field and recording the vegetation data. The NPS and Pacific Meridian Resources identified sixteen areas to concentrate this effort. For each area, each unsupervised cluster was highlighted on screen and new training sites were delineated. . A total of 243 training sites were delineated. By concentrating in just sixteen areas, field logistics could effectively be planned and field costs minimized. These areas were selected to cover as broad a range of vegetation types as possible and cover areas of the park that were not already covered by IMA plots, GT plots, or field notes from 1996.

Hard copy plots at 1:63360 of the classification was produced for each 15-minute quad covering the park and preserve. Hydrology was also plotted on these maps to help in orienteering. Plots of the unclassified imagery was also plotted. These plots were taken to the field, along with the aerial photos, and the newly delineated training sites.

E. Field Data Collection

Between July 14 and July 22, 1997, Page Spencer from NPS and Mike Golden (the analyst from Pacific Meridian Resources) performed field data collection and general reconnaissance within the park and preserve. A helicopter was used for all transportation to and from field locations, using Port Alsworth as a base. The purpose of field work was to:

(1) collect additional training site vegetation data across the park. Most of the field sites were described entirely from aeiral reconnaissance from approximately 100’ to 500’ above the ground. Vegetation was recorded on a standardized field data collection form. An example form can be found in Appendix B. When practical and/or required, the helicopter landed and the crew collected vegetation data from the ground.

(2) perform an initial field-based review of the preliminary land cover classification. While flying between training site locations, and to and from Port Alsworth, notes were taken on the field map denoting areas correctly classified and areas needing reclassification.

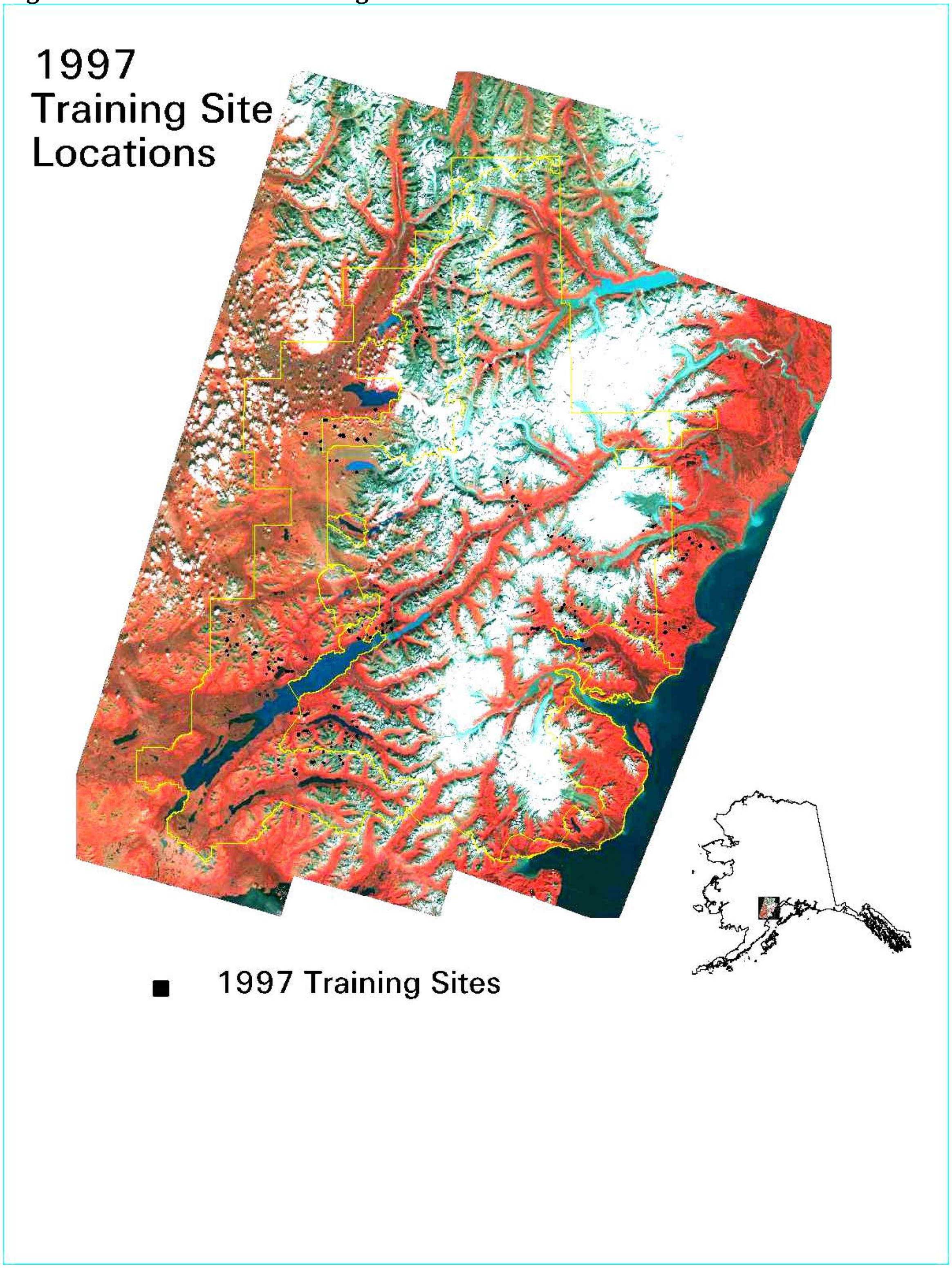
(3) gain a better understanding of the vegetation types within the park and preserve, and how that vegetation varied across the park. Special notice was taken to the distribution of classes across the park and general aspect/elevation ranges of classes (e.g., the upper elevation range of prostrate shrub tundra in different parts of the park, etc.).

(4) gather additional vegetation cover type notes. While flying additional notes were taken on the photos and field maps detailing the mapping class at specific sites. These notes would augment the notes taken during the reconnaissance in 1996.

(5) calibrate the photo interpretation. Whenever the helicopter shut down (for training sites, lunch breaks, etc), the crew examined stereo photo pairs and compared them to the corresponding vegetation cover in the area. This helped calibrate the analyst for photo interpretation and image interpretation later back in the office.

The locations of the training sites collected in 1997 are presented in Figure IV-4.

Figure IV-4. 1997 Field Training Sites.



F. Post-Field Processing

After the field data collection, all the new training sites were labeled and entered into a FoxPro database. These sites were digitized and the spectral signatures for each training site were added to the training sites used in the previous interim classification. Another iteration of spectral analysis (clustering of signatures means, quick alarms, and ellipse plots described above) was performed. Again, a list of any signatures eliminated due to spectral confusion was maintained for future processing.

A second classification was run on the signature set developed after the spectral analysis. This classification was reviewed on screen, again using all available information (except accuracy assessment site data). At this point, the individual training site classes were not recoded to the mapping classes. Rather, the original training site class was maintained, and the appropriate mapping class color was assigned to each training site. The review indicated that while many pixels were misclassified, the spatial patterns in the pixels closely matched the vegetation patterns in the photos and imagery. It was decided that the most efficient way to reprocess and refine the classification was to rely on photo interpretation and spectral class labeling rather than additional iterations of masking, spectral analysis, and automated classification. This was particularly true for discriminating between alder shrubs and the broadleaf forest classes.

The photo interpretation/spectral labeling was conducted primarily on a watershed by watershed basis. Individual watersheds (or comparable areas) were clipped from the image and processed individually, then overlain back into the classified image. The classification was compared to the photography, and field data and notes; and individual classes were highlighted on screen. Individual classes were then re-labeled where appropriate, often confined to specific portions of the watershed being reprocessed. Those training sites eliminated during spectral analysis were also examined at this point for re-introduction into the classified map. Particular attention was paid to sites that were collected within the area being re-processed at that time. These training sites were applied to a parallel-piped classifier on a class by class basis. Several iterations with varying parameter settings were often necessary to accurately classify the appropriate pixels. The final iteration was then saved and overlain back into the classified image. Quality control was maintained by taking copious notes, comparison to the field data and notes, and an index image map used to track which watersheds had been re-processed and the boundaries of each processing area.

The final step in the reprocessing of the image involved simple manual editing of the pixels. Once again, the field data and notes, as well as knowledge of vegetation variation across the park, guided the decisions on map edits.

G. Post-Classification Modeling

Much of the remaining class confusion involved particular classes across wide areas in the images. These problems were best corrected using spatial models. Page Spencer and Mike Golden developed the models described below. Users of the final map should pay particular attention to the parameters of these models, particularly before determining elevational and aspect thresholds for particular species based on the map. Elevation/aspect thresholds may be due to the models, rather than a real threshold found in the field.

