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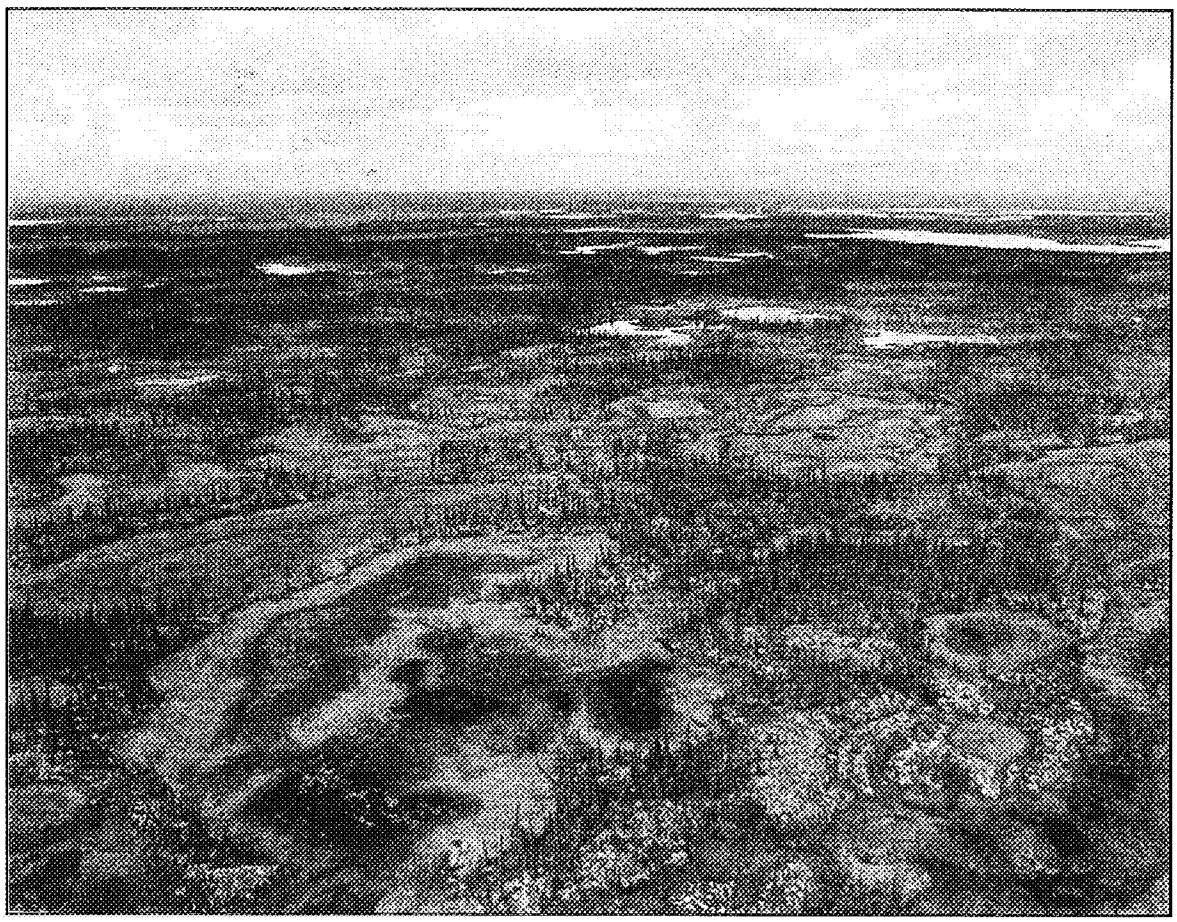
U.S. Department of the Interior
U.S. Fish and Wildlife Service

Ducks Unlimited, Inc.

Innoko Earth Cover Classification



Mission Statement

The Bureau of Land Management (BLM) sustains the health, diversity and productivity of the public lands for the use and enjoyment of present and future generations.

Partners

The Department of the Interior, Bureau of Land Management, U.S. Fish and Wildlife Service, and Ducks Unlimited, Inc. completed this project under a cooperative agreement.

Cover

The cover photo shows a portion of the Innoko National Wildlife Refuge. It depicts the remoteness of the area and the need to use helicopters for data collection.

Technical Reports

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Innoko
Earth Cover Classification

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U. S. Department of the Interior
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Abstract

The Bureau of Land Management (BLM) – Alaska and Ducks Unlimited, Inc. (DU) have been cooperatively mapping wetlands and associated uplands in Alaska using remote sensing and geographic information system (GIS) technologies since 1988. The goal of this project was to continue the mapping effort by mapping the Innoko National Wildlife Refuge (INWR) and surrounding BLM, Native, and State lands—hence called the Innoko Earth Cover Mapping Project (approximately 22 million acres). Because the entire project area was so large, three sub-project areas were defined: the Innoko National Wildlife Refuge (INWR), the Unalakleet area, and the Aniak area. Sub-project boundaries were delineated using several factors, including acquisition dates of available Landsat images, limitations in field logistics, geographic features, and political boundaries (i.e. - mapping the entire INWR in one sub-project area). Fieldwork, image classification, and accuracy assessment were completed independently for each of the sub-project areas. The digital maps produced for the three areas were mosaicked post-classification to produce an earth cover map for the entire Innoko project area. A total of six Landsat Thematic Mapper (TM) satellite scenes (two for INWR: Path 76, Rows 15 and 16, acquired August 26, 1991; three for the Unalakleet area: Path 77 Rows 15-17, acquired August 8, 1995; and one for the Aniak portion: Path 76 Row 17, acquired August 26, 1991) were used to classify the project area into 34 earth cover categories. An unsupervised clustering or seeding technique was used to determine the location of field sites and a custom field data collection card and digital database were used to record field information. Helicopters were utilized to gain access to field sites throughout the project area. Global positioning system (GPS) technology was used both to navigate to pre-selected sites and to record locations of new sites selected in the field. Data were collected on 1,544 field sites during a 17-day field season from July 17, 1998 through August 2, 1998. A modified supervised/unsupervised classification technique was performed to classify the satellite imagery. The classification scheme for the earth cover inventory was based on Viereck *et al.* (1992) and revised through a series of meetings coordinated by the BLM – Alaska and DU. The overall accuracy at the +/-5% level of variation for each project area was 86%, 80%, and 84% for the Aniak, Unalakleet, and INWR areas, respectively. The cooperators in this project were the Bureau of Land Management-Alaska, the U.S. Fish and Wildlife Service, and Ducks Unlimited, Inc.

Introduction

The Bureau of Land Management (BLM) – Alaska and Ducks Unlimited, Inc. (DU) have been cooperatively mapping wetlands and associated uplands in Alaska using remote sensing and geographic information system (GIS) technologies since 1988 (Ritter *et al.* 1989). The earliest mapping projects focused exclusively on mapping wetlands (Ritter *et al.* 1989) but it soon became apparent that mapping the entire landscape was more cost-effective and ultimately more useful to land managers. The BLM is currently in the process of creating a satellite inventory of all BLM managed lands in Alaska. Many other agencies in Alaska (i.e. National Park Service, U.S. Fish and Wildlife Service, U.S. Forest Service, Alaska Department of Natural Resources, Alaska Department of Fish and Game) are also using similar techniques, and cooperating on multi-agency mapping projects. This project represents a cooperative effort between the BLM, the Innoko National Wildlife Refuge (INWR), and DU to map the INWR and the BLM's Unalakleet area lands, as well as State and Native lands between and surrounding the Refuge and BLM lands. The objective of this earth cover mapping project is to provide an inventory of Alaska's land base that can be used for regional management of land and wildlife. The earth cover database will allow researchers, biologists, and managers to define and map crucial areas for wildlife, to perform analysis of related habitats, to detect changes in the landscape, to plot movement patterns for large ungulates, to generate risk assessments for proposed projects, and to provide baseline data to which wildlife and sociological data can be related.

Landsat Thematic Mapper (TM) satellite imagery was chosen as the primary source for the BLM/DU earth cover mapping effort. Satellite imagery offers a number of advantages for region-wide projects. It is a cost-effective data source for regional mapping; can be processed using automated mapping techniques; and is collected on a cyclical basis, providing a standardized data source for future database updates or change detection studies (Kempka *et al.* 1993). In addition, TM imagery includes a mid-infrared band, which is sensitive to both vegetation and soil moisture content and has proven useful in identifying earth cover types. When combined with other GIS data sets, such as elevation, slope, aspect, shaded relief, and hydrology, Landsat TM imagery can produce highly accurate classifications with a moderately detailed classification scheme.

The Innoko Earth Cover Mapping Project area contains highly diverse landscapes and is important for its wildlife and recreational values. The project boundary (Figure 1) stretches from just north of the village of Koyuk, on Norton Sound, southward along Norton Sound to the northeast portion of the Yukon Delta National Wildlife Refuge near Russian Mission, to the Russian Mountains in the east, moving north to include most of the INWR, and then northwest back towards Koyuk. The eastern and northern boundaries of the project area are defined by the extent of the satellite images purchased for the project. The project area encompasses approximately 22 million acres and includes lands owned or managed by several Federal and State agencies, Native corporations, and private landowners

(Figure 2 and Table 1). Geographically located in the Yukon and Kuskokwim River drainages, this area is vital habitat for many types of waterfowl and for a large population of moose. The upland areas are in the migration paths of the Mulchatna and Western Arctic caribou herds, and have significant populations of bears and wolves. The Innoko Earth Cover Mapping Project covers approximately 400 miles of the Yukon River and almost 70 miles of the Kuskokwim River drainage. The data gathered from this project will assist in the critical process of resource planning for this valuable and diverse area.

Project Objective

The objective of this project was to develop a baseline earth cover inventory using Landsat TM imagery for the INWR, the BLM's Unalakleet area lands, and surrounding Native, State, and Federal lands. More specifically, this project purchased, classified, field verified, and produced high quality, high resolution digital and hard copy resource base maps. The result of this project is an integrated GIS database that can be used for improved natural resources planning.

Project Area

Aniak Project

The Aniak Project makes up the southern portion of the Innoko Earth Cover Mapping Project. This portion of the greater Innoko Project is named for the town of Aniak located at the intersection of the Aniak and Kuskokwim Rivers, which is roughly the center of the project area. The project area is sectioned into thirds in a north-east to south-west direction by the Yukon and Kuskokwim Rivers, with the Yukon River cutting through the north-west third, and the Kuskokwim River sectioning off the south-eastern third of the project area. The project area extends to the west of Aniak including the town of Russian Mission. To the north, the project is bounded by the town of Holy Cross, and to the south extends into the Kilbuck Mountains. The eastern border of the project runs from the eastern edge of the Russian Mountains, south to the Kilbuck Mountains. The project covers portions of the Russian Mission, Sleetemute, and Bethel 1:250,000 United States Geological Survey (USGS) scale quadrangles.

A diverse selection of habitat is represented in the Aniak Project, from the innumerable small lakes and lowland black spruce muskeg of the Kuskokwim and Yukon River drainages, to the rock and lichen peaks of the Kilbuck and Russian Mountains at elevations of 3000 feet. A diverse population of wildlife is present in the Aniak Project area. Large populations of moose were observed and logged with their position and physical characteristics for use in the Bureau of Land Management's wildlife database. A variety of waterfowl and other bird species were also observed, including sandhill cranes, northern harriers, tundra swans, short-eared owls, and ptarmigan.

Unalakleet Project

The Unalakleet Project encompasses the western half of the Innoko Earth Cover Mapping Project area. The Yukon River forms the eastern boundary. The northern boundary is defined by the extent of the Landsat image for path 77, row 15. The eastern boundary is formed by Norton Sound and a 10-mile buffer along the western edge of the Unalakleet, Holy Cross, and Russian Mission 1:250,000 scale USGS quadrangles. The Unalakleet Project includes the majority of BLM lands within

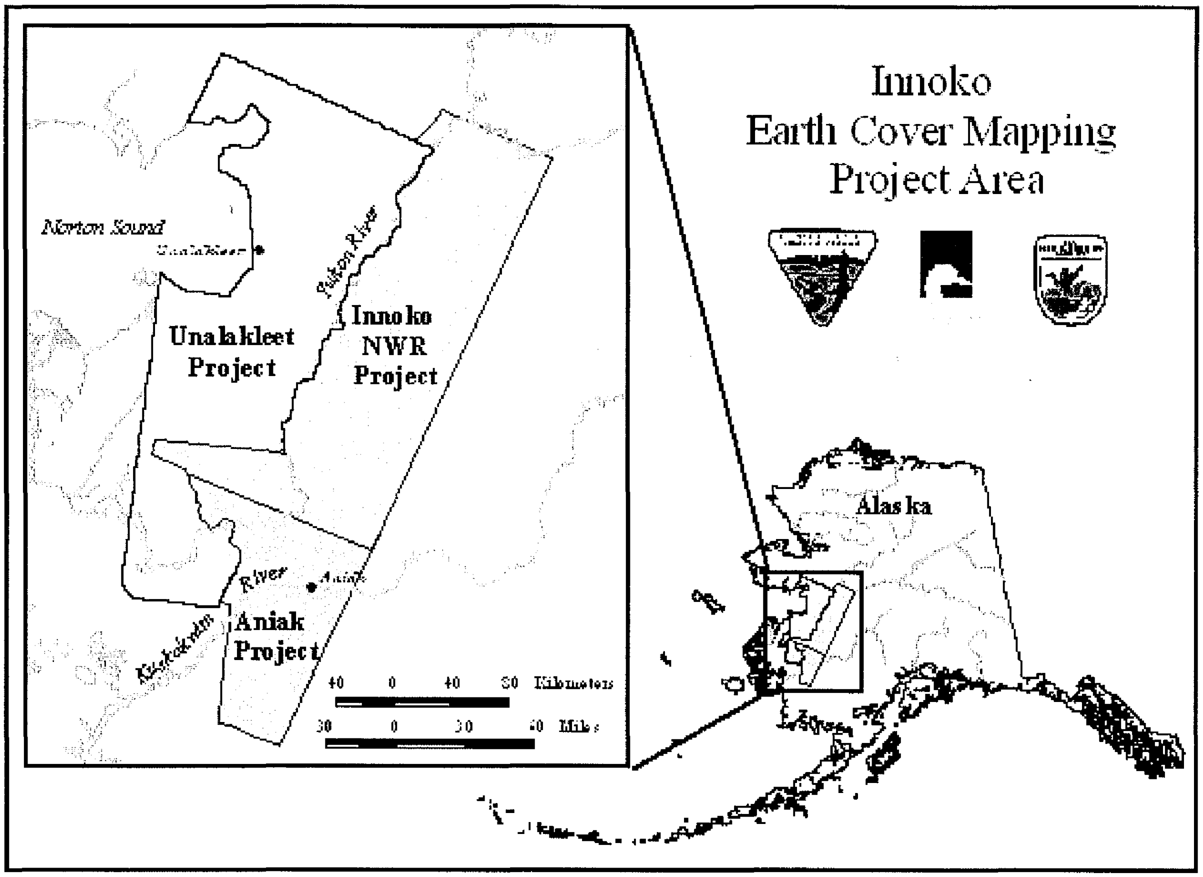

Figure 1. Map of Innoko mapping project location and sub-project boundaries.

Table 1. Acreage of project area by land status.

Land Status	Acres
Bureau of Land Management	5,937,690
U.S. Fish and Wildlife Service	6,969,010
Stated Patent or TA	1,862,132
State Selected	2,333,599
Native Patent or IC	3,411,948
Native Selected	1,362,680
Military	8,829
Private	1,921
Total	21,887,809

the Innoko Project area. The project area is very diverse and contains two major ecoregions; the coastal plains near Norton Sound in the west, and the more interior-likeboreal forest and river flats along the Yukon River drainage and in the Nulato Hills in the east.

The western half of the project area is flat, mostly treeless, plains and treeless rolling hills that are influenced by coastal weather patterns. These areas, near Norton Sound, are comprised primarily of tussock tundra, dry graminoid, and dwarf shrub cover types, with stringers of tall shrub, low shrub, and deciduous trees in riparian areas, and tall shrub and low shrub on hill-slopes. The tundra and dwarf shrub plains contain significant amounts of lichen, which provides an important food source during the annual migration of the Western Arctic caribou herd.

The eastern portion of the Unalakleet Project is comprised of rolling hills of needleleaf and deciduous trees along the Yukon River. The northern portion includes higher elevations in the Nulato Hills, containing dwarf shrub, dwarf shrub lichen and sparse vegetation on the hilltops, and boreal forest types in the valleys and at lower elevations. The southern portion of the project area is within the flats of the Yukon River drainage, including portions of the Yukon Delta National Wildlife Refuge (NWR), and has numerous, small lakes and ponds, wetlands, and dwarf shrub/dry graminoid uplands between the waterbodies.

Innoko National Wildlife Refuge Project

The Innoko National Wildlife Refuge (INWR) Project encompassed the majority of INWR lands. A small portion of INWR is located to the north, beyond the extent of the Landsat imagery, and was, therefore, not mapped as part of this project.

The Yukon River flows along the north and west sides of the project area and also serves as the boundary between the Unalakleet and INWR projects; the Innoko River bisects the southern portion of the INWR from the northeast to the southwest. The project area extends south of the INWR and includes the town of Flat and the old settlement of Iditarod. The town of McGrath lies approximately 100 miles outside the east boundary of the INWR project. Portions of the following 1:250,000 USGS scale quadrangles are included in the project area: Nulato, Ophir, and Iditarod. This project area contains a variety of lowland environments primarily around lake complexes, streams and rivers. Much of the vegetation found in these areas, including a variety of floating and emergent vegetation, sedges, mosses, lichens, shrubs, and black spruce, is associated with bogs and muskegs. The upland vegetation is primarily black spruce with lichen understory, birch, and a variety of shrubs. Much of the area contains little relief. Outside the northern section of the INWR, however, the Kaiyuh Mountains extend to just above 2000 feet and contain various herbaceous or barren cover types such as tussock tundra, sedge meadows, lichens, and rock.