Prostrate Shrub Tundra (pst) versus Saltwater Marsh. Below 100' elevation, pst was recoded to salt marsh. Within the coast imagery (path 446), there had been consistent spectral confusion between pst and salt marsh. The saltwater pixels in high elevations had been corrected in the reprocessing stage. This model corrected the pst pixels that should have been labeled as salt marsh.

Prostrate Shrub Tundra versus Gravel and Sparsel Vegetated (gsv). Between elevations of 100' and 1000', pst was recoded to gravel and sparsely vegetated (gsv). This corrected the pixels in stream beds classified as prostarte shrub. Between elevations of 1000' and 1500', spectral confusion between pst and gsv was corrected through manual editing. Above 1500', pst was not recoded to gsv.

Prostrate Shrub Tundra versus Rock. For prostrate shrub tundra an upper elevational limit was set. For the interior image (paths 442 and 445) above 3500', pst was recoded to rock. This was based on field notes, and review of the imagery and photos. For the coast image (path 446), the upper limit for pst was 4500'. Above 4500', pst was recode to rock.

Rock versus Marine Mud. Along the coast, pixels of marine mud were often being labeled as rock. This model recoded rock to maine mud below an elevation of 100'.

Rock versus Gravel and Sparsely Vegetated. In the interior image (paths 442 and 445), gravel and sparsely vegetated (i.e. talus) was overclassing in high elevation areas of rock. Above 4000' elevation on southwest to northeast aspects, several of the classes from the first unsupervised classification were recoded from gravel and sparsely vegetated to rock.

Alder versus Broadleaf Classes. In the interior image, there was consistent confusion between alder and broadleaf forest classes in several of the training sites. An elevation of 1800' was used to separate these classes according to Table IV-2.

Table IV-2. Alder versus broadleaf spatial model

Training Site #	Below 1800 recode to:	Above 1800 recode to:
79	Closed birch	Closed alder
145	Open mix	Open alder
155	Open mix	Closed alder
157	Open mix	Closed alder
172	Closed birch	Closed alder
174	Closed birch	Open alder

Gravel in Lakes. In the interior image, pixels of water in many lakes and ponds were being classed as gravel and sparsely vegetated. Training site number 186 was the primary training sites responsible for this confusion. To correct this, on slopes less than or equal to one percent, training site 186 was recoded to clear water.

Water classed on shadowed slopes. A consistent spectral confusion in most any image classification is water and steep shadowed slopes (both appear very dark in the imagery). Aspect and elevation were used to correct this. First, pixels classed as water on the shadowed slopes were examined to determine the appropriate class. In some areas the appropriate class was ice and snow; in other areas the appropriate class was rock. An Imagine area-of-interest (aoi) file was used to identify the appropriate areas. The pixels of water were then recoded if the aspect was between 0 and 30, or greater than 290, and the slope was greater than 50 percent.

Wetland classes mis-classed on high elevation sites. On high elevation sites, often pixels were often mis-classified as wet sedge or sedge-shrub bog. The imagery, photos, and field notes were reviewed and the appropriate classes identified. On slopes greater than 15 percent and elevations above 2953 feet (900 meters), wet sedge was recoded to prostrate shrub tundra. On slopes greater 15 percent and elevations less than 2953 feet, wet sedge was recoded to open alder. For sedge-shrub bog pixels, if the slope was greater than 23 percent and the elevation greater than 2953 feet, the pixels were recoded to prostrate shrub tundra. For slopes greater than 23 percent and elevations below 2953 feet, sedge-shrub bog pixels were recoded to open alder.

H. Draft Map and Editing

After reprocessing and post-classification modeling, quad-based maps of the classified images were plotted at a scale 1:63360 scale for each of the 15' quadrangles within the project area. The draft maps were given to the NPS for review and comments. During January, 1998, the draft maps were reviewed by Page Spencer and Lee Fink, Leon Alsworth, John Branson, and John Bundy from Lake Clark National Park. Comments were written directly on the draft maps as site specific comments and as general comments covering broad areas of the park and preserve.

The comments from the draft map review were then incorporated into the classified map. At the same time, the field notes and training sites were again reviewed and incorporated into the map. This process involved manual editing of the map on a quad by quad basis. The resulting map was then recoded from the training site pixel classes to the thirty-two final mapping classes. This map was delivered to NPS and used in accuracy assessment, described in Section VI.

I. Post Accuracy Assessment Editing

The accuracy assessment analysis was conducted and the results reviewed by Pacific Meridian Resources and NPS. While the accuracy was relatively high for land cover maps produced from remotely sensed data, Pacific Meridian Resources and NPS agreed to use the accuracy assessment results to further improve the map. In particular, accuracy assessment had identified class confusion between willow shrubs and low shrub. Based on these results, the willow class was redefined. Much of what was previously willow was redefined as low shrub (see Section III for final definitions of these classes). These changes were then incorporated into the map through an area recode and review of the photos and field data and manual editing. Since the accuracy assessment results would no longer be valid for the newly edited map, the accuracy assessment sites were now available for improving the classification. Those sites, and surrounding areas, misclassified were corrected during this editing stage. The results of the post accuracy assessment editing constitute the final map for the project.

V Results

A. Land Cover Map

Figure V-1 presents the final classified map for the Lake Clark Mapping Project. Table V-1 presents the pixel totals and acre totals for the entire mapping project. Table V-2 presents the pixel totals and acre totals for just Lake Clark Park and Preserve.

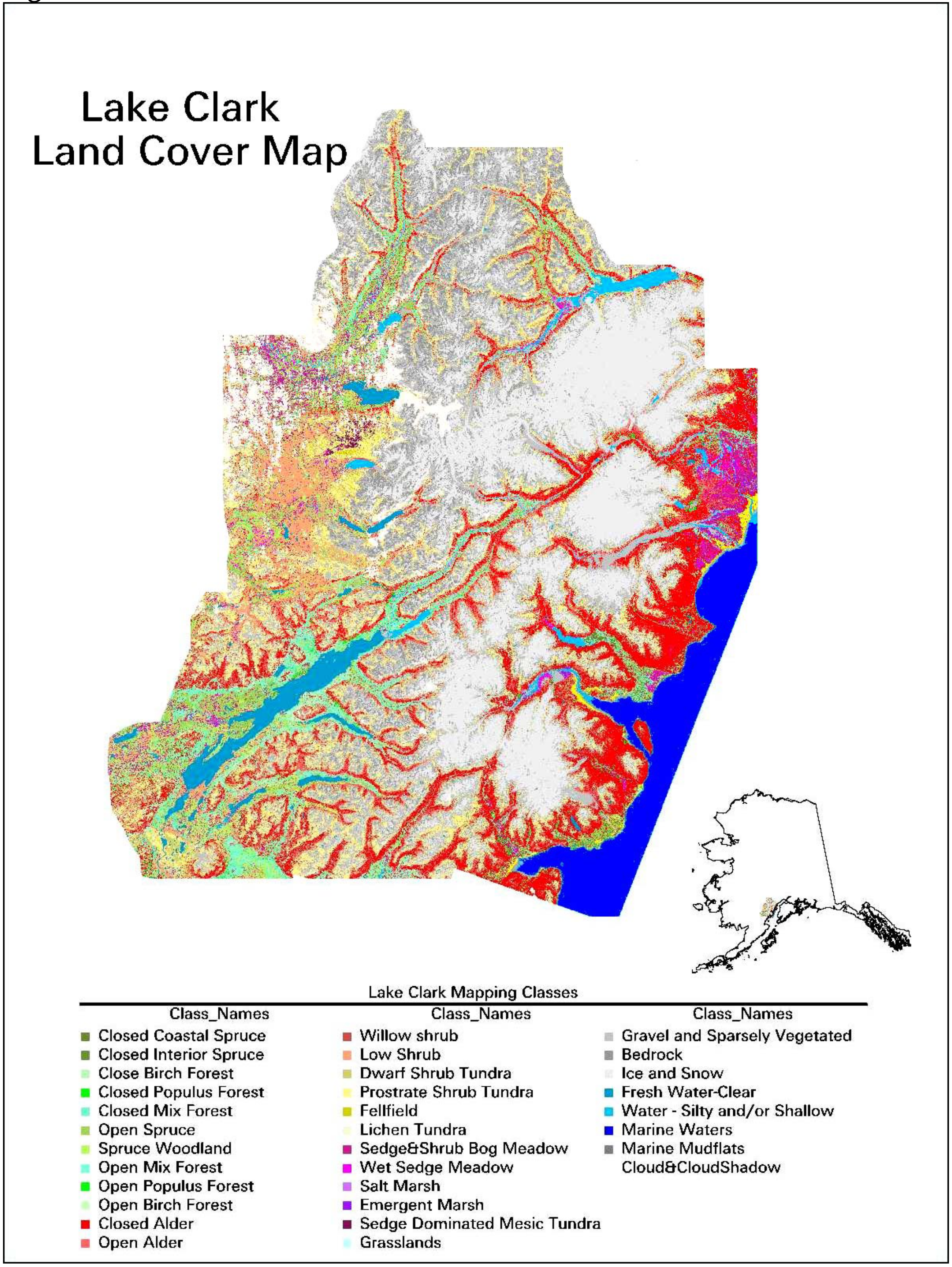
Table V-1. Summary of Land Cover Classification