Moose, bear, and beaver can be found throughout the project area, as well as variety of waterfowl and shorebird species, including white fronted geese, northern pintail, American wigeon, green-wing teal, scaup *spp.*, canvasback, lesser yellowlegs, snipe, and dowitcher *spp*. Much of the project lies in a low, well-drained area and is heavily impacted by fire. The central and southern part of INWR is made up of mossy bogs and hummocks with abundant wetland vegetation (sedges, grasses, and other herbaceous species) surrounding lake complexes, while much of the northern and eastern regions near the Yukon River are covered with black spruce and a variety of shrubs.

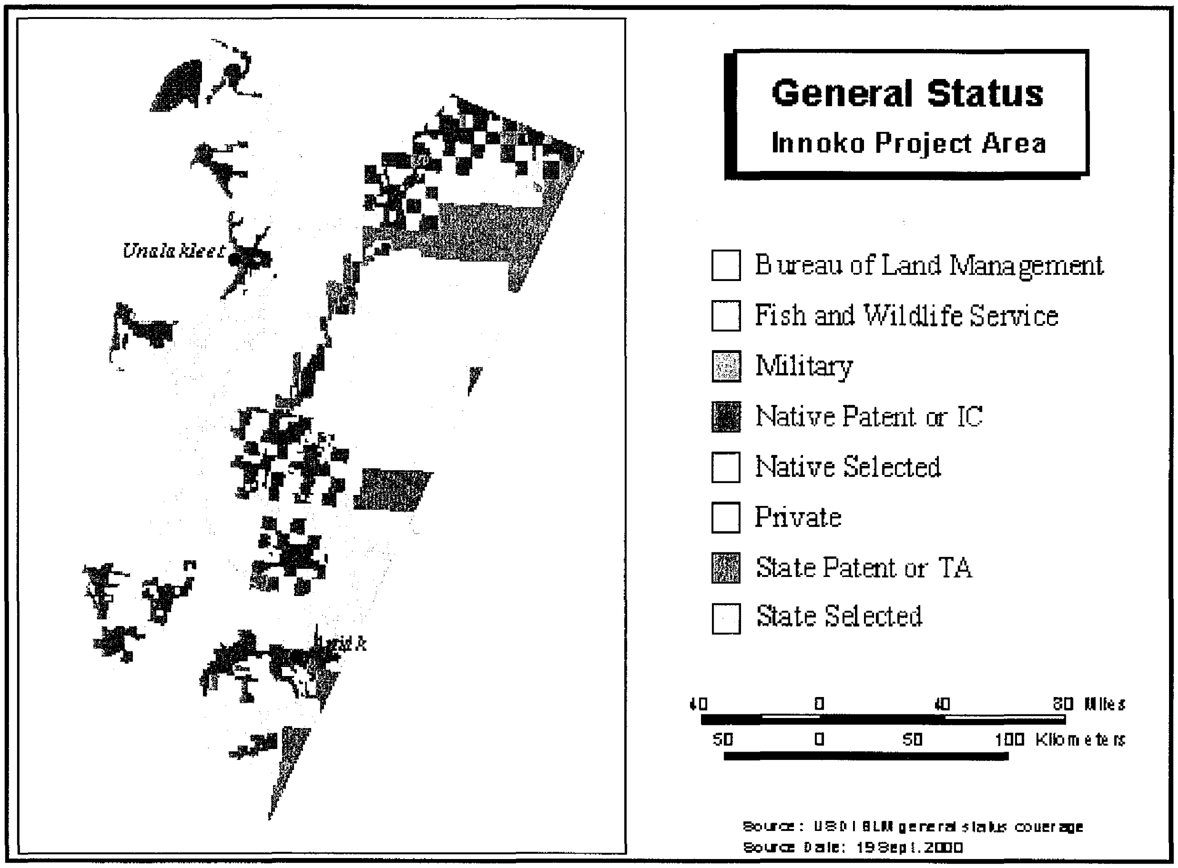

Figure 2. General status within the Innoko mapping project area.

Data Acquisition

A total of seven Landsat TM satellite scenes were used in this project: Two for INWR - Path 76, Rows 15 and 16, acquired August 26, 1991; three for Unalakleet - Path 77, Rows 15-17, acquired August 8, 1995; and one image for Aniak - Path 76, Row 17, acquired August 26, 1991 (Figure 3). The scenes were purchased from EROS Data Center in Universal Transvers Mercator (UTM) projection and were terrain-corrected by EROS Data Center.

Field data for all project areas was collected from July 17 to August 2, 1998. The ancillary data used in this project included 1:65,000 scale aerial photographs (color infrared transparencies from 1976, 1978, 1984, and 1985) on loan from the BLM Alaska State Office, as well as USGS 1:63,360 scale Digital Elevation Models (DEM).

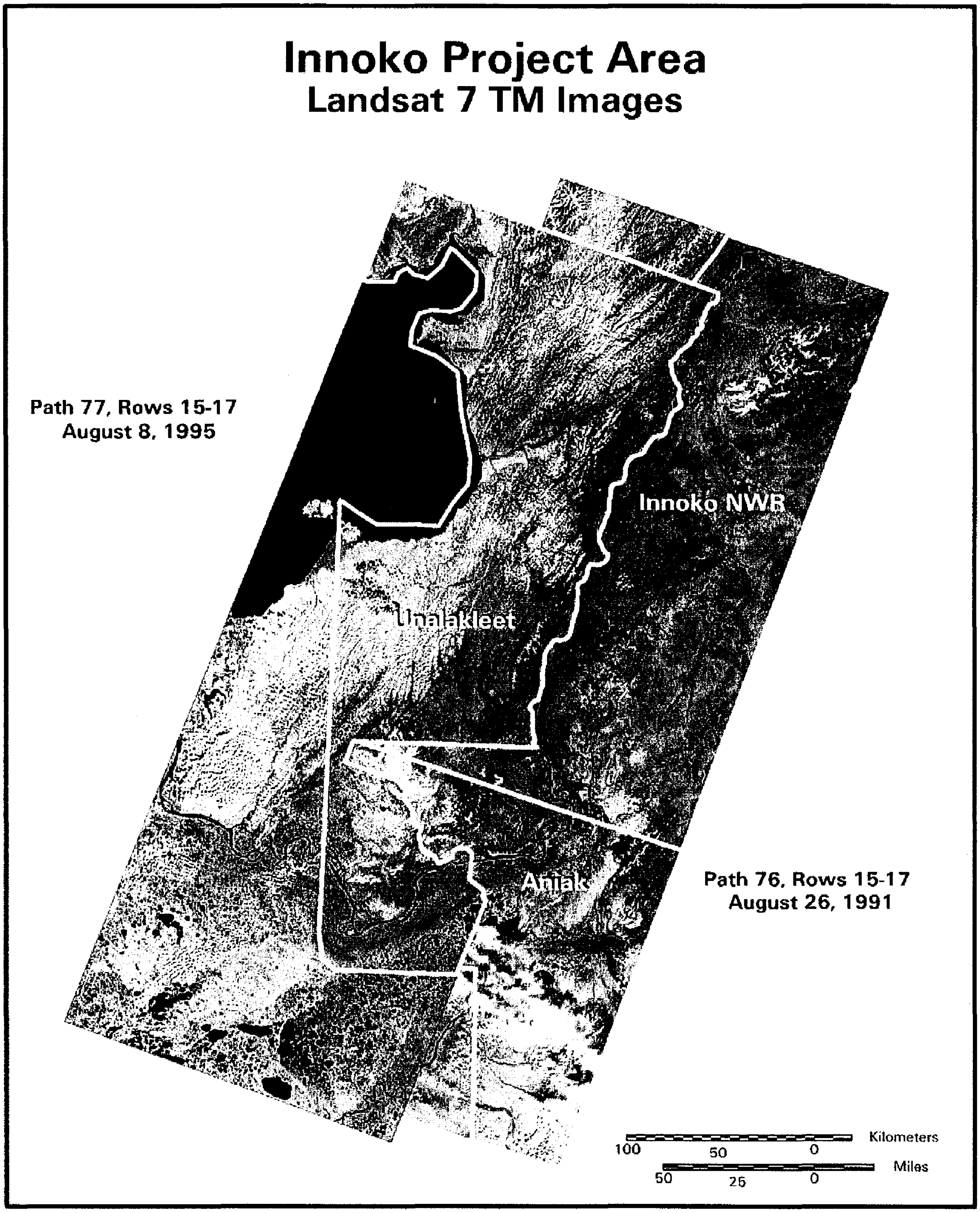

Figure 3. The satellite imagery used for the Innoko earth cover mapping project. Sub-project boundaries shown in yellow.

Methods

Classification Scheme

The classification system (Table 2) categorized the features to be mapped. The system was derived from the anticipated uses of the map information and the features of the earth that could be discerned by Landsat Thematic Mapper (TM) data. The classification system had two critical components: (1) a set of labels (e.g., forest, shrub, water); and (2) a set of rules, or a system for assigning labels. The set of rules for assigning labels was mutually exclusive and totally exhaustive (Congalton 1991). That is, any given area fell into only one category and every area was to be included in the classification.

Until recently, the BLM/DU classification systems were project-specific. As projects expanded in size, and as other cooperators began mapping and sharing data across Alaska, the necessity for a standardized classification system became apparent. At the BLM Earth Cover Workshop in Anchorage from March 3-6, 1997, a classification system based on the existing Alaska Vegetation Classification (Viereck *et al.*, 1992) was designed to address this need. The goal of this meeting was to: (1) develop an earth cover classification system for the State of Alaska that can be used in large regional mapping efforts, and (2) build consensus for the system among multiple land management agencies. The classification system has been slightly improved since this meeting.

The classification scheme consisted of ten major categories and 27 subcategories. A classification decision tree and written description (Appendices A and B) were developed to clarify the classification. Though based largely on Level III of the Viereck *et al.* (1992) classification, some classes have been modified, added or omitted for the earth cover mapping projects: e.g., rock, water, ice, cloud and shadow classes were added. Other classes that could not reliably be discerned from satellite imagery were collapsed, such as open and closed low shrub classes, or dryas, ericaceous, willow, and dwarf shrub classes. Because of the importance of lichen for site characterization and wildlife, and because the presence of lichen can be detected by satellite imagery, shrub and forested classes with and without a component of lichen were distinguished. A few classes from Level IV of the Viereck *et al.* (1992) classification were also mapped because of their identifiable satellite signature and their importance for wildlife management. These Level IV classes included tussock tundra and low shrub tussock tundra.

Image Preprocessing

Each image was examined for quality and consistency. Each band was examined visually and statistically by reviewing the histogram. Combinations of bands were displayed to check for band to band registration and for clouds, shadows, and haze. Positional accuracy was checked by comparing the image to available ancillary data such as adjacent imagery, hydrography, or Digital Elevation Models (DEM's).

To optimize helicopter efficiency, field sites were identified and plotted on field maps before fieldwork began. Sufficient samples for each mapped class were selected to span the variation of spectral responses within

Table 2. Classification scheme developed at the BLM Earth Cover Workshop

Level I	Level II/III	Level IV
1.0 Forest	1.1 Closed Needleleaf	
	1.2 Open Needleleaf	1.21Open Needleleaf Lichen
	1.3 Woodland Needleleaf	1.31 Woodland Needleleaf Lichen
	1.4 Closed Deciduous	1.41 Closed Paper Birch
		1.42 Closed Aspen
		1.43 Closed Balsam Poplar/Cottonwood
		1.44 Closed Mixed Deciduous
	1.5 Open Deciduous	1.51 Open Paper Birch
		1.52 Open Aspen
		1.53 Open Balsam Poplar/Cottonwood
		1.54 Open Mixed Deciduous
	1.6 Closed Mixed Needleleaf/Deciduous	
	1.7 Open Mixed Needleleaf/Deciduous	
2.0 Shrub	2.1 Tall Shrub	
	2.2 Low Shrub	2.21 Low Shrub Willow/Alder
		2.22 Low Shrub Tussock Tundra
		2.23 Low Shrub Lichen
		2.24 Low Shrub Other
	2.3 Dwarf Shrub	2.31 Dwarf Shrub Lichen
		2.32 Dwarf Shrub Other
3.0 Herbaceous	3.1 Bryoid	3.11 Lichen
		3.12 Moss
	3.2 Wet Herbaceous	3.21Wet Graminoid
		3.22 Wet Forb
	3.3 Mesic/Dry Herbaceous	3.31 Tussock Tundra
		3.32 Mesic/Dry Sedge Meadow
		3.33 Mesic/Dry Grass Meadow
		3.34 Mesic/Dry Graminoid
		3.35 Mesic/Dry Forb
4.0 Aquatic Vegetation	4.1 Aquatic Bed	
	4.2 Emergent Vegetation	
5.0 Water	5.1 Snow	
	5.2 Ice	
	5.3 Clear Water	
	5.4 Turbid Water	
6.0 Barren	6.1 Sparsely Vegetated	
	6.2 Rock/Gravel	
	6.3 Mud/Silt/Sand	
7.0 Urban		
8.0 Agriculture		
9.0 Cloud/Shadow	9.1 Cloud	
	9.2 Shadow	
10.0 Other		

that class throughout the entire image. For example, a shrub class in the southern part of an image may have a different spectral response than the same shrub class in the northern part of that image. Many factors contribute to such variation, including aspect, terrain shadow, or small differences in soil moisture. In addition, each earth cover type encompassed a variety of subtypes; e.g., the open needleleaf class included forested areas with 25%-60% crown closure, trees of varying height, and a diverse understory composition.

An unsupervised classification was used to identify spectrally unique areas within the study area. The image analyst individually selected training sites from these spectrally unique areas. Whenever possible, training sites were grouped in clusters to reduce the amount of travel time between sites. The image analyst also tried to place training sites near landmarks that were easily recognizable in the field, such as lakes, streams, or abrupt changes in cover type. A tally of the estimated number of field sites per class was kept until all of the target map classes were adequately sampled throughout the project area. The coordinates of the center points of the field sites were then uploaded into a Y-code Rockwell Precision Lightweight Global Positioning System Receiver (PLGR) for navigational purposes. Training sites were overlain with the satellite imagery and plotted at 1 inch = 1 mile scale. These field maps were used for recording field notes, placing additional field sample sites, and navigating to field sites.

Field Verification

The purpose of field data collection was to assess, measure, and document the on-the-ground vegetation variation within the project area. This variation was correlated with the spectral variation in the satellite imagery during the image classification process. Low-level helicopter surveys were a very effective method of field data collection since a much broader area was covered with an orthogonal view from above, similar to a satellite sensor. In addition, aerial surveys were the most efficient alterNative due to the large area and the lack of roads throughout the project area.

To obtain a reliable and consistent field sample, a custom field data collection form (Kempka *et al.*, 1994) was developed and used to record field information (Figure 4). Five-person helicopter crews performed the field assessment. Each crew consisted of a pilot, biologist, recorder, navigator, and alternate. The navigator operated the GPS equipment and interpreted the satellite image derived field maps to guide the biologist to the pre-defined field site. It was valuable for the image processor to gain first-hand knowledge of the project area, therefore, the image processor also fulfilled the role of the navigator. The biologist identified plant species, estimated the percent cover of each cover type, determined the overall earth cover class, and photographed the site. The recorder wrote species percentages and other data on the field form and generally assisted the biologist. The alternate was responsible for crew flight following, data entry, and substitution in case of sickness. The majority of sites were observed without landing the helicopter. Ground verification was performed when identification of dominant vegetation was uncertain. These BLM /DU procedures for collecting field

Rev 7/15/97

Sample Field Form

1997-XXXX - 1 - XXX Yr Project Crew Site Number	DF/JH/LF Observers	Obs. Date: 8 / 13 / 97 Mo Day Year	1 (2) 3 4 Obs. Level	Obs.Time: 16 : 27 Hr Min
Digital Photo 2 . 12, 13 Session # Photo #	LAT (GPS) ______ Decimal Degrees		LONG (GPS) ______ Decimal Degrees	
%Slope (Avg) 45	Elev	Aspect: N NE E (SE) S SW W NW Flat		
Average Distance Between Stems:	10-15' 15-20' 20-25' 25-30' 30-35' 35-40'		(Open or Woodland Needleaf Only)	

(Circle Lichen where present)

Forest	Forest	Shrub	Herbaceous	Herbaceous	Aquatic Veg/Water	Barren	Other
Closed Needleaf	Open Deciduous	Tall	Lichen	Dry Sedge	Aquatic Bed	Sparse Veg	Other
Open Needleleaf	(Closed Mixed)	SA/AL Low	Moss	Dry Graminoid	Emergent	Rock/Gravel	
Woodland Needleleaf	Open Mixed	Tussock Low	Wet Sedge/Gr	Dry Sedge/Gr	Snow/Ice	Mud/Silt/Sand	
Wdlnd Ndlf-Lichen		Other Low-Lichen	Wet Forb	Dry Forb	Turbid Water		
Closed Deciduous		Dwarf-Lichen	Tussock-Lichen		Clear Water		

TREES

%Cov	Height	TREES	
50	14	(White Spruce)	Picea glauca
		Black Spruce	Picea mariana
30	15	(Aspen)	Populus tremuloides
	15	(Birch)	Betula papyrifera
		Balsam Poplar	Populus balsamifera
		Larch, Tamarack	Larix laricina

SHRUBS

%Cov	Height	SHRUBS	
		Willow	Salix spp.
	1.5	(Alder)	Alnus crispa
		Dwarf Arctic Birch	Betula nana/glandulosa
		Blueberry	Vaccinium uliginosum
		Low Bush Cranberry	Vaccinium vitis-idea
		Bearberry	Arctostaphylos spp.
		Kinnikinnick	Arctostaphylos uva-ursi
		Crowberry	Empetrum nigrum
		Alpine Azalea	Loiseluria procumbens
		Mountain Avens	Dryas spp.
		Mountain Bell Heather	Cassiope tetragona
		Labrador Tea	Ledum palustre
5	0.4	(Rose)	Rosa acicularis
		Cinquefoil	Potentilla spp.
		Fireweed	

HERBACEOUS

%Cov	HERBACEOUS	
	Sedge/Graminoid	
	(Grass)	
	Poa	Poa spp.
	Cotton Grass	Eriophorum spp.
	Holy Grass	Hierochloe alpina
	Sedge	Carex spp.
85	Subtotal % Cover	

HERBACEOUS con't

%Cov	HERBACEOUS con't	
	Forbs	
	Saxifrage	Saxifrage spp.
	Vetch	Astragalus spp.
	Horsetails	Equisetum spp.
	Fireweed	Epilobium spp.
	Coltsfoot	Petasites frigidus
	Cinquefoil	Potentilla spp.
	Bistort	Polygonum spp.
	Rubus	Rubus spp
	Bryoid	
5	(Moss)	
	Lichen	Color:

AQUATIC

%Cov	AQUATIC	
	Water Lily	Nuphar polysepalum
	Pondweed	Potamegeton spp.
	Buttercup	Ranunculus spp.
	Mare's Tail	Hippuris spp.
	Buckbean	Menyanthes trifoliata
	Marsh Fivefinger	Potentilla palustris
	Horsetails	Equisetum spp.