Mapping Class	Number of Pixels	Acres	% of Cover
1. Closed Coastal Spruce	117402	11604	0.19
2. Closed Interior Spruce	86562	8556	0.14
3. Closed Birch Forest	275580	27238	0.45
4. Closed Populus Forest	155081	15328	0.25
5. Closed Mixed Forest	772483	76352	1.27
6. Open Spruce	1785237	176453	2.93
7. Spruce Woodland	1386918	137083	2.27
8. Open Mix Forest	1529295	151156	2.51
9. Open Populus Forest	118371	11700	0.19
10. Open Birch Forest	171797	16980	0.28
11. Closed Alder	5319544	525784	8.72
12. Open Alder	4357817	430727	7.15
13. Willow Shrub	335266	33138	0.55
14. Low Shrub	1743986	172376	2.86
15. Dwarf Shrub Tundra	2055457	203161	3.37
16. Prostrate Shrub Tundra	5941335	587242	9.74
17. Fellfield	32442	3207	0.05
18. Lichen Tundra	655564	64796	1.08
19. Sedge and Shrub Bog Meadow	1360306	134453	2.23
20. Wet Sedge Meadow	349707	34565	0.57
21. Salt Marsh	161973	16009	0.26
22. Emergent Marsh	121551	12014	0.20
23. Sedge Dominated Mesic Tundra	117744	11638	0.20
24. Grasslands	605439	59842	0.99
25. Gravel and Sparsely Vegetated	9462587	935282	15.52
26. Bedrock	3354784	331587	5.50
27. Ice and Snow	11048456	1092029	18.12
28. Clear and Deep Water	1319905	130459	2.16
29. Silty or Shallow/Murky Water	781081	77202	1.28
30. Marine Water	32341079	320348	5.32
31. Marine Mudflats	81051	8011	0.13
33. Cloud and Cloud Shadow	2132378	210764	3.50
Total	60980369	6027083	100.00

Table V-2. Summary of Land Cover Classification within Park/Preserve Boundary.

Mapping Class	Number of Pixels	Acres	% of Cover
1. Closed Coastal Spruce	89022	8799	0.22
2. Closed Interior Spruce	61335	6062	0.15
3. Closed Birch Forest	211658	20921	0.52
4. Closed Populus Forest	101091	9992	0.25
5. Closed Mixed Forest	494787	48906	1.21
6. Open Spruce	1237395	122307	3.03
7. Spruce Woodland	974615	96333	2.39
8. Open Mix Forest	1034434	102246	2.54
9. Open Populus Forest	89645	8861	0.22
10. Open Birch Forest	162199	16032	0.40
11. Closed Alder	3265566	322776	8.01
12. Open Alder	3065567	303007	7.52
13. Willow Shrub	229126	22647	0.56
14. Low Shrub	1247201	123276	3.06
15. Dwarf Shrub Tundra	1413138	139678	3.46
16. Prostrate Shrub Tundra	4243441	419431	10.40
17. Fellfield	32282	3191	0.08
18. Lichen Tundra	447943	44276	1.10
19. Sedge and Shrub Bog Meadow	699602	69150	1.72
20. Wet Sedge Meadow	193090	19085	0.47
21. Salt Marsh	30029	2968	0.07
22. Emergent Marsh	18472	1826	0.05
23. Sedge Dominated Mesic Tundra	96961	9583	0.24
24. Grasslands	411158	40640	1.01
25. Gravel and Sparsely Vegetated	7247245	716333	17.77
26. Bedrock	2600282	257017	6.38
27. Ice and Snow	8097950	800419	19.85
28. Clear and Deep Water	1197250	118339	2.94
29. Silty or Shallow/Murky Water	340099	33616	0.83
30. Marine Water	3414	337	0.01
31. Marine Mudflats	3650	361	0.01
33. Cloud and Cloud Shadow	1446301	142956	3.55
Total	40785955	4031372	100.00

Figure V-1. Lake Clark Land Cover.



B. Discussion of Results

The Lake Clark Mapping Project was a joint endeavor between the National Park Service and Pacific Meridian Resources. The primary data sources were SPOT multispectral images, Alaska NHAP color infra-red photography, extensive field data and notes, and input from NPS personnel most familiar with the park.

This project differed from most image-based land cover mapping in that it relied more heavily on photointerpretation. The imagery provided the geographic base for the mapping. While the initial classifications were supervised and unsupervised computer classifications of the imagery, most subsequent processing was performed on a watershed by watershed basis guided by photointerpretation. Two factors made this the most efficient and effective way to produce the map. First, SPOT imagery's limited spectral bands (green, red, infra-red) limited the ability of automated classification algorithms to discriminate detailed vegetation classes consistently across wide spatial extents. Results of the spectral analysis revealed that relying on computer classification alone would not produce acceptable results. However, the spatial resolution of the SPOT imagery did allow better visual image interpretation and the spatial vegetation patterns were evident in the computer classifications. Secondly, there was a wealth of field based vegetation data and notes to guide the image and photo interpretation. Between the IMA, GT, and the 1996 and 1997 field notes, nearly every drainage within the park and preserve boundary had some type of field data. This data was critical in reviewing computer classifications, in guiding the reprocessing, and the final editing. Without this data, results from this approach would have been disappointing, if not unacceptable.

Another factor contributing to the success of this project was the local knowledge of NPS staff involved in the project. At the beginning of the project, the proposed mapping classes accurately reflected the vegetation classes found in the park, as well as those classes mappable with the imagery, photos, and data available. Also, the effort of NPS personnel during the draft map review greatly enhanced the quality of the final map product.

While the spatial resolution of the imagery is 20 meters (each pixel is 20 meters by 20 meters), the map should not be used at inappropriately large scales. Because much of the mapping was based on the 1:60,000 photography (training sites were delineated on the photos, visual review of the map on screen was compared to photos, and much of the reprocessing was based on photointerpretation), the appropriate scale of this map is that of the photos (1:60,000). Use of the map at larger scales is highly discouraged

VI Accuracy Assessment

A. Methods

A1.   Background. Quantitative accuracy assessment (aa) of maps produced from remotely sensed data involves the comparison of a map with reference information. The purpose of quantitative accuracy assessment is the identification and measurement of map errors. There are two primary motivations for accuracy assessment: (1) to determine the overall accuracy or reliability of the map and the accuracy of individual classes, and (2) to understand the errors in the map. While more attention is often paid to the first motivation, understanding the errors is arguably the most important aspect of accuracy assessment. For any given class on the map, it is critical to know the probability of the site being labeled correctly and what other classes (and their probability) might truly be found there. Quantitative accuracy assessment can answer those questions.

Usually funding limitations preclude the assessment of every spatial unit on the map. Because comparison of every spatial point is impractical, sample comparisons are used to estimate the accuracy of maps. These samples are commonly referred to as accuracy assessment sites. The standard method of reporting accuracy assessment results is the error matrix, a square matrix tallying sites by reference label (in the matrix rows) and by map label (in the matrix columns) (Congalton, 1991). Quantitative accuracy assessment is laborious and expensive, requiring many accuracy assessment sites to be statistically valid. A generally accepted rule of thumb suggests a minimum of 50 accuracy assessment sites per mapping class (Congalton, 1991). Rarely does time and budget constraints allow for this level of analysis and much fewer sites per class are often selected. Such compromises between statistical rigor and budgets are required in most quantitative accuracy assessments. These compromises must be considered when interpreting the results.

A more detailed description of general accuracy assessment topics is presented in Appendix A.

Accuracy assessment procedures involve four basic steps: (1) the selection of accuracy assessment sites, (2) labeling and rating of the accuracy assessment site labels, and (3) reporting the accuracy assessment results in an error matrix, and (4) analyzing the results of the assessment.

A2. Selection of Accuracy Assessment Sites. As described in Section IV.D., after the IMA sites were reviewed and labeled, one-half of the sites for each class were randomly selected (by class) and set aside as accuracy assessment sites. Some sites were obscured by clouds on the imagery and were subsequently eliminated. The IMA sites had all been located in vegetated polygons, so the NPS supplemented them with sites selected in non-vegetated classes. These sites were selected by visual scanning of the photos and selecting sites representative of the particular non-vegetated class. After reviewing and eliminating cloud cover sites, a total of 216 sites were available for accuracy assessment. Table VI-1 tallies the sites by class.

Each aa site location had been delineated on the aerial photography. The aa sites were then digitized on screen over the imagery.

Table VI-1. Accuracy assessment sites by class

Mapping Class	Number of Sites	Mapping Class	Number of Sites
1. Closed. Coastal Sp.	1	17. Fellfield	0
2. Closed Interior Sp.	1	18. Lichen Tundra	1
3. Closed Birch	2	19. Sedge&Shrub Bog	10
4. Closed Populus	2	20. Wet Sedge Meadow	7
5. Closed Mix	5	21. Salt Marsh	2
6. Open Spruce	16	22. Emergent Marsh	3
7. Spruce Woodland	12	23. Sedge Dominated Mesic Tundra	0
8. Open Mix	12	24. Grasslands	1
9. Open Populus	3	25. Gravel & Sparsely Vegetated	20
10. Open Birch	3	26. Bedrock	10
11. Closed Alder	24	27. Ice and Snow	10
12. Open Alder	16	28. Clear Water	10
13. Willow Shrub	8	29. Silty and/or Shallow Water	3
14. Low Shrub	10	30. Marine Water	3
15. Dwarf Shrub Tundra	9	32. Marine Mudflats	4
16. Prostrate Shrub Tundra	8		

A3. Site Labeling and Rating. Each aa site is assigned two class labels: a reference label, and a map label. The reference label was assigned after reviewing the field vegetation data for the site and using the mapping class definitions described in Section III-B. During the review, sites that fell near class breakpoints were not considered acceptable as accuracy assessment sites. The reference label represents the overall covertype class for the entire site.

For the accuracy assessment map label, the digitized site locations were overlain on the cover type map and a summary of pixels within each site was generated. Rarely does a single pixel class fill an accuracy assessment site completely. Rather, aa sites are usually composed of a mixture of pixel classes. In order to compare reference labels to map labels, a map label, or range of map labels, must be assigned to the aa site based on the distribution of pixel classes falling within the site. Assigning labels to a mixture of pixel classes can be a subjective process subject to variation in human interpretation, and can have profound effects on accuracy assessment results (see discussion in Appendix A). To account for this variation, a simple form of fuzzy set theory (Gopal and Woodcock, 1994) was adapted for assigning map labels, described in the following paragraphs.

Pacific Meridian Resources and the NPS developed general labeling "rules" (or guidelines) for assigning map labels from the pixel summaries. Using these guidelines, for each aa site all possible map labels were rated as "best", "acceptable", or "unacceptable". If a single pixel class constituted two-thirds of the polygon, that class was assigned a "best" rating. For pixels with a forested label, the mid-point of the crown cover class was used to compute a weighted average composite crown cover call for the site. The weights used were: closed - 80%, open - 42.5%, and woodland - 17.5%. Likewise for alder pixels, the midpoints of closed (87.5%) and open (50%) were used to compute a composite alder crown cover estimate. The computed calls were then used to guide the rating of the map labels. The computed crown cover was not necessarily a hard rule for rating labels, but rather a guide.

After assigning a “best” label for the site, the remaining possible map labels were assigned either “acceptable” or “unacceptable” ratings. Typically, if the calculated crown cover was within 10% of a class break, the adjacent label would be rated as “acceptable”. After determining “acceptable” labels, all other possible labels were rated as “unacceptable”. Pacific Meridian Resources and the NPS worked jointly on rating all the aa map labels.

This approach for developing map labels from the pixel has been developed and applied in numerous Pacific Meridian Resources mapping projects, including the other mapping project under this contract (Wrangell-St. Elias). This approach has been found to be the most consistently reliable method for developing map labels for a single polygon based on it’s composition of individual pixels within the polygon. Polygon-based labels are necessary for comparison to the accuracy assessment reference site label that also describes the polygon as a whole, rather than the individual components making up the polygon. While computer algorithms may be developed to “calculate” a best label or a series of acceptable labels, rarely is there a better substitute for human visualization, knowledge of the mapping classes, and labeling of the site based on the composition of pixels making up the accuracy assessment site.

A.4. Accuracy Assessment Table and Matrix Generation. The results of the site labeling and rating were tallied in an Microsoft Access database table (see Appendix C). Each site was entered as a row in the table, with fields for the site identification, the reference label, ‘best’ map label, and the individual class label ratings. For each possible map label ratings, a zero was entered for ‘unacceptable’ and a 1 for “acceptable”. The records in the table were then tallied in the error matrix presented in the next section.

B. Results

Table VI-2 (presented as an Excell spreadsheet) contains the error matrix for the cover type map. Each accuracy assessment site was tallied in the matrix in the appropriate column (based on the best map label) and row (based on the reference label). Non-diagonal cells in the matrix contain two tallies. The first number represent those sites where the reference label matched an “acceptable” map label. These sites are considered a “match” for estimating overall accuracy. The second number in the cell represents those sites where the reference label matched an “unacceptable” map label. Overall accuracy was estimated as the percentage of sites where the best or acceptable map label(s) matched the reference label. The overall accuracy of the cover type map is estimated to be 83% (180/216). Individual class accuracies can be estimated by summing the
number of matches in its row (or column) and dividing by its row total (or column total). Class accuracy by row represents “producer’s” class accuracy. That is, from a map producer’s viewpoint, when we know what the class label should be, what is the proportion of sites correctly mapped. Conversely, class accuracy by column represents “user’s” class accuracy. When a site is mapped a particular class on the map, user’s class accuracy estimates the percent of time the site is mapped correctly. Individual class accuracy estimates range from a high of 100% for several classes to a low of 0% (0/2 for Closed Populus producer’s accuracy). However, recall the discussion earlier regarding compromises between sample size and budget contraints. Many of the individual classes had very few accuracy assessment sites. Some classes had no accuracy assessment sites. Because of the small number of accuracy assessment sites per class, the estimated user’s accuracy and producer’s accuracy for individual classes are not statistically valid. Very little can be concluded from an estimate of 100% based on 1 sample (e.g., Closed Birch user’s accuracy) or an estimate of 0% based on just two samples (e.g., Closed Populus producer’s accuracy).

Table V-2. Lake Clark Accuracy Assessment Error Matrix

		Map Labels																																
		Closed Coastal Spruce	Closed Interior Sprcue	Closed Birch	Closed Populus	Closed Mix	Open Spruce	Woodland Spruce	Open Mix	Open Populus	Open Birch	Closed Alder	Open Alder	Willow	Low Shrub	Dwarf Shrub Tundra	Prostrate Shrub Tundra	Fellfield	Lichen Tundra	Sedge/Shrub Bog	Wet Sedge Meadow	Salt Marsh	Emergent Marsh	Sedge Dominated Mesic Tundra	Grasslands	Gravel and Sparsely Vegetated	Bedrock	Snow and Ice	Clear Water	Silty and/or Shallow Water	Marine Water	Marine Mudflats	Clouds and Cloud Shadow	
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	33	Total
	1						1,0																											1/1
	2						1,0																											1/1
	3					1,0					1,0																							2/2
	4									0,2																								0/2
	5					3			2,0																									5/5
	6						13	2,0												0,1														15/16
	7						0,1	9							1,0	1,0																		11/12
	8					1,0	2,0		8				1,0																					12/12
R	9									1		0,1			0,1																			1/3
e	10			1,0								0,1	0,1																					1/3
f	11											15	5,3							0,1														20/24
e	12											7,0	9																					16/16
r	13							0,1	0,1				1,1		1,1	0,1					0,1													2/8
e	14							0,1							6	0,2	1,0																	7/10
n	15														0,1	5	2,1																	7/9
c	16														0,1		6			0,1														6/8
e	17																																	
	18																1,0																	1/1
L	19														1,1					6	2,0													9/10
a	20																			1,1	5													6/7
b	21																			0,1		1												1/2
e	22																						3											3/3
l	23																																	
s	24																								1									1/1
	25																									18		1,0		1,0				20/20
	26																0,1									1,2	2	1,3						4/10
	27																											10						10/10
	28																												9	0,1				9/10
	29																													3				3/3
	30																														3			3/3
	31																									0,1						3		3/4
	33																																	
	Total			1/1		5/5	17/18	11/13	10/11	1/3	1/1	22/24	16/21	0/0	9/14	6/9	10/12			7/12	7/8	1/1	3/3		1/1	19/22	2/2	12/15	9/9	4/5	3/3	3/3		180/216

Key to interpreting off-diagonal cell values: 5,3

1st digit indicates sites in which "acceptable" labels matches reference site label

2nd digit indicates sites in which map label does not match reference site label

Total Number of Accuracy Assessment Sites: 216
Total Matches: 180
Overall Accuracy Estimate (180/216) 83.3 percent

C. Discussion of Results

Recall from Sections IV.H and IV.I that these accuracy assessment results are for the map prior to the post accuracy assessment editing. These results were used to further improve the map. While we can assume that the final editing improved the map, treads identified in the accuracy assessment are important to note and understand.