NON-VEGETATED

%Cov	NON-VEGETATED	
	Clear/Turbid Water	(circle one)
	Snow/Ice	(circle one)
	Mud/Silt/Sand	(circle one)
	Gravel/Rock	(circle one)
	(Litter)	
10	(Bare Ground)	
15	Subtotal % Cover	
100	GRAND TOTAL % COVER	

C#	COMMENTS

CALL Class if NEED. NPS 8/4/97

Figure 4. Customized field data entry form.

data have evolved into a very efficient and effective means of data collection. The navigator used a GPS to locate the site and verified the location on the field map. As the helicopter approached the site at about 300 meters above ground level, the navigator described the site and the biologist took a picture with a digital camera. The pilot then descended to approximately two to five meters above the vegetation and laterally moved across the site while the biologist called out the vegetation to the recorder. The biologist took another picture with the digital camera for a close-up view of the site. The pilot then ascended to approximately 100 meters so the biologist could estimate the percentages of each species for the recorder. The navigator then directed the pilot to the next site. On average, it took approximately five to eight minutes to collect all of the information for one site.

Field Data Analysis

The collected field information was entered into a digital database using the Ducks Unlimited Field Form (DUFF) custom data entry application, designed jointly by the BLM and DU and programmed by GeoNorth. The relational database was powered by SQL Anywhere software, while the user interface was programmed in Visual Basic. The user interface was organized similarly to the field form to facilitate data entry (Figure 5). The application utilized pull down menus to minimize keystrokes and checked for data integrity to minimize data entry errors. The database program also calculated an overall class name for each site based on the recorded species and their cover percentages. Digital images from each site were stored in the database and were accessible from within the user interface. The number of field sites per earth cover class was tracked daily to ensure that adequate samples were being obtained within each class.

Classification

Every image is unique and presents special problems in the classification process. The approach used in this project (Figure 6) has proven successful over many years. The image processors were actively involved in the field data collection and had first-hand knowledge of every training site. The image processors' site-specific experience and knowledge, in combination with high quality ancillary data, overcame image problems to produce a high quality, useful product.

Erdas Imagine (vers. 8.4) was used to perform the classification and manage all raster datasets. ArcInfo (vers. 7.2.1 and vers. 8.0.1) was used to manage the field site polygons and all other vector datasets. Various word processing and data analysis software packages were also used during the image classification including Microsoft Word, Excel, and Access.

Generation of New Bands

The Landsat TM imagery contained seven bands of data: three visible bands, one near-infrared band, two mid-infrared bands, and one thermal band. One new band was generated for this project. This new band was created using a band-4/band-3 ratio, a band ratio that typically reduces the effect of shadows in the image and enhances the differences between vegetation types (Kempka *et al.* 1995, Congalton *et al.* 1993). This 4/3 ratio band replaced the thermal

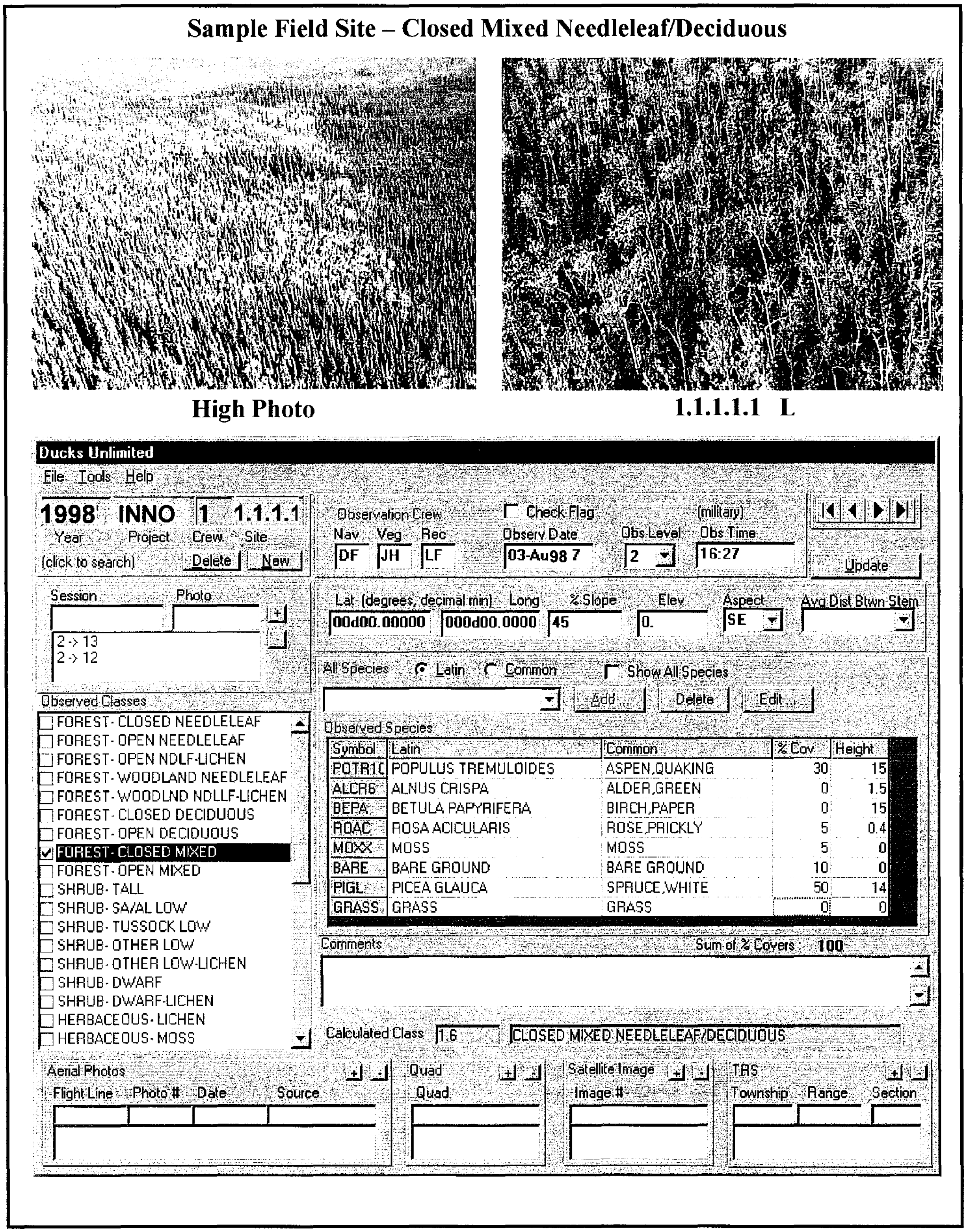

Figure 5. The customized database and Ducks Unlimited Field Form (DUFF) user interface for field data entry.

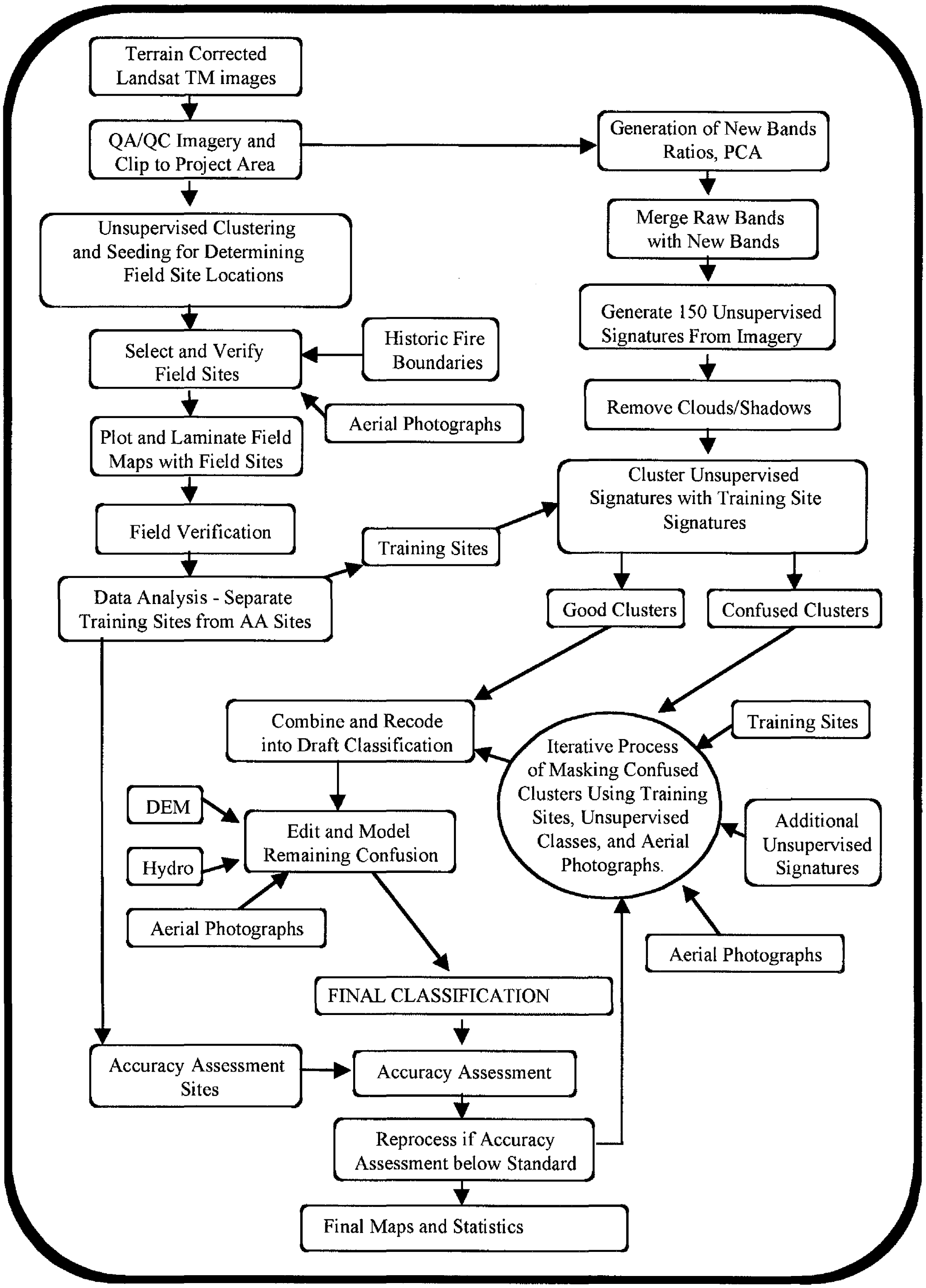

Figure 6. The image processing flow diagram.

band (band six) to retain a seven-band image for classification.

Removal of Clouds and Shadows

The clouds and cloud shadows that were present in the imagery were removed from the image before field sites were selected. This process eliminated any confusion between clouds, cloud shadows, and other vegetation types. They were removed using an unsupervised classification and manual on-screen editing. Clouds were separated from shadows and classes were recoded to their respective class number. The cloud/shadow layer was then combined with the rest of the classified image during the last step in the classification process.

Several areas in the Unalakleet project area were cloud-covered on the path 77 images from August 8, 1995. In areas where the 1991 (path 76) images overlapped the path 77 imagery, classification of the 1991 imagery was performed and "stitched" into the final classification to replace the clouds in the path 77 images.Terrain shadows were identified with models using unsupervised classifications and shaded relief images as inputs. The shaded relief images were produced in Erdas Imagine using USGS 1:63,360 scale DEM's. Where 1:63,360 scale DEMs were unavailable, 1:250,000 scale DEMs were substituted. Solar azimuth and solar angle values for use in the shaded relief algorithm were obtained from the header files of the appropriate Landsat TM images. This allowed the shaded relief images to most closely mimic the terrain shadows present at the times of the Landsat TM image acquisitions. The terrain shadow images consisted of values ranging from 0.0 to 1.0 with the most shaded areas equal to 0.0 and the brightest or least shaded areas equal to 1.0. Terrain shadows were most often spectrally confused with earth cover classes that appeared very dark on the image, e.g. water, closed needleleaf, closed mixed needleleaf deciduous, and open needleleaf. An unsupervised classification was used to identify spectral classes that confused terrain shadowed areas with these spectrally "dark" earth cover classes. The model then compared the pixels from these spectral classes to the most shaded areas in the shaded relief image. If a pixel fell within one of these classes and had a relatively low value in the shaded relief image, it was labeled as a terrain shadow. The image processor determined the threshold value for the shaded relief image after viewing the terrain shadow image over the raw TM imagery, and by examining field site data and notes taken on field maps. Some additional on-screen digitizing was used to identify terrain-shadowed pixels that were not identified by the modeling procedure. All the remaining "non-shadow" pixels were put back into the image for further iterations of combined supervised/unsupervised classifications that were used to identify earth cover classes.

Seeding Process

Spectral signatures for the field sites that were designated as training areas were extracted from the imagery using a "seeding" process in ERDAS Imagine (Imagine). A pixel within each training area was chosen as a "seed" and adjoining pixels were evaluated for inclusion in each training site, using a threshold value based on a spectral Euclidean distance. The standard deviations of the seeded areas were kept at or below three and all seeded areas were required to be over 15 pixels (approximately 3.75 acres) in size. Along with the field training areas, additional "seeds" were generated for the water, turbid water, and snow classes. These classes were not visited in the field because they are easily recognized on the imagery and aerial photography, and time spent visiting these easily identifiable classes was an inefficient use of helicopter time. The output of the seeding process in Imagine is a signature file that contains all of the statistics for the training areas. The signature file is then used in the modified supervised/unsupervised classification.

Generation of Unsupervised Signatures

An unsupervised classification was generated using the six raw bands and the 4/3 ratio band. One hundred and fifty signatures were derived from the unsupervised classification using the ISODATA program in Imagine. The output of this process was a signature file similar to that of the seeding process but containing the 150 unsupervised signatures. A maximum likelihood classification of the 150 unsupervised signatures was generated using the supervised classification program in Imagine.

Modified Supervised/Unsupervised Classification

A modified supervised/unsupervised classification approach (Chuvieco and Congalton, 1988) was used for the classification. This approach uses a statistical program to group the spectrally unique signatures from the unsupervised classification with the signatures of the supervised training areas. In this way, the spectrally unique areas were labeled according to the supervised training areas. This classification approach provided three major benefits: (1) it aided in the labeling of the unsupervised classes by grouping them with known supervised training sites; (2) it helped to identify classes that possessed no spectral uniqueness, (i.e. training sites that were spectrally inseparable); and (3) it identified areas of spectral reflectance present in the imagery that had not been represented by a training site. This approach is an iterative process because all of the supervised signatures do not cluster perfectly with the unsupervised signatures the first time. The unsupervised signatures that matched well with the supervised signatures were inspected, labeled with the appropriate class label, and removed from the classification process. The remaining confused clusters were grouped into general categories (forest, shrub, non-vegetation, etc.) and re-run through the process. This process was repeated until all of the spectral classes were adequately matched and labeled, or until the remaining confused classes were spectrally inseparable. Throughout this iterative process, interim checks of classification accuracy were performed by intersecting the classified image with a coverage of the training sites to determine if the training sites were being accurately labeled by the classification. Areas with incorrectly classified training sites were run through further iterations of the supervised/unsupervised classification and further refined. The iterative process of interim accuracy assessments and refining classifications is terminated when the accuracy assessments indicate no improvements between one iteration and the next.

Editing and Modeling

In any image classification there are areas where the spectral data alone cannot distinguish between different earth cover classes. Models that incorporate ancillary data sets such as elevation, slope, aspect, shaded relief, or hydrography can often help to separate these confused classes. For instance, water may be classified where there are terrain shadow effects. Most of this shadow/water confusion can easily be modeled out of the classification using a shaded relief layer derived from DEM's.