Overall accuracy of the map was estimated at 83%. As with the review of most land cover classification error matrices, however, the most interesting and informative information can be acquired through a careful examination of the off-diagonal elements in the matrix. In following paragraphs, discussion of individual class accuracies will focus on user's map accuracy. This is the more important measure from a map user's perspective.

One indication of trends within a class is the difference in number sites of that class in the reference data and in the map data. More sites in the map data indicates that the map tends to overestimate that class. Conversely, more sites in the reference data indicates that the map underestimates that class. For most classes, the row and column totals are comparable. The map seems to overestimate the amount of open alder (21 map labels versus 16 reference labels). From the matrix we can see that closed alder and willow account for most of the overclassed sites. We see the same trend in prostrate shrub tundra (12 map labels versus 8 reference labels). In this case, dwarf shrub tundra and low shrub account for most of the overclassed sites. For the willow class, we see the opposite; the map is underclassing willow (no map labels versus 8 reference labels). From a producer's viewpoint (2 of 8 sites correct), we can see that the mis-classed sites were a variety of classes. This result prompted the decision to proceed with the post accuracy assessment editing.

Another trend can be seen if we look at just forest cover density. The map tends to estimate forest crown cover lower than the reference data both for conifer and broadleaf species. On possible explanation of this trend is the difference in how individuals estimate crown cover (FirePro field crew versus the image analyst).

Information on individual class accuracy can be categorized into three groups: 1) areas of high classification accuracy, 2) areas of class confusion, and 3) classes under sampled in the analysis. Each of these categories are discussed below.

Areas of high classification accuracy.

Open forested classes all had relatively high classification accuracy (from 86% for woodland spruce, to 94% for open spruce) with the exception of open Populus. The spruce forest appeared distinct on both the imagery and the photos, and the accuracy reflects the reliable discrimination of these sites.

Closed and open alder were mapped at accuracies of 92% and 76%, respectively. If we combine both classes, overall accuracy of alder is 91% (41/45). Some confusion exists between the alder classes and open birch and open Populus. This is not surprising since all four classes have similarly high reflectance in the infra-red band in the imagery. Also when the birch and Populus trees are small they appear very similar on the photos to the alder. Much of the confusion between alder and the broadleaf tress seems to occur when the trees are fairly small.

Wet sedge meadow was also mapped at a high accuracy (87.5%). The wetland classes as a group (sedge-shrub bog, wet sedge meadow, emergent marsh, and salt marsh) were accuracy mapped at 83% (20/24). As with the spruce stands, the wetland classes were discernable on the imagery (when using specific image enhancements designed for wetlands) and this contributed to their relatively high accuracy.

Finally, all of the non-vegetated classes had high estimated accuracy. Of those non-vegetated sites mis-classified, all were confused with other non-vegetated sites.

Areas of class confusion.

Open Populus was the one forested class with low user's accuracy (33%, 1/3). However, this class only had three sites and is also listed with those sites under sampled. Examining user's class accuracy, the mis-classed sites were closed Populus. Examining producer's class accuracy shows us that open Populus is sometimes confused with alder. This is not surprising since alder is typically the understory component in open Populus sites.

As described above, the willow class had the most confusion with other classes. As part of the post aa editing, willow was re-defined and this mitigated some of the confusion. The final edits also paid particular attention to the willow class. Willow remains one of the most difficult classes to map. It is often confused with alder on the map as well as on the photos.

Low shrub user's class accuracy is estimated at 64%. This accuracy should be higher in the final map because of the redefinition of the willow and the final edits. It is sometimes confused with dwarf shrub and/or prostrate shrub in the map. Likewise dwarf shrub (user's accuracy of 67%) is sometimes confused with low shrub and prostrate shrub.

Sedge-shrub bog user's accuracy is estimated at 58%. However, producer's accuracy is 90%. This implies that where sedge-shrub bog is found on the ground, it has been mapped correctly; however, the map is identifying additional areas incorrectly as sedge-shrub bog. Sixteen percent of the time the correct class was another wetland type (wet sedge meadow or salt marsh). The rest of the confusion was with open spruce, alder, and prostrate shrub (a surprising result).

Classes undersampled in the analysis.

None of the mapping classes met the rule of thumb of 50 accuracy assessment sites per class. Some of the class had so few samples that conclusions are hard to draw about their class accuracy. This was due to budget constraints. Accuracy assessment sites were drawn from the existing IMA polygons (one-half of the sites per class), supplemented with non-vegetated photo sites not visited in the field. Table VI-3 lists those sites that had few or no accuracy assessment sites.

Table VI-3. Undersampled Classes in Accuracy Assessment Analysis

Mapping Class	Number of Sites by Reference Label	Number of Sites by Map Label
Closed coastal spruce	1	0
Closed interior spruce	1	0
Closed birch	2	1
Closed Populus	2	0
Open Populus	3	3
Open birch	3	1
Fellfield	0	0
Lichen Tundra	1	0
Salt Marsh	2	1
Emergent Marsh	3	3
Sedge Dominated Mesic Tundra	0	0
Grasslands	1	0

VII. Conclusion

The land cover of Lake Clark National Park and Preserve was mapped using SPOT mulit-spectral imagery, color infra-red photography, and extensive field data and notes. The mapping extent extended to just outside the park and preserve boundary. Areas outside the park were restricted due to limited photo coverage. A total of 31 land cover classes (plus cloud cover) were identified. While the spatial resolution of the imagery is 20 meters (each pixel is 20 meters by 20 meters), the map should not be used at inappropriately large scales. Because much of the mapping was based on the 1:60,000 photography (training sites were delineated on the photos, visual review of the map on screen was compared to photos, and much of the reprocessing was based on photointerpretation), the appropriate scale of this map is that of the photos (1:60,000). Use of the map at larger scales is highly discouraged.

This project integrated digital image classification, photointerpretation, ground-based vegetation data, and knowledge of the vegetation of the park by NPS and Pacific Meridian Resources personnel. Initial mapping was accomplished using automated computer classification of the SPOT imagery. Subsequent iterations used the imagery as a geographic base and relied on photointerpretation and ground based vegetation data. The map was further improved by the use of spatial models developed by the NPS and Pacific Meridian Resources.

Overall accuracy of the land cover map is estimated at 83%. However, due to the limited number of accuracy assessment sites per class, conclusions regarding individual class accuracies are dificult. Estimates of individual class accuracy are not statistically valid. Additional editing of the map after the accuracy assessment analysis improved the map above that reported.

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Appendix A

Background Information on Vegetation Mapping through Processing of Satellite Imagery

A. Vegetation Mapping through Processing of Satellite Imagery

With the launch of Landsat-1 in 1972, a new dimension was added to the capability of acquiring and analyzing natural resource data. Today, satellite imagery presents a more consistent, readily updateable, less expensive source of data for vegetation mapping. Several types of digital satellite imagery are currently commercially available and are increasingly used for mapping vegetation and other natural resource features. A digital satellite image is composed of pixels, or picture elements, which are the smallest spatial unit in the image. The spectral reflectance of each pixel in each band of an image is represented by a digital number (DN). Some imagery, such as SPOT panchromatic data, is composed of only one band. Other imagery, such as Landsat Multispectral Scanner (MSS), Landsat Thematic Mapper (TM), or SPOT multispectral, has multiple bands; each band representing a particular wavelength of energy. Spatial resolution also varies with the type of imagery. SPOT multispectral data, for example, has 20 meter pixels while Landsat TM pixel size is 30 meters and MSS data has a spatial resolution of 80 meters.