For this project, the final steps of the classification process were to model the confused classes remaining after the iterative supervised/unsupervised classification process and to make final edits in areas that still had classification errors. Editing of classification errors was a process of comparing the classified image to the raw satellite image, aerial photography, and notes on field maps to identify errors remaining in the classification. These errors were then corrected by manually changing the class value for the pixels, that were classified in error, to their correct class value.

Accuracy Assessment

There were two primary motivations for accuracy assessment: (1) to understand the errors in the map (so they can be corrected), and (2) to provide an overall assessment of the reliability of the map (Gopal and Woodcock, 1992). Factors affecting accuracy included the number and location of test samples and the sampling scheme employed. Congalton (1991) suggests that 50 samples be selected for each map category as a rule of thumb. This value has been empirically derived over many projects. A second method of determining sample size includes using the multinomial distribution and specifying a given confidence in the estimate (Tortora 1978). The results of this calculation tend to favorably agree with Congalton's rule of thumb. Once a sample size is determined, it must be allocated among the categories in the map. A strictly proportional allocation is possible. However, the smaller categories in areal extent will have only a few samples and this may severely hamper the analysis. The other extreme is to force a given number of samples from each category. Depending on the extent of each category, this approach can significantly bias the results. Finally, a sampling scheme must be selected. A purely random approach has excellent statistical properties, but is practically difficult and expensive to apply. A purely systematic approach is easy to apply, but could result in sampling from only limited areas of the map.

Alaska Perspective

Obtaining adequate reference data for performing an accuracy assessment can be extremely expensive in remote areas. Aircraft is the only means of transportation throughout most of Alaska. Aerial photographs are available for most of Alaska, but most are at a scale that makes it difficult, if not impossible, to distinguish some vegetation classes. Ideally, fieldwork would be performed during one summer, the classification would be performed during the winter, and the reference data would be collected the next summer. This procedure would allow a stratified random sample of the classification and ensure adequate sampling of all the classes. Unfortunately, this methodology is not typically feasible, due to the cost of obtaining the field data in Alaska.

In this project, the fieldwork for obtaining the training sites used in classifying the imagery, and the reference data for the accuracy assessment, were accomplished at the same time. Special care was taken during the pre-processing stage, and in the field, to make sure adequate samples were obtained. However, funding limitations did not allow for the number of samples suggested for each class (n=50) for the accuracy assessment. Some earth cover classes were naturally limited in size and distribution, so that a statistically valid accuracy assessment sample could not be obtained without additional field time. For classes with low sample sizes, few, if any, field sites were withheld for the accuracy assessment. This does not indicate that the classification for these types is inaccurate but rather that no statistically valid conclusions can be made about the accuracy of these classes. However, withholding even a small percentage of sites for the accuracy assessment provided some confidence in the classification and guided the image processor and end user in identifying areas of confusion in the classification.

Selection of Accuracy Assessment Sites

Approximately 30% of the collected field sites were set aside for use in the assessment of map accuracy, while the remaining sites were utilized in the classification process. Unfortunately, given time and budget constraints, it was not always possible to obtain enough sites per class to perform both the classification and a statistically valid accuracy assessment. Generally, a minimum of 15 sites in an individual class (five for accuracy assessment, ten for image processing training sites) were required before any attempt was made to assess the accuracy of that class. Classes with less than 15 field sites were still classified. However, much fewer, if any, field sites were utilized for accuracy assessment for these classes. Accuracy assessment sites were selected randomly across the project area to reduce bias.

Qualification of Accuracy Assessment Standards

While the accuracy assessment performed in this project is not a statistically robust test of the classification, it gives the user some confidence in using the classification. It also provides enough detail for the end user to determine where discrepancies in the classification may cause a problem while using the data. It is also important to note the variations in the dates of the imagery, aerial photographs, and field data. For this project, the imagery was from 1991 and 1995; the aerial photographs spanned a nine-year period from 1978 through 1987, and the field data was collected in July/August 1998. Differences due to environmental changes from the different sources may have had a significant impact on the accuracy assessment.

In addition, several major ecological changes have occurred throughout the study area during the past three to eight years, since the acquisition date of the satellite imagery. Primarily, significant land cover change has occurred throughout the project area as a result of the natural processes of flooding, river/stream channel meandering, revegetation of formerly sparsely or barren areas, and fire activity. This ongoing phenomenon has had a remarkable impact on the density and composition of forest and other vegetative species within the study area. The objective of this mapping project was to classify and map earth cover conditions as they existed in 1991 and 1995, when the satellite imagery was acquired. Capturing field data for accuracy assessment in 1998, for 1991 and 1995 imagery, obviously results in the *potential* introduction of error and/or variation in human interpretation of land cover composition that may impact the reliability and consistency of the reference accuracy assessment data.

A major assumption of quantitative accuracy assessments 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 errors

(Congalton and Green, 1993). Unfortunately, error matrices can be inadequate indicators of map error because they are often confused by non-map error differences. Some of the non-map errors that can cause confusion are: 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, and variation in classification and delineation of the reference data due to inconsistencies in human interpretation of vegetation.

Images were terrain corrected to minimize registration errors between map locations and GPS locations in the field. Rigorous quality checks of the data were used to reduce and, hopefully, eliminate any data entry errors. Efforts were also made to account for some of the variation in human interpretation in the accuracy assessment process. In addition to generating a standard accuracy assessment that assumed 100% accuracy in human interpretation of reference data, overall classification accuracies were also generated assuming a +/- 5% variation in estimation of vegetation compositions for each of the accuracy assessment sites. In other words, if a variation of +/- 5% in the interpretation of species crown cover percentages would have resulted in the generation of a different reference site label, this new label was also considered an acceptable mapping label for the reference site.

Error Matrix

The standard method for assessing theaccuracy of a map is to build an error matrix, also known as a confusion matrix, or contingency table. The error matrix compares the reference data (field site or photo interpreted site) with the classification. The matrix is a square array of numbers set out in rows and columns that express the number of sites assigned to a particular category in the reference data, relative to the number of sites assigned to a particular category in the classification. The columns usually represent the reference data, while the rows indicate the classification (Lillesand and Kiefer, 1994). An error matrix is an effective way to represent accuracy in that the individual accuracy of each category is plainly described along with both the errors of inclusion (commission errors) and errors of exclusion (omission errors) present in the classification. A commission error occurs when an area is included in a category it does not belong. An omission error is excluding that area from the category in which it does belong. Every error is an omission from the correct category and a commission to a wrong category. Note that the error matrix and accuracy assessment are based on the assumption that the reference data was 100% correct. This assumption was not always true.

In addition to clearly showing errors of omission and commission, the error matrix can be used to compute overall accuracy, producers accuracy, and users accuracy (Story and Congalton, 1986). Overall accuracy is simply the sum of the major diagonal (i.e., the correctly classified samples) divided by the total number of samples in the error matrix. This value is the most commonly reported accuracy assessment statistic. Producers and users accuracies are ways of representing individual category accuracy, instead of just the overall classification accuracy.

Results

Field Verification

Bell Jet Ranger helicopters were used to gain access to the field sites. Three field crews performed the field sampling. Although the areas mapped by the Aniak, Unalakleet, and Innoko NWR projects varied greatly in size, the entire project area was split into three nearly equal areas for field sampling (Figure 7). This optimized helicopter efficiency by eliminating long travel distances between base camps and field sites, and therefore provided a better distribution of field sites throughout the project area. Upon returning from the field, field sites were redistributed among image processors so all field sites visited, regardless of the crew responsible for sampling, were grouped by the boundaries for image processing.

Although helicopter surveys are the most efficient and economical sampling method for this type of fieldwork, they are still extremely expensive. In an effort to minimize travel time between sites, and maximize sampling time, priority was given to sampling areas with an abundance of pre-selected field sites concentrated in areas of high cover class diversity. Sampling of other, more scattered pre-selected sites was accomplished, usually when less common cover classes were encountered while en route between areas with higher concentrations of pre-selected sites. This sampling method produced a distribution of clustered sites that were scattered across the entire image. Field data was collected during a 17 day field season, from July 17 through August 2, 1998. Flight time did not exceed six hours per day. A total of 1,544 sites were visited, 460 by the Aniak field crew, 490 by the INWR field crew, and 594 by the Unalakleet field crew. The distribution of sites per class for each project area is listed in Table 3. The proportions of sites per class largely reflect the proportion of corresponding earth cover types within the project area.

Classification

To simplify the image processing for the three project areas, boundaries were developed based on images with the same acquisition date and/or ecological similarities. As a result, the areas processed follow the colored boundaries shown in Figure 7. The boundary between INWR and Unalakleet follows the Yukon River. Thirty-four earth cover classes were mapped (Figure 8), not including clouds, cloud shadows, and terrain shadows. Acreage summaries by earth cover class for the entire Innoko mapping project area and for each sub-project area are presented in Table 4. The following classification descriptions, acreages, and percentages refer to each sub-project area.

Aniak Project

The most extensive class of the Aniak project area unfortunately was clouds and cloud shadows. A relatively cloud-free scene was not available for this area. The use of adjacent scenes with their overlap made it possible to adjust the boundaries for the processing of the data. This adjustment optimized the use of cloud-free imagery for the greater Innoko mapping project, giving us the best possible final product. However, cloud cover still represents approximately 18.5% of the Aniak project area.

Table 3. Field sites per mapped class.

Class Name Crew:	Total # Field Sites per Class by Field Crew			Sites Withheld for Accuracy Assessment**		
	Aniak	Unal	INWR	Aniak	Unal	INWR
CLOSED NEEDLELEAF			1			0
OPEN NEEDLELEAF						
OPEN NEEDLELEAF	31	70	32	5	23	20
OPEN NEEDLELEAF LICHEN	3	7	55	0	0	22
WOODLAND NEEDLELEAF						
WOODLAND NEEDLELEAF	23	32	25	0	9	17
WOODLAND NEEDLELEAF LICHEN	12	4	20	5	0	14
CLOSED DECICUOUS	28	27	39	4	6	18
*CLOSED BIRCH**	*(18)*	*(19)*	*(4)*			
*CLOSED ASPEN**	*(1)*	*(0)*	*(0)*			
*CLOSED POPLAR**	*(1)*	*(3)*	*(1)*			
*CLOSED MIXED DECIDUOUS**	*(8)*	*(5)*	*(34)*			
OPEN DECIDUOUS	14	7	12	0	0	0
*OPEN BIRCH**	*(12)*	*(6)*	*(3)*			
*OPEN POPLAR**	*(2)*	*(1)*	*(2)*			
*OPEN MIXED DECIDUOUS**	*(0)*	*(0)*	*(7)*			
CLOSED MIXED NEEDLELEAF/DECIDUOUS	0	5	15	0	0	9
OPEN MIXED NEEDLELEAF/DECIDUOUS	25	21	17	6	6	13
TALL SHRUB	48	48	27	9	17	17
LOW SHRUB						
LOW SHRUB – WILLOW/ALDER	3	26	0	0	8	0
LOW SHRUB – TUSSOCK/TUNDRA	3	2	3	0	0	0
LOW SHRUB – LICHEN	6	10	1	1	0	0
LOW SHRUB – OTHER	30	49	27	7	16	19
DWARF SHRUB						
DWARF SHRUB – LICHEN	34	52	18	9	16	11
DWARF SHRUB – OTHER	35	58	46	5	18	18
LICHEN	16	25	13	3	10	5
MOSS	23	30	52	5	9	26
WET GRAMINOID	18	24	25	5	8	18
WET FORB	0	0	3	0	0	0
TUSSOCK TUNDRA						
TUSSOCK TUNDRA LICHEN	1	8	5	0	0	0
TUSSOCK TUNDRA	6	12	1	0	0	0
MESIC/DRY GRAMINOID	10	37	15	0	5	5
*MESIC/DRY SEDGE MEADOW **	*(2)*	*(13)*	*(6)*			
*MESIC/DRY GRASS MEADOW **	*(8)*	*(16)*	*(8)*			
*MESIC/DRY GRAMINOID **	*(0)*	*(8)*	*(1)*			
MESIC/DRY FORB	1	1	0	0	0	0
AQUATIC BED	5	0	4	0	0	0
EMERGENT VEGETATION	7	4	23	3	0	19
CLEAR WATER	10	0	0	0	0	10
TURBID WATER	1	0	0	0	0	6
ROCK/GRAVEL	12	12	1	6	0	0
SPARSE VEGETATION	18	8	0	2	0	0
NON-VEGETATED SOIL	7	8	1	1	0	0
OTHER	30	7	9	0	0	0
TOTAL	**460**	**594**	**490**	**76**	**151**	**267**

* Classes grouped into next highest hierarchical class for classification. **Some accuracy assessment totals result from combining accuracy assessment sites from multiple field crews.

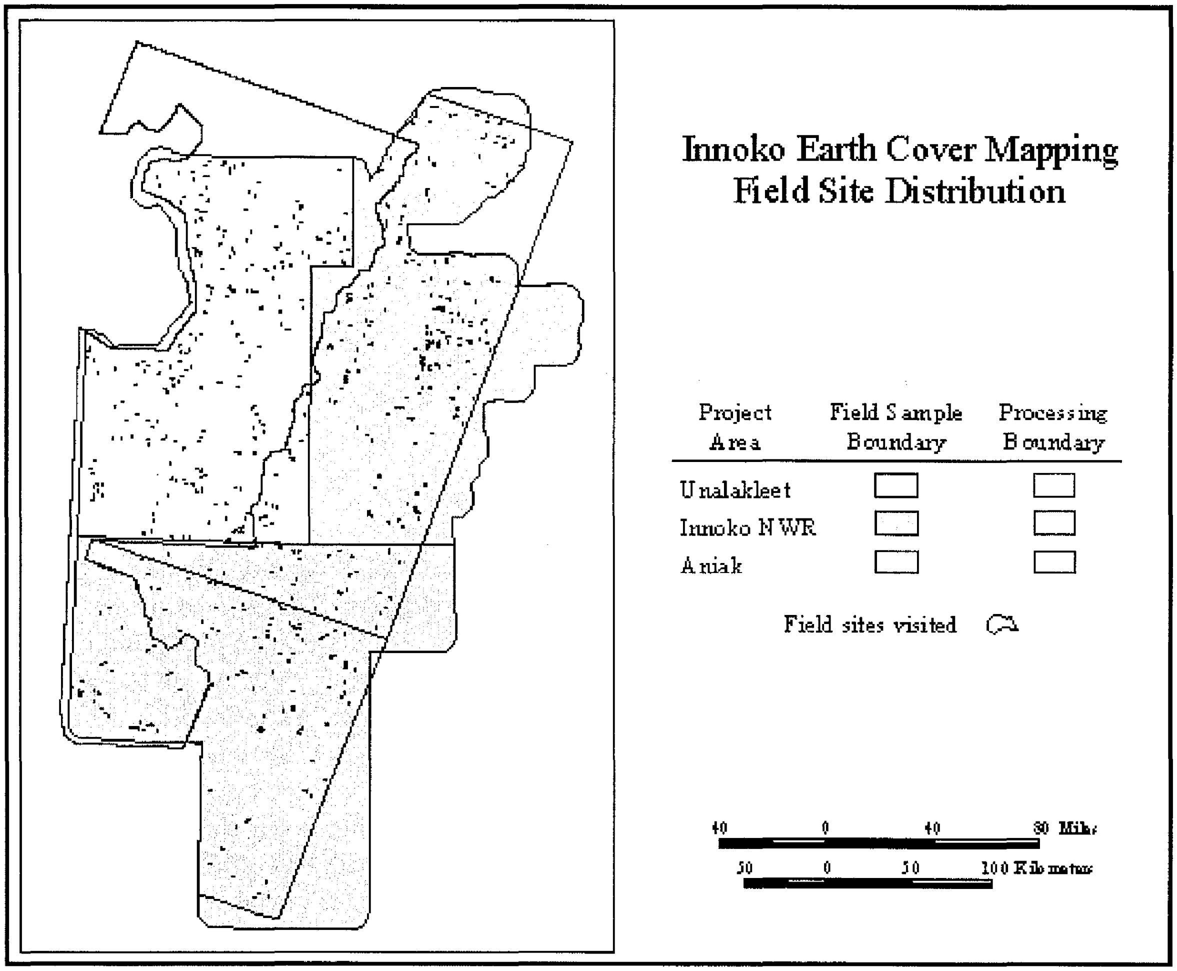

Figure 7. Field site distribution

The remaining 81.5% of the project area was made up of a diverse group of earth cover types. Shrub types predominated, accounting for 1,624,596 acres, or 39% of total area. Distribution within the shrub classes was: dwarf shrub – 416,183 acres (9.9% of total area), dwarf shrub lichen – 447,572 acres (10.6% of total area), low shrub – 408,591 acres (9.7% of total area), low shrub lichen – 39,597 acres (0.9% of total area), and tall shrub – 312,653 acres (7.4% of total area). The effect of the Yukon and Kuskokwim River's drainage basins, and their associated lowland areas, dominate this region. Mottled with many small lakes and the oxbows of the aforementioned rivers, the Aniak project area consists of 203,600 acres of clear water or 4.8% of the total area. Other large classes included closed mixed needleleaf/deciduous forest, commonly found in broad riparian corridors of the major river drainages, as well as on steep west- and northwest-facing slopes. Stands of closed-canopy deciduous trees were found on steep, well-drained, south-facing slopes in the northern portion of the project area, or on alluvial deposits near major rivers. These stands were composed primarily of birch. Mixed needleleaf/deciduous stands also appeared to be constrained by soil conditions and were found only near major river drainages. Large expanses of dwarf shrub lichen cover a good portion of the northwestern and southern portion of the project area. These areas are interspersed with a dwarf shrub component. This is due mainly to the higher elevations and rolling type hills leading up to the Kilbuck Mountains.