Early in the Landsat era, it was found that forest site types could be mapped faster and often with lower costs than when employing many traditional methods such as basic photo-interpretation (Hame, 1986). Use of satellite imagery to map forest vegetation led to the recognition that there are several advantages of utilizing digital satellite data. These include the ability to classify a very large land area:
(1) with great consistency; (2) despite poor accessibility; and (3) much more quickly and cost effectively than using traditional classification approaches, e.g. photo-interpretation (Talbot and Markon, 1986).

Initial vegetation and landscape characterizations using satellite imagery were limited to relatively low resolution Landsat Multi-Spectral Scanner (MSS) data. Fleming and Hoffer (1977) initiated much of the work related to classifying forest stand characteristics using MSS data including identifying various coniferous and deciduous forest species and defining a general classification break for spruce-fir crown closure. Another example of the use of Landsat MSS imagery to map forest land cover is a project in the Olympic National Park (Cibula and Nyquist, 1987).

More recently, vegetation classification studies implementing digital satellite data have utilized higher spatial, spectral, and radiometric resolution Landsat Thematic Mapper (TM) data. Several studies have shown that the higher information content of TM data results in significant improvements in classification accuracy for more distinctive classes. For instance, classification accuracies of forest species (Horler and Ahern, 1986) and forest stand characteristics (Peterson et al., 1986, Williams and Nelson, 1986) were shown to improve with TM data, as opposed to MSS data.

Forest stand characteristics and tree species in all of the national forests and national parks in the Pacific Northwest have been mapped using Landsat TM data in order to assess the extent and distribution of potential old growth forests remaining in those areas (Green, 1990, and Green and Congalton, 1990). In this study conducted by Pacific Meridian Resources, forest tree size, stand structure, crown closure and tree species were mapped in order to identify portions of forest land that met USFS. Region 6 criteria for potential old growth based on the above characteristics. The project produced potential old growth classification accuracies of greater than 80% for the study area as a whole (Teply and Green, 1991). Similar studies utilized Landsat TM data in the classification of old growth forests in New Mexico (Gonzales, et al., 1992), and private and public forestland in the State of Washington (Bernath et al., 1992).

In the classification of digital data, the means of obtaining training statistics for identifying various spectral classes within a study area are often crucial to the success of the classification. The process of multi-spectral classification is often thought of as being performed using either of two methods for obtaining training statistics: supervised or unsupervised (Jensen, 1986). Additional approaches based on modification of these two basic methods have proved more successful than one or the other. Two hybrid techniques, termed multi-cluster blocks and mono-cluster blocks respectively, have been found to produce a higher classification accuracy than either the unsupervised (clustering) or supervised approaches

(Fleming et al., 1975; and Fleming and Hoffer, 1977).

A methodology for combining unsupervised classes and supervised training fields for use in a classification process has been described by Chuvieco and Congalton (1988). Utilizing the cluster analysis statistical technique, training statistics generated from both supervised and unsupervised approaches are grouped together. The merging shows two major benefits. (1) It aids in the labeling of the unsupervised classes by grouping them with a known supervised training field while (2) it also helps to identify classes that possess no spectral uniqueness, which greatly restricts them from being accurately classified (Chuvieco and Congalton, 1988). This approach of obtaining training statistics for the classification of Landsat TM data has been shown to be very effective. Various mapping projects conducted by Pacific Meridian Resources in the Pacific Northwest have successfully utilized this method of training statistic derivation (Green and Congalton, 1990, and Teply and Green, 1991). This combined approach was used in this project.

When an image is registered to the ground, each pixel contains x,y coordinates allowing for both the spectral and spatial analysis of the image. The spectral and spatial properties of satellite imagery can be used to map land cover using methods similar to those used in photo interpretation. The key to image classification (as well as to photo interpretation) is to learn when the image is a good predictor of vegetation type, and when it is not.

Typically, photo interpreters assess photo color, tone, and texture to classify an aerial photograph. Often the color, tone, and texture of the photograph is insufficient information for the accurate classification of the photo. Thus, photo interpreters also rely on their knowledge of ecological relationships between vegetation, location, and position. Photo interpretation, while an extremely useful tool, is expensive, often inconsistent, and unable to account for the biodiversity inside a vegetation type polygon.

The integration of GIS and image processing has allowed for the full implementation of photo interpretation techniques into image classification. Color, tone, and texture are represented in the image. Locational and positional information is available in ancillary GIS coverages such as elevation, slope, and aspect. Knowledge of ecological relationships is enhanced through other ancillary information such as research plot data and hydrology.

The keys to the successful use of satellite imagery to map vegetation are analysis techniques and tools that emphasize (1) understanding the relationships between image variation and vegetation variation, and (2) the integration into the mapping process of (a)field information, (b) analog and digital ancillary data, (c) statistical analysis of the spectral and ancillary data, and (c) efficient classification, reprocessing, and editing techniques.

B. Development of Database of Vegetation Characteristics

Satellite imagery can be used as a basis for developing many of the desired vegetation data themes through the integration of various ancillary data sources. Remotely sensed data (be it satellite imagery or aerial photography) can be used to collect information about vegetation conditions because there is a high correlation between variation in the imagery and variation in vegetation.

Fortunately, most of the characteristics which cannot be directly mapped from the imagery, can be mapped through the development of relationships between the imagery, fire history, and/or landform characteristics. For example, vegetation height cannot be mapped directly from aerial photos or reflective satellite imagery. Vegetation height is, however, highly correlated with vegetation species compositions which can be estimated from remotely sensed data. The challenge is to determine what types of information are most effective and cost efficient for the development of the desired vegetation database.

A more specific discussion of the application of these concepts to this vegetation landcover classification project is contained in the methods sections of this report.

C. Accuacy Assessment Background

Quantitative accuracy assessment of maps produced from remotely sensed data involves the comparison of a map with reference information (often erroneously referred to as "ground truth"). The purpose of quantitative accuracy assessment is the identification and measurement of map errors. There are two primary motivations for accuracy assessment:

- to understand the errors in the map (so they can be corrected), and
- to provide an overall assessment of the reliability of the map (Gopal and Woodcock, 1992).

Usually funding limitations preclude the assessment of every spatial unit on the map. Because comparison of every spatial point is impractical, sample comparisons are used to estimate the accuracy of maps. Accuracy assessment requires (1) the design of unbiased and consistent sampling procedures, and (2) rigorous analysis of the sample data.

In the past, thematic maps, such as forest type and vegetation cover maps, have often been prepared directly from aerial photography with no rigorous assessment of reliability. During the 1980's, discussion of accuracy assessment of maps derived from remotely sensed data was initiated (Smith and Kovalick, 1985; Congalton and Mead, 1983; Story et al., 1984; Congalton, l991). While published research on accuracy assessment is now extensive, much less accuracy assessment has been accomplished on actual mapping projects.

Experience with accuracy assessment indicates that the following factors are critical to successful design and implementation of map accuracy assessment:

1. The classification rules used to produce the map being assessed must be rigorous and well-defined.
2. Accuracy assessment procedures must be unbiased and consistent. Sites used to train the photo interpreter or image processing system cannot be used for accuracy assessment. Existing ground or photo data can be used only if it is reinterpreted under accuracy assessment procedures.
3. The sample design must be cost efficient. Because accuracy assessment can require a large number of sample sites, cost efficient design is imperative.
4. The accuracy of the reference data must be evaluated. In the past, reference data has been assumed to be 100 percent accurate. Pacific Meridian's experience has shown that differences between reference data and mapped data are often caused by factors other than map error (Congalton and Green, 1993). Photo interpretation often varies, especially in heterogeneous vegetation. It is important, therefore, that variation in reference data be quantified before being used to assess map accuracy.
5. The imagery or photos used to assess the accuracy of the maps must be of the same general vintage as those originally used in map classification. The greater the time period between the media used in map classification and that used in assessing map accuracy, the greater the likelihood that differences are due to change in vegetation (from succession, disease, etc.) rather than from misclassification.

In the 1970's, researchers, notably Hord and Brooner (1976), van Genderen and Lock (1977), and Ginevan (1979), proposed criteria and techniques for testing map accuracy. In the early 1980's more in-depth studies were conducted and new techniques were proposed (Rosenfield et al., 1982; Congalton et al., 1983; and Aronoff, 1985). As a result of this work and work by others, the error matrix (Story and Congalton, 1986) became the standard medium for reporting remotely sensed data classification accuracies.

Error matrices compare map data to reference data (usually from photo interpretation or ground visits). Because field data are expensive to collect, the accuracy assessment of maps created from satellite imagery is usually performed by comparing the map to photo interpreted reference sites (Congalton and Green, 1993; Maus et al, 1992; Bernath et al., 1992; Czaplewski, 1992).