Unalakleet Project

The open needleleaf class (17.6% or 1.7 million acres) was the most common class in the Unalakleet project area, although shrub and graminoid classes, combined, accounted for approximately 54% of the overall area. The large percentage of shrubs and graminoids was a result of the largely treeless areas found in proximity to Norton Sound and the higher elevation treeless areas in the Nulato Hills. Forested areas were found mostly in the eastern half of the project area, near the Yukon River, and in the lower elevation areas of the Nulato Hills, in the northern portion of the project area. Closed mixed needleleaf/deciduous forests (54,024 acres or 0.6% of the project area) were restricted almost exclusively to hillsides and flats along the Yukon River and its major tributaries. Open mixed needleleaf/deciduous forests were more widespread throughout the forested portions of the project area. Closed and open deciduous classes were most common in the more forested, eastern portion of the project area along the Yukon River, but were also found along rivers and drainages in the mostly treeless western portions of the project area. Open and woodland needleleaf lichen classes (0.8% and 0.1%, respectively) were relatively insignificant within the project area. This was a marked difference from the INWR project area, just across the Yukon River, and seems somewhat unnatural. The field data does indicate a much greater presence of open and woodland needleleaf lichen in the INWR project area (75 sites) than in the Unalakleet project area (11 sites). This is partially accounted for by coastal influence on the western half of the Unalakleet project area, but it could possibly be a result of biases in the percent cover estimates for lichen made by the two different vegetation-callers on the Unalakleet and INWR field crews

The three major shrub cover types occurred in relatively equal proportions in the project area, with tall shrub accounting for 12.6% (1,227,400 acres), dwarf shrub and dwarf shrub lichen accounting for 16.8% (1,635,118 acres), and low shrub types accounting for 14.2% (1,384,480 acres) of the project area. Tall shrub was most commonly found on hillslopes and in drainages in the western half of the project area. It was also commonly found on the islands and flood plains of the Yukon River, around drainages at higher elevations, and in the transition areas between forested types and dwarf/low shrub types at higher elevations in the mountains. Low shrub types were found throughout the project area, with the low shrub willow/alder type being more common in the western half of the project area and the low shrub other type being slightly more common in the eastern half of the project area. Dwarf shrub and dwarf shrub lichen types were found mostly on the flat treeless areas surrounding Norton Sound and at the highest elevations in the Nulato Hills.

Graminoid types accounted for approximately 10% (1,016,412 acres) of the project area, with dry graminoid and tussock tundra types accounting for approximately 8% (827,769acres) and wet graminoids accounting for approximately 2% (188,643 acres). Dry graminoid and tussock tundra types were found primarily on the flat plains surrounding Norton Sound. These two cover types were heavily intermixed with the dwarf shrub and dwarf shrub lichen types and were very similar in species composition. The graminoid types nearly always contained a component of dwarf shrubs *(Betula nana/glandulosa, Ledum palustre, Vaccinium uliginosum,* etc.), but had a higher percentage of sedge (*carex spp.*) than the dwarf shrub types. The dwarf shrub and dry graminoid types had very similar spectral signatures, despite the differences in sedge percentages, and separating these types during the classification process was very problematic. Wet graminoids were found throughout the project area, especially around the margins of small waterbodies, in drained lakebeds, and in coastal marshes around Norton Sound. Most wet graminoid sites were characterized by *Carex aquatilus*, but the coastal marsh wet graminoid types included a variety of other species. The coastal wet graminoids were tidally influenced. The field data often did not indicate the presence of water for sites that were visited at or near low tide, but it was obvious from the species composition and the presence of exposed mud or sand that these sites were wet graminoid types.

The aquatic bed and emergent vegetation classes accounted for less than 1% of the final classified map and are most likely under-represented. Only 43 acres of aquatic bed are included in the final map of the project area, and these areas were identified from field notes. Aquatic beds and emergent vegetation were typically found in narrow strips at the edges of lakes and ponds and in the narrow oxbow lakes associated with the Yukon River and its tributaries. The narrow shape and limited spatial extent of these cover types made it very difficult to obtain adequate training site information for these cover types, therefore limiting the ability to identify these types with supervised classification techniques. In addition, the limited presence of these cover types throughout the project area, as well as their spectral similarity to the more common wet graminoid cover type, made them difficult to separate using unsupervised classification techniques. Larger expanses of emergent vegetation were encountered in the most southerly portion of the project area, mostly within the Yukon Delta NWR. These areas were more easily identified as emergent vegetation in the classification process, but there was still considerable difficulty in separating emergents from wet graminoids due to the high water content in the spectral signatures for both classes.

The sparsely vegetated, rock/gravel, and non-vegetated soil cover types accounted for 2% of the project area. These types were limited to the highest elevations, to islands and gravel bars along major rivers, and to small sandbars and beaches along Norton Sound.

Innoko National Wildlife Refuge Project

Forest cover types such as open needleleaf, woodland needleleaf, open/closed deciduous and open/closed mixed forests dominated much of the project area, accounting for 64% of the INWR earth cover map. Needleleaf forests covered 44% of the project area with open needleleaf and open needleleaf-lichen accounting for 12% and 20%, respectively. Deciduous and mixed needleleaf/deciduous forest accounted for 9% and 11% of the project area, respectively. Black spruce muskegs dominated the flat lowlands in the central portion of the INWR, while dwarf shrub and low shrub, with black spruce-lichen complexes, dominated the northern portion of the INWR. Large complexes of wet sedge (*Carex spp.*), mosses, and shrubs followed the Innoko and Iditarod rivers. West of the Innoko River was primarily forested, with black spruce and spruce lichen covering most of the lower elevations, while the hills were dominated by deciduous forests, primarily birch. The Yukon River basin was lined with open and closed mixed forest primarily composed of birch, cottonwood, and spruce of varying densities.

Shrubs (dwarf, low, and tall) were found throughout the project area (22%) mostly in areas that have been burned, at higher elevations above tree line, or where spruce trees are sparse. Many shrubs also occurred along open flat areas near major rivers such as the Yukon and Innoko rivers.

The remaining area (14%) is comprised of a wide variety of herbaceous and non-vegetated cover types. Moss (4%), wet graminoid (2%), and clear water (2%) were most prevalent in these areas. Much of the moss type occurred as vast expanses of moss, or as stringers of moss between stringers of black spruce lichen hummocks within large lake complexes (south of the Iditarod River and south of the Innoko River within the INWR).

Modeling

Modeling was performed using the shaded relief images and an elevation zone image. The shaded relief images were used to help separate spectrally confused classes (e.g. terrain shadow and deep water). The elevation image was used to model cover types that were limited by slope, aspect or elevation. While these slope, aspect, and elevation limitations did provide good consistent measures for identifying and correcting misclassifications throughout the study area, they cannot be trusted to represent actual vegetation occurrence 100% of the time. Therefore, careful, manual confirmation of model results was performed and anomalies corrected following the execution of each spatial model.

Modeling was primarily used to identify misclassified areas. Since water, wet graminoid, closed and open needleleaf forest, and shadows all have similar spectral signatures, these classes were often confused. Water obviously did not occur on a slope, but terrain shadows or needleleaf forest did. A slope-based model was used to search out shadowed areas that had been misclassified as water or wet graminoid. Tussock tundra signatures were confused with dwarf shrub, but unlike dwarf shrub, tussock tundra does typically not occur at the highest elevations or on steep slopes. Models were used to identify pixels at high elevations and on steep slopes that were classified as tussock tundra, and these pixels were then examined for errors by referencing field notes and aerial photos. Closed and open canopy needleleaf was found only at lower elevations within the project area, so modeling was also used to check for terrain shadow at higher elevations, above tree-line, that had been misclassified as forest.

It is important to note that the modeling process was used primarily to identify *potentially* misclassified cover types throughout the project area. In order to maximize the reliability and classification accuracy in this mapping effort, manual review and editing techniques were utilized to correct the misclassified pixels to their appropriate mapped classification.

Editing

Editing was performed on all classes to various extents depending on how well the iterative classification process worked for each. The edits were verified with field sites, aerial photography, and field notes wherever possible. Some editing centered on ecological differences across the project area. For example, a single signature could classify open needleleaf along the flood plains and bluffs of the Yukon River and water in the ponds and lakes throughout the study area. Editing in this case consisted of correctly labeling and separating classes along ecological boundaries. Because the project area was relatively diverse, this kind of editing was often necessary.

Another kind of editing was needed to classify areas that fell in the middle of the gradient between one class and another, for example, between moss and open needleleaf-lichen. Much of the area within the INWR was often wet and contained a complex of moss, open needleleaf-lichen and wet sedge. Similarly, areas found outside of the INWR were confused between woodland, dwarf shrub, low shrub, and wet sedge. These transitional areas and signatures had to be examined and a classification decision made based on the available data, such as field sites and notes.

The wet graminoid, emergent vegetation, and aquatic bed classes were heavily edited based on aerial photography and field notes. These cover types commonly require extra editing because they are generally both limited in extent and highly variable. Aquatic beds often occur in narrow strips around the edges of lakes, often only a few pixels wide, making it very difficult to obtain reliable ground samples. Wet graminoid sites may be more extensive and common, but they are highly variable with respect to spectral reflectance. Small differences in soil moisture content, density of vegetation, and the proportion of senescent plants drastically affect the reflectance values. Standing water creates a very dark signature, while senescent plants create a very bright signature. Dense, lush graminoid vegetation that completely obscures the presence of water creates a third signature, often confused with other leafy cover types, like tall shrub. Editing of the wet graminoid class was based upon field notes, aerial photography, and the image processors' ability for color and pattern recognition of wet graminoid types on the satellite imagery.

Accuracy Assessment

Some earth cover classes were not adequately represented in the field data available for training and accuracy assessment, primarily because of their scarcity within the project area and because of the high cost of field data collection in conjunction with a limited budget. One option for dealing with this was to collapse classes with a limited sample size into the next highest hierarchical class, thus combining samples from several under-sampled but specific cover types into one better sampled but more general cover type. For example, the closed and open deciduous classes could be grouped into a general deciduous class, or the low shrub other, low shrub lichen, and low shrub willow/alder classes could be grouped into a general low shrub class. This grouping often would result in only eight to ten accuracy assessment classes vs. the 15-20+ classes for which there are accuracy assessment sites available. This approach also tends to increase the overall map accuracy because the number of classes is reduced and the classes that are grouped tend to be spectrally similar classes that would normally show the most confusion. However, this approach may group classes based solely on their specific mapping class labels, versus grouping individual sites based on their ecological composition or function. By

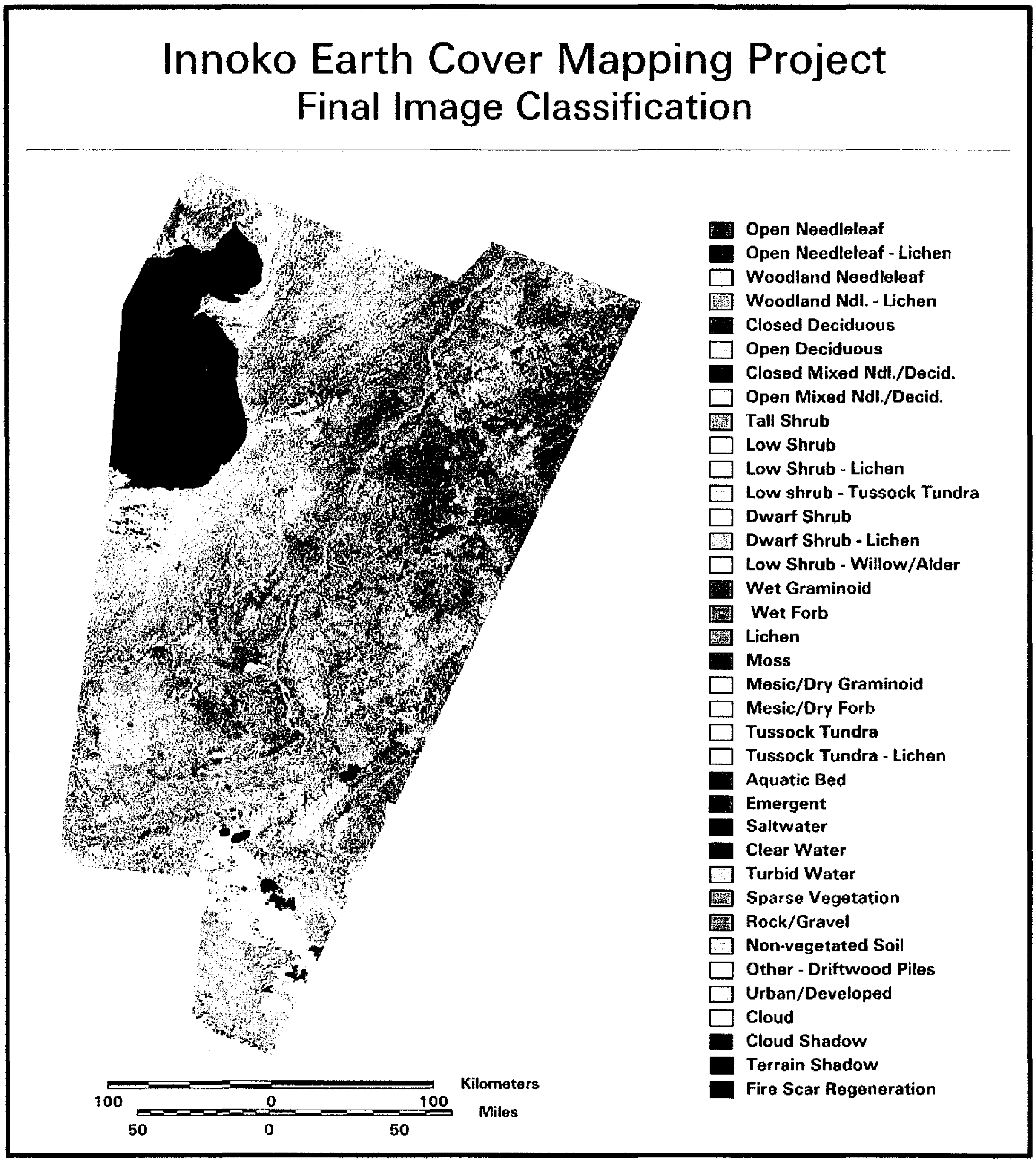

Figure 8. Innoko earth cover classification map.

Table 4. Acreage of earth cover classes within the project area.

Class Name	Aniak Acres	Aniak %*	Unalakleet Acres	Unalakleet %*	INWR Acres	INWR %*	Total Acres	Total %*
Open Needleleaf	385,156	9.2%	1,713,004	17.6%	912,367	11.6%	3,010,527	13.8%
Open Needleleaf - Lichen	53,790	1.3%	81,319	0.8%	1,597,067	20.2%	1,732,176	7.9%
Woodland Needleleaf	175,572	4.2%	495,976	5.1%	680,265	8.6%	1,351,813	6.2%
Woodland Ndl. - Lichen	19,955	0.5%	12,472	0.1%	287,635	3.6%	320,062	1.5%
Closed Deciduous	203,401	4.8%	350,276	3.6%	458,489	5.8%	1,012,166	4.6%
Open Deciduous	29,915	0.7%	133,231	1.4%	256,152	3.2%	419,298	1.9%
Closed Mixed Ndl./Decid.	37,917	0.9%	54,024	0.6%	430,096	5.4%	522,037	2.4%
Open Mixed Ndl./Decid.	278,884	6.6%	487,453	5.0%	467,381	5.9%	1,233,718	5.6%
Tall Shrub	312,653	7.4%	1,227,400	12.6%	314,864	4.0%	1,854,917	8.5%
Low Shrub	408,591	9.7%	711,841	7.3%	670,975	8.5%	1,791,407	8.2%
Low Shrub - Lichen	39,597	0.9%	133,424	1.4%	62,693	0.8%	235,714	1.1%
Low Shrub - Tussock Tundra	376	0.0%	2	0.0%	162,905	2.1%	163,283	0.7%
Dwarf Shrub	416,183	9.9%	950,555	9.8%	381,916	4.8%	1,748,654	8.0%
Dwarf Shrub - Lichen	447,572	10.6%	684,563	7.0%	108,403	1.4%	1,240,538	5.7%
Low Shrub - Willow/Alder	111	0.0%	539,213	5.5%	172	0.0%	539,496	2.5%
Wet Graminoid	34,874	0.8%	188,643	1.9%	170,713	2.2%	394,230	1.8%
Wet Forb	383	0.0%	23	0.0%	7,351	0.1%	7,757	0.0%
Lichen	64,313	1.5%	187,082	1.9%	64,231	0.8%	315,626	1.4%
Moss	41,860	1.0%	77,610	0.8%	364,059	4.6%	483,529	2.2%
Mesic/Dry Graminoid	69,341	1.6%	330,877	3.4%	31,663	0.4%	431,881	2.0%
Mesic/Dry Forb	42	0.0%	444	0.0%	696	0.0%	1,182	0.0%
Tussock Tundra	25	0.0%	211,642	2.2%	14,740	0.2%	226,407	1.0%
Tussock Tundra - Lichen	13,804	0.3%	285,250	2.9%	37,377	0.5%	336,431	1.5%
Aquatic Bed	3,241	0.1%	43	0.0%	16,232	0.2%	19,516	0.1%
Emergent	47,134	1.1%	70,418	0.7%	16,146	0.2%	133,698	0.6%
Saltwater	0	n/i	2,351,086	n/i	0	n/i	2,351,086	n/i
Clear Water	203,600	4.8%	224,162	2.3%	164,008	2.1%	591,770	2.7%
Turbid Water	50,728	1.2%	164,789	1.7%	101,766	1.3%	317,283	1.5%
Sparse Vegetation	439	0.0%	153,916	1.6%	2,467	0.0%	156,822	0.7%
Rock/Gravel	57,914	1.4%	39,470	0.4%	18,614	0.2%	115,998	0.5%
Non-vegetated Soil	192	0.0%	10,820	0.1%	2,583	0.0%	13,595	0.1%
Driftwood	0	0.0%	108	0.0%	0	0.0%	108	0.0%
Urban/Developed	75	0.0%	0	0	620	0.0%	695	0.0%
Cloud	677,994	16.1%	79,941	0.8%	17	0.0%	757,952	3.5%
Cloud Shadow	100,122	2.4%	48,593	0.5%	124	0.0%	148,839	0.7%
Terrain Shadow	4,259	0.1%	91,857	0.9%	4,776	0.1%	100,892	0.5%
Fire Scar Regeneration	22,780	0.5%	0	0.0%	88,731	1.1%	111,511	0.5%
Total	**4,202,793**	**100%**	**12,091,527**	**100%**	**7,898,294**	**100%**	**24,192,614**	**100%**

*** Saltwater excluded from percentage calculations**

grouping classes in this manner, one loses all ability to evaluate and measure the relationship between regions of the map that classify nicely into the "heart" of a mapping class and those regions that occur on the classification and ecological boundaries between the discrete mapping classes.

A better option for dealing with this is presented in the error matrices produced for this project (Appendix E). These matrices retained all the cover types for which there were accuracy assessment sites available, but accounted for sites that fall near the ecological boundary between two cover types. This was accomplished by examining all "off-diagonal" or incorrect sites to determine why they were misclassified and if the error was considered "acceptable" or "unacceptable" at a +/-5% level of variation in the percent cover estimations.

For example, the vegetation caller may interpret a site to contain 20% tree cover (17% black spruce, 5% paper birch) and 80% various shrub and herbaceous understory species. This interpretation results in a woodland needleleaf label for the site. If the final map labeled the majority of this site as open needleleaf, a standard error matrix would tally this label as an incorrect label. Since the literature generally accepts that even the most experienced visual estimates of earth cover consider a range of variation in interpretation of +/-10% to be acceptable, this particular accuracy assessment site containing 20% tree cover would also be considered acceptably classified as open needleleaf and tallied as such. Evaluating the earth cover classification in this manner provides the end user with a more realistic measure of reliability of the classified map as it relates to the actual continuum of vegetation composition, as compared to simply lumping mapping classes for evaluation based on their discrete class name.

The error matrices represent the reliability/accuracy of the earth cover classification. Accuracy assessment data is presented for each sub-project area separately. The error matrices should not be combined to produce one error matrix for the entire project area because the processing was done separately for each project area and then stitched together after the classification for each was completed. The accuracy of classes within each project area is independent of the class accuracies in the other project areas. The error matrices present values for users accuracy, producers accuracy, and the overall accuracy for 0% and +/-5% variation in the vegetation caller's interpretation of the reference data. In the error matrices, numbers along the main diagonal of the matrices indicate exact matches between the reference labels and map labels of the accuracy assessment sites. A tally of these numbers, divided by the total number of sites, indicates the overall accuracy of the map at the 0% variation in interpretation level. If two numbers occupy a non-diagonal cell, the left number indicates an acceptable match between the reference data site and the map assuming a +/- 5% variation in reference data interpretation. The number on the right indicates the number of sites that are not acceptable matches. A tally of the numbers within the diagonal along with the acceptable numbers in the off-diagonal cells (left number(s)) indicates the overall accuracy of the map at the +/- 5% variation in interpretation level.

A number of important analyses can be made regarding the relationship of the mapped data with the actual vegetation distributions throughout the study area using this method of accuracy assessment. Since the off-diagonal acceptable matches are presented, an indication of the number of field sites that represent vegetation compositions on the boundary of two or more mapping classes is given. The acceptance or non-acceptance of each accuracy assessment site with an off-diagonal map class provides insight into the vegetation composition of that reference site. For instance, in Appendix E - Table 3, of the 17 accuracy assessment sites with a reference label of woodland needleleaf, one site was an acceptable match with open needleleaf, one was an acceptable match with woodland needleleaf lichen, one was an unacceptable match with closed deciduous, and one was a unacceptable match with dwarf shrub lichen. The remainder of the sites (13) were diagonal matches and mapped as woodland needleleaf. The off-diagonal matches indicate that one of the woodland needleleaf accuracy assessment sites was on the border between woodland and open needleleaf (20-25% tree canopy cover) and one site was on the border of woodland needleleaf and woodland needleleaf lichen (15-20% lichen cover). Since the number of misclassified sites are still indicated in the matrix, a user can determine in which classes the map is least reliable and with which mapping classes the unreliable classes are confused.

Aniak Project

The overall accuracy for the Aniak project area was 83% at the +/-0% level of variation and 86% at the +/-5% level of variation (Appendix E, Table 1). The number of accuracy assessment sites for all classes was severely limited and the accuracy figures must be viewed as a general indication of accuracy and not as a statistically robust accuracy assessment.

Producers and users accuracies for all classes with five or more accuracy assessment sites were high except for the open mixed needleleaf/deciduous class. This was a difficult class to map because of its spectral similarity to a variety of other classes including open and woodland needleleaf, closed mixed needleleaf deciduous, open and closed deciduous, and tall shrub. The only other trend indicated by the error matrix was the possibility that the woodland needleleaf class was slightly over-represented in the final map. Although all five woodland needleleaf accuracy assessment sites were correctly identified, there were three additional non-woodland sites that were incorrectly labeled as woodland needleleaf in the final map. The field data for one of these sites (site #130) estimated a percent cover of 5% black spruce. Therefore, the woodland needleleaf label for this site was considered acceptable at the +/-5% level. The remaining two sites were not considered acceptable errors.

Unalakleet Project

The overall accuracy for the Unalakleet project area was 72% at the +/-0% level of variation and 80% at the +/-5% level of variation (Appendix E, Table 2). The significant increase in accuracy at the +/-5% level highlights two important considerations in assessing map accuracy. First, there is difficulty in assigning discrete class labels to the continuous nature of vegetation communities. Second, slight variations in the estimated percent cover of species can change the class label for a field site. Both of these concerns are addressed to some extent by computing accuracy at the +/-5% level in addition to the standard +/-0% level.

Open needleleaf, closed deciduous, tall

shrub, dwarf shrub lichen, and low shrub willow/alder classes all had producers accuracies greater than 80% at both the +/-0% and +/-5% levels of variation. All of these classes had well over 20 training sites available for use in the classification process and the resulting accuracy levels for these classes demonstrate the importance of an adequate sample size when performing image classifications.

Several vegetation classes had the same, or very similar, plant species composition and were distinguished only by minor differences in percent cover of the component species. An example of these classes within the Unalakleet project area were dwarf shrub, dwarf shrub lichen, mesic/dry graminoid, tussock tundra, tussock tundra lichen, and lichen. Nearly all field sites in these classes share some percentage of the following species: *Betula nana/glandulosa, Ledum palustre, Vaccinium uliginosum, Carex spp., Eriophorum spp.*, lichen *spp.*, moss *spp.*, grass *spp.*, and litter. Small changes in the percent coverage of the vegetative components in these classes could change the appropriate class label based on the discrete nature of the classification scheme. In such cases, the calculated class often did not agree with the class label observed by the crew's vegetation caller. The field data for the Unalakleet project included 158 sites for which the calculated class label did not agree with the observed class label given by the biologist on the field crew. For 70 of these sites, the confusion was between the dwarf shrub, lichen, and graminoid classes listed in Table 4. Several of these were selected as accuracy assessment sites, as indicated by the abundance of off-diagonal entries in the error matrix for these classes.

The large increase in producers accuracy from the +/-0% to the +/-5% level of variation for the woodland needleleaf class is, again, an indication that many of the accuracy sites for this class fell on the boundary between woodland needleleaf and other cover type classes. Four woodland needleleaf sites were mapped as open needleleaf in the final map. Three of these sites were within 5% of falling into the open needleleaf class based on the classification scheme and were considered "acceptable" errors. Even after including "acceptable" errors, the producers accuracy at the +/-5% level of variation for the woodland needleleaf class was only 67%. This low accuracy indicates the difficulty in separating the woodland needleleaf class from several other spectrally similar classes. Only 10% - 24% needleleaf species need to be present for a site to be labeled woodland needleleaf. This means that 76% to 90% of the spectral signature for these sites is derived from non-needleleaf species. This makes it difficult, for example, to discriminate a woodland needleleaf site with a heavy tall shrub understory from a tall shrub site with some spruce present.

Four other classes, moss, lichen, wet graminoid, and dry graminoid, had producers accuracies that fell below 70% even at the +/-5% level of variation. These bryoid and graminoid cover types have similar species components to each other and to the dwarf shrub cover types. Most of the confusion in these classes occurred with the dwarf shrub and graminoid cover types. A noticeable pattern appears in the off-diagonal lichen sites. All five of these sites were mapped as some other majority class with a lichen sub-component (i.e. low shrub lichen, dwarf shrub lichen, or tussock tundra lichen). This would indicate that the presence of lichen at greater than 20% cover is detected very well by Landsat TM imagery, but there is difficulty in separating pure lichen sites from lichen sites with a significant shrub or tussock component.

Innoko National Wildlife Refuge Project

Nineteen earth cover classes were assessed for accuracy based on the fieldwork conducted in the INWR. The overall accuracy was 79% at the +/- 0% level and 84% at the +/- 5% level of variation (Appendix E, Table 3). Half of the class accuracies exceeded 70% at the +/- 0% variation level for both users and producers accuracy. Much of the confusion indicated by the error matrix occurred between classes that contained similar vegetative characteristics such as the closed mixed needleleaf/deciduous and open mixed needleleaf/deciduous classes, and the open needleleaf and woodland needleleaf classes.

Producers and users accuracy of the open needleleaf class was high (85% and 81% respectively), as would be expected since it was the most extensive cover type. The woodland needleleaf class also had a relatively high producers accuracy (76%), but a slightly lower users accuracy (68%). The high users accuracy indicates that an area classified as woodland needleleaf on the map has a high likelihood of being woodland needleleaf on the ground. The lower producers accuracy would indicate that some woodland needleleaf areas on the ground are being classed as something other than woodland needleleaf on the map. As in the Unalakleet project area, this result is partly because of the nature of the woodland class. It is a difficult class to map, due to its high diversity of possible understory components. For example, a woodland site could include 40% graminoid cover and just 10% trees, or it could contain 20% trees and 50% shrubs. In some cases, cover types other than trees dominate the signature of woodland sites, while in other cases the spruce trees may dominate.

The most difficult portion of the classification was attempting to distinguish the open mixed needleleaf/deciduous class. This is reflected in the relatively low users and producers accuracies. This is partly a result of the limited number of samples that were available for classifying this class and mostly because of the spectral similarities exhibited between this class and several other classes. The species composition of this class can be very similar to other classes, and small differences in the percentage of a species or height of a species can easily change the site label from one class to another, without largely affecting the spectral signature. For example, a site with 10% spruce and 35% willow over four meters tall would be labeled as open mixed. If the percentage of willow were 5% greater (40%), the site would then be labeled open deciduous. However, if the willow was less than four meters tall in either of those situations it would then be considered a shrub and the site would be labeled as woodland needleleaf. These changes in class label, with minor changes in species composition or height are, again, the result of forcing discrete cover type boundaries onto an ecological gradient and are inherent to any classification scheme. Compounding this problem was the fact that even sites that were not near the boundary between two classes were often spectrally inseparable.

Producers accuracies of the low shrub and dwarf shrub classes were very high, 89% for both at the +/-5% level. As with the open and woodland needleleaf classes, this is not surprising since such a large portion of the project area consisted of these two classes and there was a relatively large number of field sites collected for these classes. The users accuracies were somewhat lower for these classes (low shrub 77% and dwarf shrub 74%), indicating that they were somewhat over-represented in the final maps.

The tall shrub users and producers accuracies were both above 80% at the +/- 0% level. Although not indicated by the error matrix, it is the image processor's opinion that some confusion occurred between the tall shrub class and the deciduous and mixed needleleaf/deciduous forest classes. This is not surprising since the major components of all these classes are willow, birch, and alder, and there is very little spectral difference between these species.

A significant portion of the confusion in the final maps is associated with the dwarf shrub and herbaceous classes as indicated by the clustering of off-diagonal occurrences in that portion of the error matrix. As discussed in the Unalakleet error matrix section, this is a result of the high degree of similarity in species composition for these earth cover types.

Large complexes of patchy black spruce, lichen, and moss were found throughout the central part of the refuge, which resulted in few field surveys. However, because ample sites of these classes were taken throughout the rest of the refuge, these classes were well mapped in this area. Even though no accuracy assessment sites were taken in this area, a good correlation existed between field notes and areas marked on the field maps and the resulting classification. In addition, the Innoko Refuge staff found agreement between the classification and independent field verification.

Field surveys were not conducted in the most southwestern section of the refuge as a result of long distances between this part of the refuge and the base camp. The lack of training sites and field notes may have resulted in a less accurate classification in this area. Independent field reviews of the map in this area would be warranted.

Although not strongly indicated by the error matrix, there was difficulty in separating the low shrub, dwarf shrub, moss, wet graminoid, and emergent vegetation classes during the classification process and there is likely some confusion between these classes in the final map. Several areas within the refuge were flooded during field data collection, and several areas on the satellite image appeared more flooded than was observed in the field. As a result, the estimations of water present on field sites may not correspond with what is present on the image, thus showing varying results in the classification. Discussions with the refuge staff confirmed that many of the low-lying areas near rivers and streams tend to be intermittently flooded throughout the year, so the timing of fieldwork impacts the quality of the classification. Users of the classification need to acknowledge that these factors influence the overall quality of the data set.

Discussion

While the accuracy assessment performed in this project is by no means a robust test of the classification, it does give the user some confidence in using the classification. It also provides enough detail for the end user to determine where discrepancies in the classification may cause a problem while using the data. It is also important to note the variations in the dates of the imagery, aerial photographs, and field data. For this project, the imagery was from August 26, 1991, and August 8, 1995. The aerial photographs spanned a nine-year period from 1976 through 1985, and the field data was collected in July 1998. Differences due to environmental changes from the different sources may have had an impact on the accuracy assessment.

Final Products

The final products included a digital earth cover classification, a hard-copy map of the entire project area, and digital database of field data collected for 1544 field sites. The digital map was delivered in ArcGrid and ERDAS Imagine format. The unclassified Landsat TM images used to create the cover type map were also delivered. All vector files are stored in ArcInfo format. The field site database, a species list, and the site photo tables were stored in Dbase IV format. Digital photos of the field sites are stored as JPEG files. All of the delivered datasets were loaded into ArcView projects for display purposes.

Conclusions

The Bureau of Land Management (BLM) – Alaska and Ducks Unlimited, Inc. (DU) have been cooperatively mapping wetlands and associated uplands in Alaska using remote sensing and GIS technologies since 1988. This project continued the mapping in a joint effort with the Innoko National Wildlife Refuge (INWR) to map the BLM's Unalakleet area lands, the INWR, portions of the Yukon Delta NWR, and State and Native lands between and surrounding BLM and refuge lands.

The project area was classified into 34 earth cover categories with overall accuracies of 86%, 80%, and 84% at the +/-5% level of variation for the Aniak, Unalakleet, and INWR project areas, respectively. The digital database and map of the classification were the primary products of this project along with hard copy maps of the classification, a complete field database including digital site photos, and an ArcView project.

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Appendices

Appendix A. Alaska Earth Cover Classification Class Descriptions

1.0 Forest
Needleleaf and Deciduous Trees-
The needleleaf species generally found were white spruce (*Picea glauca*) and black spruce (*P. mariana*). White spruce tended to occur on warmer sites with better drainage, while black spruce dominated poorly drained sites, and was more common in the interior of Alaska. The needleleaf classes included both white and black spruce.

The deciduous tree species generally found were paper birch (*Betula papyrifera*), aspen (*Populus tremuloides*) and cottonwood (*P. balsamifera* and *P. trichocarpa*). Black cottonwoods (*P. trichocarpa*) were generally found only in river valleys and on alluvial flats. Under some conditions willow (*Salix* spp.) and alder *(Alnus rubra)* formed a significant part of the tree canopy. Deciduous stands were found in major river valleys, on alluvial flats, surrounding lakes, or most commonly, on the steep slopes of small hills. Mixed deciduous/coniferous stands were present in the same areas as pure deciduous stands. While needleleaf stands were extremely extensive, deciduous and mixed deciduous/coniferous stands were generally limited in size. The only exception to this rule was near major rivers, where relatively extensive stands of pure deciduous trees occur on floodplains and in ancient oxbows.

1.1 Closed Needleleaf
At least 60% of the cover was trees, and ≥75% of the trees were needleleaf trees. Closed needleleaf sites were rare because even where stem densities were high, the crown closure remained low. This class was not found during the fieldwork for this project. There are likely small areas of closed needleleaf within the project area, but they were very uncommon. In most areas in Alaska, closed needleleaf stands typically are found only on the floodplains of major rivers.

1.2 Open Needleleaf
From 25-59% of the cover was trees, and ≥75% of the trees were needleleaf with a height > one meter. This class was very common throughout the project area. A wide variety of understory plant groups were present, including low and tall shrubs, forbs, grasses, sedges, horsetails, mosses, and lichen.