A major assumption of the standard error matrix is that the label from the reference information represents the "true" label of the site and that all differences between the remotely sensed map classification and the reference data are due to classification and/or delineation error. Unfortunately, error matrices can be inadequate indicators of map error because they are often confused by non-map error differences (Congalton and Green, 1993). The confusion in the error matrix is a function of:

- Registration differences between the reference data and the remotely sensed map classification
- Digitizing errors

- Data entry errors
- Changes in land cover between the date of the remotely sensed data and the date of the reference data
- Mistakes in interpretation of reference data
- Variation in classification and delineation of the reference data due to inconsistencies in human interpretation of vegetation

If these sources of confusion are not controlled, then the error matrix should not be used to assess map accuracy. Confused error matrices have been shown to be biased estimators of accuracy (i.e., they systematically underestimate the accuracy of the map) (Congalton and Biging, 1992; Congalton and Green, 1993; Gopal and Woodcock, 1992). Thus, the error matrix is really a difference matrix and is only representative of error if the other sources of confusion have been accounted for. As Congalton and Green (1993) state, “It is critical that these differences be considered in any accuracy assessment."

Most of the sources of confusion can be controlled with rigorous quality control. Pacific Meridian Resources' methods include documented procedures, extensive training, and the consistent use of forms to categorize data. However, the classification systems applied to this project represent discrete classifications of phenomena that are continuous in nature with few distinct boundaries. In situations where classification system breaks represent artificial distinctions along a continuum, variation in human interpretation is often very difficult to control and, while unavoidable, can have profound effects on accuracy assessment results (Congalton, 1991; Congalton and Green, 1993).

Several researchers have noted the impact of the variation in human interpretation on map results and accuracy assessment (Gong and Chen, 1992; Lowell, 1992; Congalton and Biging, 1992). Gopal and Woodcock (1992) state, “The problem that makes accuracy assessment difficult is that there is ambiguity regarding the appropriate map label for some locations. The situation of one category being exactly right and all other categories being equally and exactly wrong often does not exist." Gopal and Woodcock instituted the phrase "fuzzy set" logic to refer to this phenomenon. Lowell (1992) calls for "a new model of space which shows transition zones for boundaries, and polygon attributes as indefinite". As Congalton and Biging (1992) conclude in their study of the validation of photo interpreted stand type maps, "The differences in how interpreters delineated stand boundaries was most surprising. We were expecting some shifts in position, but nothing to the extent that we witnessed. This result again demonstrates just how variable forests are and the subjectiveness of photo interpretation."

However, photo interpretation has been used for over 60 years to effectively classify land cover type. Resource managers have long accepted maps made in this manner. The long history of reliance on photo interpretation for the production of resource maps is a testimony to both the value of the technique and the acceptance of some levels of confusion. While it is difficult to control variation in human interpretation, it is possible to measure the variation, and to use the measurements to compensate for differences between reference and map data that are caused not by map error but by variation in interpretation. There are two options available to control the variation in human interpretation to reduce the impact of this variation on map accuracy. One is to measure each reference site precisely to reduce variance in reference site labels. This method can be prohibitively expensive, usually requiring extensive field sampling. The second option incorporates fuzzy logic into the reference data to compensate for non-error differences between reference and map data. While the photo interpreter is an integral part of the process, an objective and repeatable method to capture the impacts of human variation is required.

Appendix B

Field Forms

A. IMA Data Form.

THEMATIC MAPPER LANDCOVER MAPPING PROJECT

IMU FIELD DATA FORM

DATE: 6/11/91 OBSERVERS: CUSICK, FRIESEN PARK: LACL

IMU No. 13 POLYGON No. 250 PHOTOS: roll 6 frames 15 ~~(MAYBE 14?)~~

DRAINAGE: dry mesic wet SUBSTRATE/LANDFORM

COVER (VEGETATION) TYPE(S)*: CLOSED LOW BIRCH SHRUB

LANDCOVER TYPE DESCRIPTION:

~40 BENA — 5 WILLOW

~35 HI ERICH - LEDUM

~10 LO ERICH - CROW

~5 PIGL

~5 GRASS

*If 20% or more of the polygon contains a matrix with patches of vegetation or barren areas that are greater than 2500 ft^2 (225 m^2), is the patch area 10,000 ft^2 (900 m^2) or more? YES NO

COMMENTS: HUMMOCKY, SOME H_2O COURSING THROUGH, FAIRLY FLAT.

B. GT Data Form

PARK LACL TEAM/DATE Smith 9/13/84 CIR PHOTO 113/4835 SITE 113/4835C

USGS QUAD Lake Clark C-1 EVEV (ft) 1000' SLOPE (%) 0-5 ASPECT (deg) Flat

VEG TYPE Pigl/Alder/Hylocomium MULTI AGE: yes/no/? VEG STRUCT: ml/h/s/vg/m/og

AV HT OF UPPER STORY (m)	<0.2	0.2-1.5	1.5-3.0	3.0-5.0	>5.0
% COV OF SIGNATURE LAYER	35		25		40

% COV OF INERT MATERIALS (EXCLUDING WATER) ∅ GRND CNTRL PHOTO ID ✓

COVER %: 1/0-5 2/5-25 3/25-50 4/50-75 5/75-95 6/95-100:

TREES	%C	TREES	%C	SHRUBS	%C	HERBS	%C
Total	3	Total		Total	3	Total	6
Picea glauca	3			Alnus crispa	3	Hylocomium splendens	6
Populus balsamifera	1					Cladina rangiferina	1

COMMENTS: Pigl & balsam poplar vary along this glacial/alluvial fan - Runs of Pigl, balsam poplar, Beke, Alnus, Viburnum & Calamagrostis alternate with more Pure Pigl, Alnus, Hylocomium.

This spot was 'truthed' in the pure Pigl/Hylcomium

FUEL DATA ENTRY

GRASS COMPONENT:

MODEL Static Dynamic

TYPE Fine Med Coarse VC

BULK DEN (1-6)

DEPTH (ft)

% 10 HR TL

MAX % LIVE (Dynamic) N/A

OR

CURRENT % LIVE (Static)

COVERAGE (0-100%)

SHRUB COMPONENT:

TYPE (1-5)	2
BULK DEN (1-6)	4
DEPTH (ft)	8.0'
% 1 HR TL	12
% 100 HR TL	3
% LEAVES/LIVE TWIGS	80
OIL OR WAX	Yes No
COVERAGE(0-100%)	30

LITTER COMPONENT:

LITTER SOURCE

Conifer Hardwood Both

LITTER COMPACTNESS

Loose Normal Compact

COMPONENT DEPTH (ft)	.1
% 1 HR TL	90
% 100 HR TL	5
COVERAGE (0-100%)	30

MOSS-LICHEN COMPONENT:

DEPTH (ft)	.2
COVERAGE (0-100%)	100
% MOSS	95
% LICHEN	5

COMMENTS:

C. 1997 Data Form

LACL Field Form

Site Number	Observer	Obs. Date (Mo/Day/Year)	%Slope (Avg)	Aspect (Avg)	Elev'n
7-122	PS MG	7 / 16 / 97			

Air Photo: Reel	Photo	1:63,360 Quad:	Drainage: dry mesic wet
2616	4825	Lake Clark C-1	mesic

Substrate/Landform

1) Coastal Spruce	6) Open Interior Spruce	11) Closed Alder	17) Fellfield	19) Sedge/shrub bog meadow	25) Gravel/sparse veg
2) Closed Interior Spr	7) Spruce Woodland	12) Open Alder	18) Lichen tundra	20) Wet Sedge Meadow	26) Bedrock
3) Closed Birch	8) Open Mix	13) Willow Shrub		21) Salt Marsh	27) Ice and snow
4) Closed Populus	9) Open Populus	14) Low Shrub		22) Emergent Marsh	28) Fresh water-clear
5) Closed Mix	10) Open Birch	15) Dwarf Shrub Tundra		23) Sedge dom mes tun	29) Fresh water-silty
		16) Prostrate Shrub Tun		24) Grasslands	30) Marine waters
					31) Marine mudflats
					32) Beetle Infest Spr

%	Height	TREES	Genus	Species
25		White Spruce	Picea	glauca
		Black Spruce	Picea	mariana
5		Alaska Paper Birch	Betula	papyrifera
20		Cottonwood	Populus	balsamifera
		Quaking Aspen	Populus	tremuloides
50				

%	Height	SHRUBS	Genus	Species
50		Alder	Alnus	
		Willow	Salix	
		Dwarf Arctic Birch	Betula	
		Labrador-tea	Ledum	
		Ericaceous		
		Vaccinium	Vaccinium	
		Sweetgale	Myrica	
		Mountain-avens	Dryas	
		Crowberry	Empetrum	

%	HERBACEOUS	Genus	Species
	GRASS		
	Bluejoint	Calamagrostis	
	SEDGE		
		Carex	
	Cottongrass	Eriophorum	
	RUSH		

%	HERBACEOUS con't	Genus	Species
	FORBS		
	Fireweed	Epilobium	
	Horsetail	Equisetum	
	Cinquefoil	Potentilla	
	Cloudberry	Rubus	
	Saxifrage	Saxifraga	
	LICHEN	Fruticose	
		Crustose	
	MOSS		

%	AQUATIC	Genus	Species
	Mare's tail	Hippuris	
	Buckbean	Menyanthes	
	Pond lily	Nuphar	
	Pondweed	Potomegetum	
	Burreed	Sparganium	

%	NON-VEGETATED	
	Water	
	Snow/Ice	(circle one)
	Mud/Silt/Soil	(circle one)
	Sand	
	Gravel/Rock	(circle one)

	TOTAL % COVER

COMMENTS

Appendix C.