1.21 Open Needleleaf Lichen
From 25-59% of the cover was trees, ≥75% of the trees were needleleaf with a height > one meter, and ≥ 20% of the understory was lichen.

1.3 Woodland Needleleaf
From 10-24% of the cover was trees, and ≥75% of the trees were needleleaf. Woodland understory was extremely varied and included most of the shrub, herbaceous, or graminoid types present in the project area.

1.31 Woodland Needleleaf Lichen
From 10-24% of the cover was trees, ≥75%

of the trees were needleleaf, and ≥ 20% of the understory was lichen.

1.4 Closed Deciduous (Mixed Deciduous Species 1.44)
At least 60% of the cover was trees, and ≥75% of the trees were deciduous. Occurred in stands of limited size, generally on the floodplains of major rivers, but occasionally on hillsides or riparian gravel bars, or bordering small lakes. This class included paper birch, aspen, or cottonwood.

1.41 Closed Birch
At least 60% of the cover was trees, ≥75% of the trees were deciduous, and ≥75% of the trees were paper birch (*Betula Papyrifera).*

1.42 Closed Aspen
At least 60% of the cover was trees, ≥75% of the trees were deciduous, and ≥75% of the trees were aspen.

1.43 Closed Poplar
At least 60% of the cover was trees, ≥75% of the trees were deciduous, and ≥75% of the trees were cottonwood/balsam poplar.

1.5 Open Deciduous (Mixed Deciduous Species 1.54)
From 25-59% of the cover was trees, and ≥75% of the trees were deciduous. There was generally a needleleaf component to this class, though it was less than 25%.

1.51 Open Birch
From 25-59% of the cover was trees, ≥75% of the trees were deciduous, and ≥75% of the trees were paper birch.

1.52 Open Aspen
From 25-59% of the cover was trees, ≥75% of the trees were deciduous, and ≥75% of the trees were aspen.

1.53 Open Cottonwood
From 25-59% of the cover was trees, ≥75% of the trees were deciduous, and ≥75% of the trees were cottonwood.

1.6 Closed Mixed Needleleaf/Deciduous
At least 60% of the cover was trees, but neither needleleaf nor deciduous trees made up ≥75% of the tree cover. This class was uncommon and found mainly along the meanders of major rivers.

1.7 Open Mixed Needleleaf/Deciduous
From 25-59% of the cover was trees, but neither needleleaf nor deciduous trees made up ≥75% of the tree cover. This class occurred in regenerating burns, on hill slopes, or bordering lakes.

2.0 Shrub
The tall and low shrub classes were dominated by willow species, dwarf birch (*Betula nana* and *B. glandulosa*), and *Vaccinium* species, with alder being common on tall shrub sites and somewhat less common on low shrub sites. Occassionally, the proportions of willow to birch and the relative heights of the shrub species varied widely, which created difficulties in determining whether a site was made up of tall or low shrub. As a result, the height of the shrub species making up the largest proportion of the site dictated whether the site was called a low or tall shrub. The shrub heights were averaged within a genus, as in the case of a site with both tall and low willow shrubs. Dwarf shrub was usually composed of dwarf ericaceous shrubs and Dryas species, but often included a variety of forbs and graminoids. The dryas/dwarf shrub sites were nearly always found on hilltops or mountain plateaus, and typically included some rock. Ericaceous dwarf shrub types were found at high elevations, and in vast expanses in the lower elevation, treeless areas near Norton Sound.

2.1 Tall Shrub
Shrubs made up 25-100% of the cover and either ≥25% of the site consisted of shrubs ≥1.3 meters in height, OR shrubs ≥1.3 meters were the most common shrubs. This class generally had a major willow component that was mixed with dwarf birch and/or alder, but could also have been dominated by nearly pure stands of alder. It was found most often in wet drainages, at the head of streams, or on slopes.

2.21 Willow/Alder Low Shrub
Shrubs made up 25-100% of the cover, ≥75% of the shrub cover was willow and/or alder, and either ≥25% of the site consisted of shrubs .25-1.3 meters OR shrubs .25-1.3 meters were the most common shrubs.

2.22 Other Low Shrub/Tussock Tundra
Shrubs made up 25-100% of the cover, ≥35% of the cover was made up of tussock forming cotton grass *(Eriophorum vaginatum*), and either ≥25% of the site consisted of shrubs .25-1.3 meters in height OR shrubs .25-1.3 meters were the most common shrubs. This class was found in extensive patches in flat, poorly drained areas. It was generally made up of cotton grass, ericaceous shrubs, willow and/or alder shrubs, other graminoids, and an occasional black spruce.

2.23 Other Low Shrub/Lichen
Shrubs made up 25-100% of the cover, ≥20% of the cover was made up of lichen, and either 25% of the site consisted of shrubs .25-1.3 meters in height OR shrubs .25-1.3 meters were the most common shrubs. This class was found at mid-high elevations. The shrub species in this class were nearly always dwarf birch.

2.24 Other Low Shrub
Shrubs made up 25-100% of the cover and either 25% of the site consisted of shrubs .25-1.3 meters in height OR shrubs .25-1.3 meters were the most common shrubs. This was the most common low shrub class. It was generally composed of dwarf birch, willow species, *Vaccinium* species, and *ledum* species.

2.31 Dwarf Shrub/Lichen
Shrubs made up 25-100% of the cover, ≥20% of the cover was made up of lichen and either 25% of the site consisted of shrubs ≤ .25 meters in height OR shrubs ≤ .25 meters were the most common shrubs. This class was generally made up of dwarf ericaceous shrubs and *Dryas* species, but often included a variety of forbs and graminoids. Dryas type dwarf shrub/lichen sites were nearly always found at higher elevations on hilltops, mountain slopes, and plateaus. Ericaceous dwarf shrub/lichen types were found at high elevations and in large expanses in the areas around Norton Sound.

2.32 Other Dwarf Shrub
Shrubs made up 40-100% of the cover and either 25% of the site consisted of shrubs ≤ .25% meters in height OR shrubs ≤ .25 meters were the most common shrubs. This class was generally made up of dwarf ericaceous shrubs and *Dryas* species, but often included a variety of forbs and graminoids, and some rock. Dryas type dwarf shrubs were nearly always found at higher elevations on hilltops, mountain slopes, and plateaus. Ericaceous dwarf shrub types were found at high elevations and in large expanses in the areas around Norton Sound.

3.0 Herbaceous
The classes in this category included bryoids, forbs, and graminoids. Bryoids and forbs were present as a component of most of the other classes but rarely appeared in pure stands. Graminoids, such as *Carex*

spp., *Eriophorum* spp., or bluejoint grass (*Calamagrostis canadensis*) may have dominated a community.

3.11 Lichen
Composed of ≥40% herbaceous species, ≤25% water, and ≥ 50% bryoid species of which ≥50% were lichen species.

3.12 Moss
Composed of ≥40% herbaceous species, ≤25% water, and ≥50% bryoid species of which ≥50% were moss species.

3.21 Wet Graminoid
Composed of ≥40% herbaceous species, 5-25% water or ≥20% *Carex aquatilis*, and where ≥50% of the herbaceous cover was graminoid. This class represented wet or seasonally flooded sites. It was often present in stands too small to be mapped at the current scale.

3.22 Web Forb
Composed of ≥40% herbaceous species, 5-25% water or ≥20% *Carex aquatilis*, and where <50% of the herbaceous cover was graminoid.

3.31 Tussock Tundra
Composed of ≥40% herbaceous species, ≤25% water, where ≥50% of the herbaceous cover was graminoid, and ≥35% of the cover was made up of tussock forming cotton grass. Tussock tundra often included ericaceous shrubs, willow and/or alder shrubs, forbs, bryoids, and other graminoids, and was usually found at lower elevations in flat, poorly drained areas.

3.311 Tussock Tundra/Lichen
Composed of ≥40% herbaceous species, ≤25% water, where ≥50% of the herbaceous cover was graminoid, and ≥20% of the cover was lichen, and ≥35% of the cover was made up of tussock forming cotton grass. Tussock tundra often included ericaceous shrubs, willow and/or alder shrubs, forbs and other graminoids, and was usually found at lower elevations in flat, poorly drained areas. This class included a major component of lichen.

3.32 Mesic/Dry Sedge Meadow
Composed of ≥40% herbaceous species, ≤5% water, and <35% tussock, with the non-bryoid herbaceous species being ≥50% graminoid (sedge, grass, tussock) and ≥50% sedge (i.e., dominated by sedge species).

3.33 Mesic/Dry Grass Meadow
Composed of ≥40% herbaceous species, ≤5% water, and <35% tussock, with the non-bryoid herbaceous species being ≥50% graminoid (sedge, grass, tussock) and ≥50% by grass (i.e., dominated by grass species).

3.34 Mesic/Dry Graminoid
Composed of ≥40% herbaceous species, ≤5% water, and <35% tussock, with the non-bryoid herbaceous species being ≥50% graminoid (sedge, grass, tussock) but <50% of either sedge or grass (i.e., neither sedge nor grass is clearly dominant).

3.35 Mesic/Dry Forb
Composed of ≥40% herbaceous species, ≤5% water, with the non-bryoid herbaceous species being <50% graminoid. Regenerating burn areas dominated by fireweed *(Epilobium angustifolium)* fell into the mesic/dry forb category. However, forb communities without significant graminoid or shrub components were generally rare in the interior of Alaska.

4.0 <u>Aquatic Vegetation</u>
The aquatic vegetation was divided into aquatic bed and emergent classes. The aquatic bed class was dominated by plants with leaves that float on the water surface, generally pond lilies (*Nuphar polysepalum*).

The emergent vegetation class was composed of species that were partially submerged in the water, and included freshwater herbs such as horsetails (*Equisetum* spp.), marestail (*Hippuris* spp.), and buckbean (*Menyanthes trifoliata*).

4.1 Aquatic Bed
Aquatic vegetation made up ≥20% of the cover, and ≥20% of the aquatic vegetation was composed of plants with floating leaves. This class was generally dominated by pond lilies, pondweed *(Potamogeton spp.*), and bur-reed *(Sparghanium spp.*).

4.2 Emergent Vegetation
Aquatic vegetation made up ≥20% of the cover, and ≥20% of the aquatic vegetation was composed of plants other than pond lilies. Generally included freshwater herbs such as horsetails, marestail, or buckbean.

5.1 Snow
Composed of ≥50% snow.

5.2 Ice
Composed of ≥50% ice.

5.3 Clear Water
Composed of ≥80% clear water. A general separation between saltwater and freshwater was made in this project. This allowed for the exclusion of the nearly two million acres of saltwater within Norton Sound when calculating acreage percentages for the project area. The split between saltwater and freshwater is very generalized and was determined by a five class unsupervised classification and significant amounts of editing along the land/saltwater boundary. Distinctions on the map between saltwater and freshwater within bays and estuaries is very arbitrary and should not be used for scientific analyses.

5.4 Turbid Water
Composed of ≥80% turbid water.

6.0 Barren
This class included sparsely vegetated sites, (e.g., abandoned gravel pits or riparian gravel bars,) along with non-vegetated sites, (e.g., barren mountaintops or glacial till).

6.1 Sparse Vegetation
At least 50% of the area was barren, but vegetation made up ≥20% of the cover. This class was often found on riparian gravel bars, on rocky or very steep slopes, and in abandoned gravel pits. The plant species were generally herbs, graminoids, and bryoids.

6.2 Rock/Gravel
At least 50% of the area was barren, ≥50% of the cover was composed of rock and/or gravel, and vegetation made up less than 20% of the cover. This class was most often found on hilltops and along rivers and shorelines.

6.3 Non-vegetated Soil
At least 50% of the area was barren, ≥50% of the cover was composed of mud, silt, sand, or soil, and vegetation made up less than 20% of the cover. This type was generally along shorelines or rivers.

7.0 Urban/Roads
At least 50% of the area was urban and/or roads. This class was only used in the vicinity of Galena. Any other roads/development large enough to be detected by the Landsat Thematic Mapper (TM) imagery were labeled as rock/gravel.

8.0 Agriculture
At least 50% of the area was agriculture. This class was not found in this project area.

9.1 Cloud/Shadow
At least 50% of the cover was cloud or shadow.

9.2 Cloud
At least 50% of the cover was made up of clouds.

9.3 Cloud Shadow
At least 50% of the cover was made up of cloud shadows.

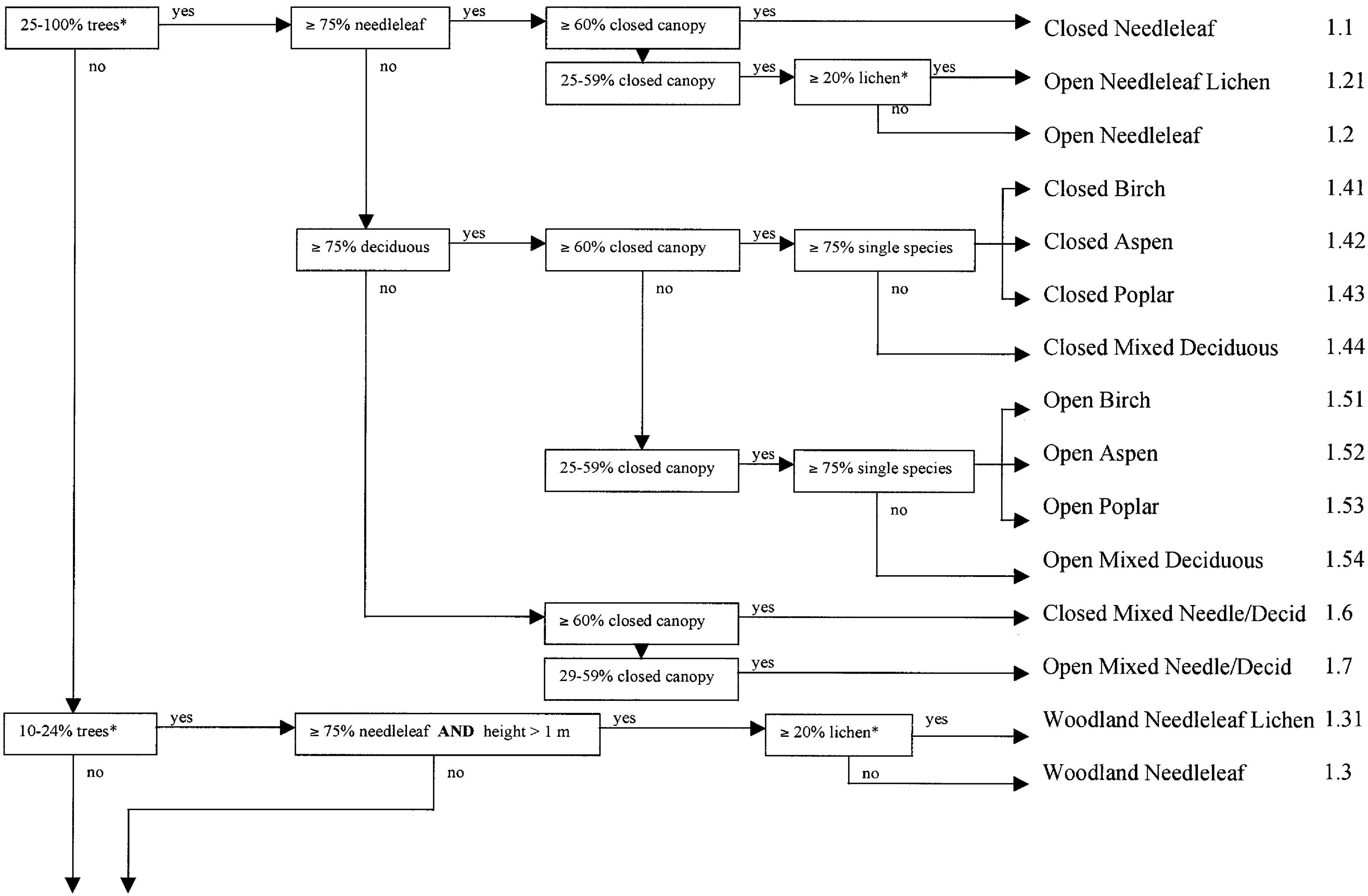
9.4 Terrain Shadow
At least 50% of the cover was made up of terrain shadows.