Accuracy Assessment Tally Table

Appendix C. AA Tally Table

Map Label Ratings: 1 = acceptable, 0 = unacceptable

Site-id	Ref label	Map label (best)	Match	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	33
01-003	19	19	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
01-007	9	9	1	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
01-008	21	21	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
01-011	10	11	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
01-012	12	12	1	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
01-021	25	25	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
02-024	15	15	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
02-028	5	5	1	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
02-032	14	14	1	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
02-036	5	5	1	0	1	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
02-038	15	15	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
02-040	7	7	1	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
03-041	12	11	1	0	1	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
03-044	5	8	1	0	1	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
03-049	12	12	1	0	1	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
03-050	12	11	1	0	1	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
03-051	15	16	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
03-052	24	24	1	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
03-059	9	11	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
03-060	11	11	1	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
04-000A	1	6	1	1	2	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
04-062	16	16	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
04-063	6	6	1	1	2	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
04-067	19	20	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0
04-076	20	20	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
04-077	11	11	1	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
05-082	11	11	1	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
05-083	21	19	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
05-085	11	11	1	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
05-086	11	11	1	0	1	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
05-087	4	9	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
05-090	11	11	1	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
05-091	11	11	1	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
05-092	11	11	1	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
06-095	25	25	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
06-096	13	15	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
06-098	25	25	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
06-099	26	26	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0
06-101	16	16	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
06-103	14	14	1	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
06-104	11	12	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
06-106	11	11	1	0	1	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
06-108	14	14	1	0	1	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
06-112	13	12	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
07-126	19	14	1	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
07-127	14	15	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
07-129	7	7	1	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
07-131	14	15	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
07-136	6	6	1	0	1	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
07-137	14	14	1	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
08-144	13	8	0	0	1	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
08-146	12	12	1	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
08-151	8	6	1	0	1	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
09-155	15	14	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Appendix C. AA Tally Table																																			
Site-id	Ref label	Map label	Match	Map Label Ratings: 1 = acceptable, 0 = unacceptable																															
		(best)		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	33
09-156	16	19	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
09-157	7	14	1	0	1	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
09-158	14	14	1	0	1	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
09-161	20	19	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0
09-162	14	14	1	0	1	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
09-165	19	19	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0
09-167	16	14	0	0	1	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
09-168	12	11	1	0	1	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
09-169	8	8	1	0	1	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
09-170	11	11	1	0	1	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
09-171	12	12	1	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
09-173	6	7	1	0	1	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
09-176	6	6	1	0	1	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
09-177	7	7	1	0	1	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
09-179	11	12	1	0	1	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
09-181	13	14	1	0	1	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10-182	11	12	1	0	1	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10-189	20	20	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
10-200	11	12	1	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10-204	16	16	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
11-205	15	15	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
11-209	16	16	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
11-213	6	6	1	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
11-215	5	5	1	0	1	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
11-216	6	6	1	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
11-217	20	20	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
11-220	15	15	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
12-223	3	5	1	0	1	1	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
12-224	8	8	1	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
12-226	12	11	1	0	1	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
12-227	10	3	1	0	1	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
12-233	11	11	1	0	1	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
12-236	12	12	1	0	1	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
13-240	8	8	1	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
13-242	8	8	1	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
13-246	12	11	1	0	1	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
13-249	12	12	1	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
13-252	6	7	1	0	1	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
13-254	12	11	1	0	1	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
13-255	12	11	1	0	1	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
13-256	15	16	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
13-257	15	16	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
13-260	8	8	1	0	1	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
13-261	8	5	1	0	1	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
14-270	12	12	1	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
15-292	7	7	1	0	1	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
15-294	8	8	1	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
15-297	19	19	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
15-300	20	20	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0
15-311A	19	19	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
15-311B	13	7	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
15-314	6	6	1	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
15-315	7	7	1	0	1	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
15-318	6	6	1	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Appendix C. AA Tally Table

Site-id	Ref label	Map label (best)	Match	Map Label Ratings: 1 = acceptable, 0 = unacceptable																															
				1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	33
15-320	3	10	1	0	1	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
16-330	2	6	1	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
16-339	6	6	1	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
16-344	19	14	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
16-346A	7	7	1	0	1	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
16-346B	7	15	1	0	1	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
16-347	22	22	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
16-348	7	7	1	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
16-349	6	6	1	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
16-351	6	6	1	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
17-356	6	6	1	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
17-378	22	22	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
17-382	19	19	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
18-389	16	16	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
18-391	13	20	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
18-393	11	12	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
18-395	11	12	1	0	1	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
18-397	11	12	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
19-408	20	19	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
19-413	9	14	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
19-417	11	12	1	0	1	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
19-418	10	12	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
19-419	8	8	1	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
19-420	8	8	1	0	1	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
19-421	8	12	1	0	1	0	0	0	0	1	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
20-424	6	6	1	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
20-426	7	6	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
20-431	12	12	1	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
20-433	14	7	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
20-435	13	12	1	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
20-436	18	16	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
20-438	20	20	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0
20-439	15	15	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
21-442	25	25	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
21-444	25	25	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
21-445	13	14	0	0	1	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
21-446	14	16	1	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
21-447	16	16	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
21-451	25	25	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
21-455	7	7	1	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
21-457	7	7	1	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
21-459	11	11	1	0	1	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22-466	11	11	1	0	1	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22-467	19	19	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
22-468	6	6	1	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
23-479	12	12	1	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
23-485	11	11	1	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
23-488	4	9	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
23-492	11	11	1	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
23-495	11	19	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
24-499	5	8	1	0	1	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
24-502	8	6	1	0	1	0	0	0	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
24-510	19	20	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0
24-512	22	22	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0

Appendix C. AA Tally Table

Site-id	Ref label	Map label (best)	Match	Map Label Ratings: 1 = acceptable, 0 = unacceptable 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	33
24-515	6	19	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
AA-200	29	29	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0
AA-201	28	28	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
AA-202	25	25	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
AA-203	29	29	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
AA-204	25	25	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
AA-205	25	25	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
AA-206	26	16	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
AA-207	26	25	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
AA-208	25	25	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
AA-209	28	28	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
AA-210	27	27	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
AA-211	26	27	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0
AA-212	27	27	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
AA-213	26	27	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0
AA-214	25	25	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
AA-215	25	25	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
AA-216	25	25	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
AA-217	26	25	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
AA-218	25	27	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0
AA-219	28	29	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
AA-220	31	31	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
AA-221	31	31	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
AA-222	30	30	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
AA-223	28	28	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
AA-224	27	27	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
AA-225	27	27	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
AA-226	25	29	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0
AA-227	27	27	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
AA-228	28	28	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
AA-229	28	28	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
AA-230	26	25	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0
AA-231	28	28	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
AA-232	25	25	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
AA-234	27	27	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
AA-235	26	27	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
AA-236	31	31	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
AA-237	30	30	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
AA-238	25	25	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
AA-239	31	25	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
AA-240	30	30	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
AA-241	28	28	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
AA-242	26	26	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
AA-243	27	27	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
AA-244	25	25	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
AA-245	27	27	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
AA-246	27	27	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
AA-247	26	27	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
AA-248	28	28	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
AA-249	29	29	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
AA-250	25	25	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
AA-251	27	27	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
AA-252	28	28	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
AA-253	25	25	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0

The Department of the Interior protects and manages the nation's natural resources and cultural heritage; provides scientific and other information about those resources; and honors its special responsibilities to American Indians, Alaska Natives, and affiliated Island Communities.

NPS D-38, September 1998

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