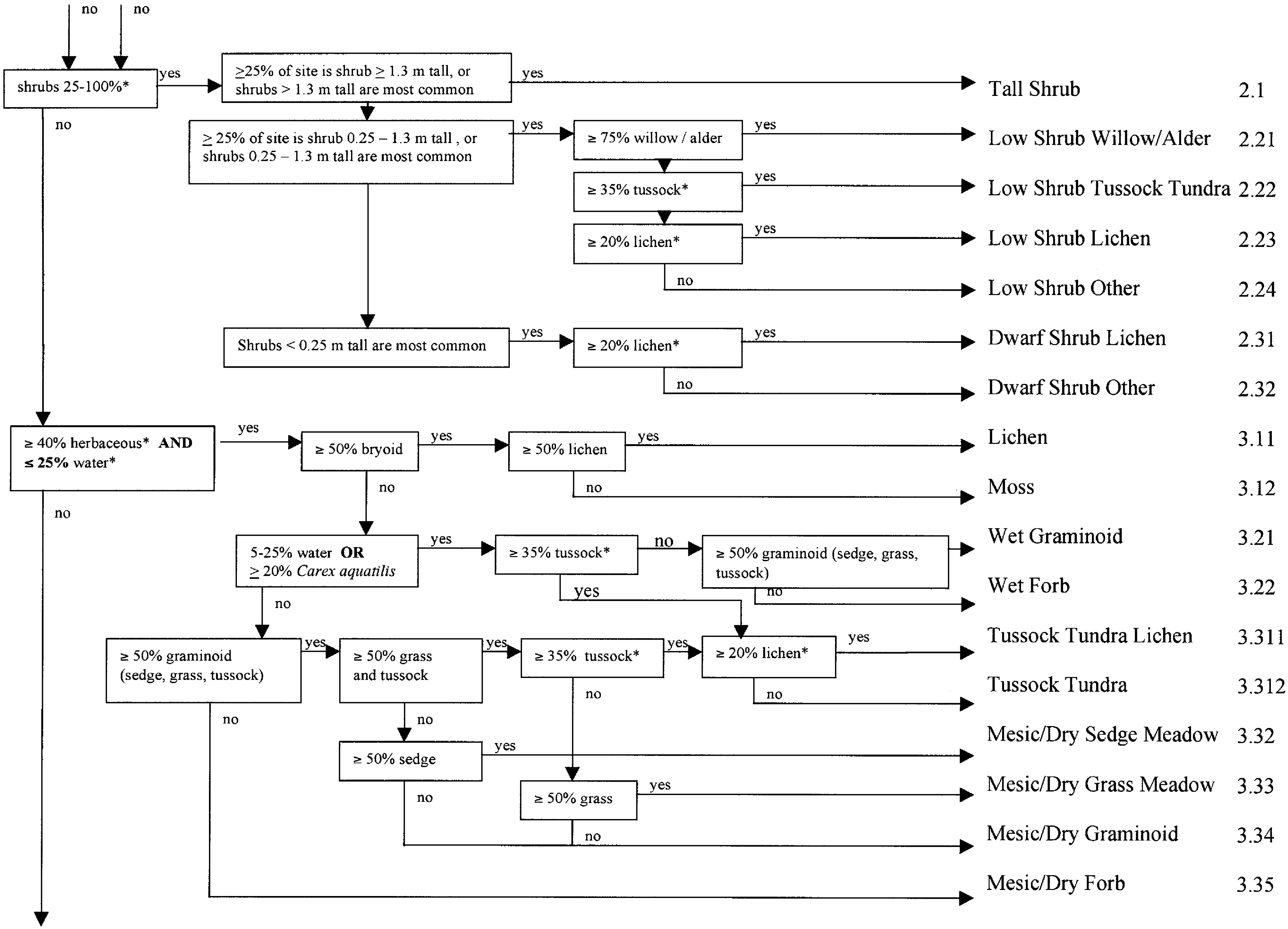
10.0 Other

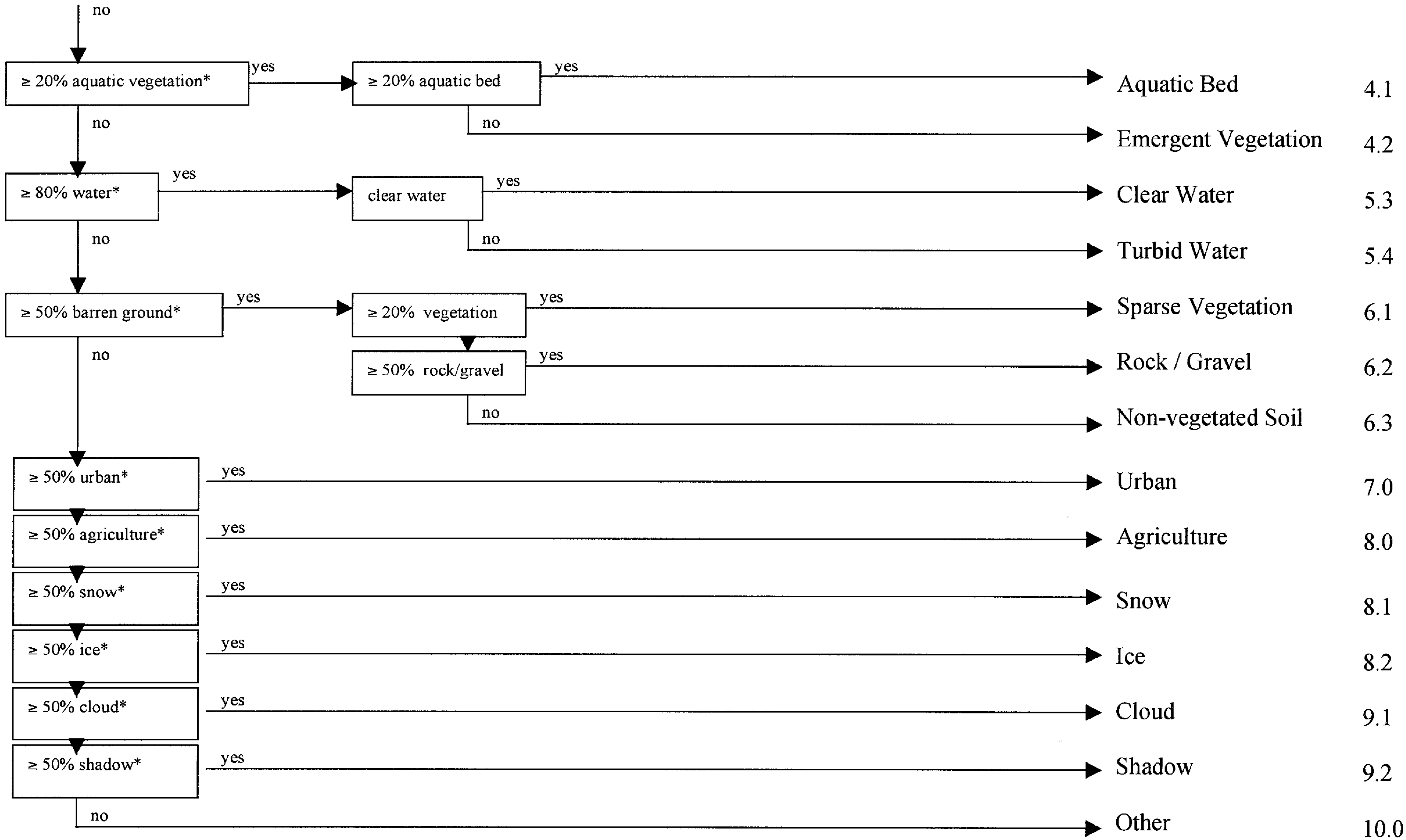
Sites that did not fall into any other category were assigned to Other. For example, sites containing 25%-80% water, <25% shrub and <20% aquatic vegetation were classed as Other. Sites classed as Other may have also included extensive areas of vegetative litter, such as downed wood.

Appendix B. Alaska Earth Cover Classification Scheme

(*Indicates %of Total Land Cover, otherwise % of Major Category)




no
no
shrubs 25-100%*
yes
≥25% of site is shrub ≥ 1.3 m tall, or shrubs > 1.3 m tall are most common
yes
Tall Shrub 2.1
no
≥ 25% of site is shrub 0.25 – 1.3 m tall , or shrubs 0.25 – 1.3 m tall are most common
yes
≥ 75% willow / alder
yes
Low Shrub Willow/Alder 2.21
≥ 35% tussock*
yes
Low Shrub Tussock Tundra 2.22
≥ 20% lichen*
yes
Low Shrub Lichen 2.23
no
Low Shrub Other 2.24
Shrubs < 0.25 m tall are most common
yes
≥ 20% lichen*
yes
Dwarf Shrub Lichen 2.31
no
Dwarf Shrub Other 2.32
≥ 40% herbaceous* AND ≤ 25% water*
yes
≥ 50% bryoid
yes
≥ 50% lichen
yes
Lichen 3.11
no
Moss 3.12
no
no
5-25% water OR ≥ 20% Carex aquatilis
yes
≥ 35% tussock*
no
≥ 50% graminoid (sedge, grass, tussock)
Wet Graminoid 3.21
yes
no
Wet Forb 3.22
no
≥ 50% graminoid (sedge, grass, tussock)
yes
≥ 50% grass and tussock
yes
≥ 35% tussock*
yes
≥ 20% lichen*
yes
Tussock Tundra Lichen 3.311
no
no
Tussock Tundra 3.312
no
no
≥ 50% sedge
yes
Mesic/Dry Sedge Meadow 3.32
≥ 50% grass
yes
Mesic/Dry Grass Meadow 3.33
no
no
Mesic/Dry Graminoid 3.34
Mesic/Dry Forb 3.35


no
≥ 20% aquatic vegetation*
yes
≥ 20% aquatic bed
yes
Aquatic Bed
4.1
no
no
Emergent Vegetation
4.2
≥ 80% water*
yes
clear water
yes
Clear Water
5.3
no
no
Turbid Water
5.4
≥ 50% barren ground*
yes
≥ 20% vegetation
yes
Sparse Vegetation
6.1
no
≥ 50% rock/gravel
yes
Rock / Gravel
6.2
no
Non-vegetated Soil
6.3
≥ 50% urban*
yes
Urban
7.0
≥ 50% agriculture*
yes
Agriculture
8.0
≥ 50% snow*
yes
Snow
8.1
≥ 50% ice*
yes
Ice
8.2
≥ 50% cloud*
yes
Cloud
9.1
≥ 50% shadow*
yes
Shadow
9.2
no
Other
10.0

Appendix C. Earth Cover Class Acreage Summaries by General Status

Source for Appendix C, Tables 1-8 is the intersection of the Innoko Earth Cover Classification and the BLM "genstat" coverage compiled on September 11, 2001.

Table C-1. Earth cover class acreages for BLM lands.

CLASSNAME	ACRES	%
Open Needleleaf	1,107,407	18.7%
Open Needleleaf - Lichen	239,071	4.0%
Woodland Needleleaf	462,959	7.8%
Woodland Ndl. - Lichen	67,092	1.1%
Closed Deciduous	209,389	3.5%
Open Deciduous	103,917	1.8%
Closed Mixed Ndl./Decid.	82,514	1.4%
Open Mixed Ndl./Decid.	292,466	4.9%
Tall Shrub	648,474	10.9%
Low Shrub	530,129	8.9%
Low Shrub - Lichen	87,837	1.5%
Low Shrub - Tussock Tundra	41,308	0.7%
Dwarf Shrub	560,346	9.4%
Dwarf Shrub - Lichen	433,428	7.3%
Low Shrub - Willow/Alder	164,187	2.8%
Wet Graminoid	60,307	1.0%
Wet Forb	1,995	0.0%
Lichen	99,572	1.7%
Moss	57,413	1.0%
Mesic/Dry Graminoid	130,118	2.2%
Mesic/Dry Forb	709	0.0%
Tussock Tundra	75,927	1.3%
Tussock Tundra - Lichen	88,922	1.5%
Aquatic Bed	1,059	0.0%
Emergent	20,702	0.3%
Saltwater	209	0.0%
Clear Water	42,500	0.7%
Turbid Water	6,428	0.1%
Sparse Vegetation	111,145	1.9%
Rock/Gravel	24,240	0.4%
Non-vegetated Soil	916	0.0%
Other - Driftwood Piles	0	0.0%
Urban/Developed	0	0.0%
Cloud	86,765	1.5%
Cloud Shadow	15,995	0.3%
Terrain Shadow	58,584	1.0%
Fire Scar Regeneration	20,522	0.3%
Total	**5,934,552**	**100%**

Table C-2. Earth cover class acreages for Fish and Wildlife Service lands.

CLASSNAME	ACRES	%
Open Needleleaf	520,072	7.5%
Open Needleleaf - Lichen	868,501	12.5%
Woodland Needleleaf	382,382	5.5%
Woodland Ndl. - Lichen	135,249	1.9%
Closed Deciduous	265,742	3.8%
Open Deciduous	116,205	1.7%
Closed Mixed Ndl./Decid.	169,559	2.4%
Open Mixed Ndl./Decid.	254,315	3.7%
Tall Shrub	460,154	6.6%
Low Shrub	595,794	8.6%
Low Shrub - Lichen	49,722	0.7%
Low Shrub - Tussock Tundra	56,808	0.8%
Dwarf Shrub	565,108	8.1%
Dwarf Shrub - Lichen	491,686	7.1%
Low Shrub - Willow/Alder	198,251	2.8%
Wet Graminoid	185,152	2.7%
Wet Forb	3,330	0.0%
Lichen	104,264	1.5%
Moss	354,571	5.1%
Mesic/Dry Graminoid	115,908	1.7%
Mesic/Dry Forb	73	0.0%
Tussock Tundra	26,364	0.4%
Tussock Tundra - Lichen	64,861	0.9%
Aquatic Bed	13,167	0.2%
Emergent	75,534	1.1%
Clear Water	367,445	5.3%
Turbid Water	63,555	0.9%
Sparse Vegetation	18,058	0.3%
Rock/Gravel	25,498	0.4%
Non-vegetated Soil	2,032	0.0%
Cloud	288,083	4.1%
Cloud Shadow	66,980	1.0%
Terrain Shadow	8,310	0.1%
Fire Scar Regeneration	45,799	0.7%
Total	**6,958,535**	**100%**

Table C-3. Earth cover class acreages for state patented lands.

CLASSNAME	ACRES	%
Open Needleleaf	347,867	18.8%
Open Needleleaf - Lichen	307,721	16.6%
Woodland Needleleaf	126,350	6.8%
Woodland Ndl. - Lichen	45,397	2.5%
Closed Deciduous	83,806	4.5%
Open Deciduous	44,693	2.4%
Closed Mixed Ndl./Decid.	91,175	4.9%
Open Mixed Ndl./Decid.	156,483	8.5%
Tall Shrub	77,757	4.2%
Low Shrub	125,170	6.8%
Low Shrub - Lichen	6,623	0.4%
Low Shrub - Tussock Tundra	39,432	2.1%
Dwarf Shrub	89,123	4.8%
Dwarf Shrub - Lichen	32,541	1.8%
Low Shrub - Willow/Alder	3,005	0.2%
Wet Graminoid	6,802	0.4%
Lichen	11,935	0.6%
Moss	11,918	0.6%
Mesic/Dry Graminoid	11,228	0.6%
Mesic/Dry Forb	179	0.0%
Tussock Tundra	8,854	0.5%
Tussock Tundra - Lichen	6,591	0.4%
Aquatic Bed	251	0.0%
Emergent	3,118	0.2%
Clear Water	6,107	0.3%
Turbid Water	28,220	1.5%
Sparse Vegetation	1,118	0.1%
Rock/Gravel	10,101	0.5%
Non-vegetated Soil	596	0.0%
Cloud	94,089	5.1%
Cloud Shadow	26,800	1.4%
Terrain Shadow	6,170	0.3%
Fire Scar Regeneration	37,801	2.0%
Total	**1,849,019**	**100.0%**

Table C-4. Earth cover class acreages for state selected lands.

CLASSNAME	ACRES	%
Open Needleleaf	403,439	17.4%
Open Needleleaf - Lichen	130,431	5.6%
Woodland Needleleaf	142,922	6.2%
Woodland Ndl. - Lichen	27,861	1.2%
Closed Deciduous	87,098	3.8%
Open Deciduous	37,260	1.6%
Closed Mixed Ndl./Decid.	37,028	1.6%
Open Mixed Ndl./Decid.	144,799	6.2%
Tall Shrub	242,221	10.4%
Low Shrub	182,793	7.9%
Low Shrub - Lichen	38,991	1.7%
Low Shrub - Tussock Tundra	15,704	0.7%
Dwarf Shrub	206,215	8.9%
Dwarf Shrub - Lichen	125,721	5.4%
Low Shrub - Willow/Alder	66,230	2.9%
Wet Graminoid	11,984	0.5%
Wet Forb	179	0.0%
Lichen	37,470	1.6%
Moss	21,226	0.9%
Mesic/Dry Graminoid	59,240	2.6%
Mesic/Dry Forb	155	0.0%
Tussock Tundra	44,299	1.9%
Tussock Tundra - Lichen	72,171	3.1%
Aquatic Bed	272	0.0%
Emergent	6,776	0.3%
Saltwater	358	0.0%
Clear Water	11,248	0.5%
Turbid Water	5,893	0.3%
Sparse Vegetation	14,093	0.6%
Rock/Gravel	21,851	0.9%
Non-vegetated Soil	702	0.0%
Cloud	87,617	3.8%
Cloud Shadow	18,289	0.8%
Terrain Shadow	11,622	0.5%
Fire Scar Regeneration	6,368	0.3%
Total	**2,320,528**	**100.0%**

Table C-5. Earth cover class acreages for native patented lands.

CLASSNAME	ACRES	%
Open Needleleaf	459,997	13.5%
Open Needleleaf - Lichen	134,677	3.9%
Woodland Needleleaf	177,876	5.2%
Woodland Ndl. - Lichen	20,221	0.6%
Closed Deciduous	292,226	8.6%
Open Deciduous	93,222	2.7%
Closed Mixed Ndl./Decid.	118,747	3.5%
Open Mixed Ndl./Decid.	305,040	8.9%
Tall Shrub	287,027	8.4%
Low Shrub	262,655	7.7%
Low Shrub - Lichen	23,764	0.7%
Low Shrub - Tussock Tundra	6,941	0.2%
Dwarf Shrub	217,409	6.4%
Dwarf Shrub - Lichen	74,526	2.2%
Low Shrub - Willow/Alder	69,056	2.0%
Wet Graminoid	108,173	3.2%
Wet Forb	2,043	0.1%
Lichen	31,861	0.9%
Moss	27,100	0.8%
Mesic/Dry Graminoid	78,326	2.3%
Mesic/Dry Forb	39	0.0%
Tussock Tundra	42,412	1.2%
Tussock Tundra - Lichen	56,231	1.6%
Aquatic Bed	4,406	0.1%
Emergent	20,964	0.6%
Saltwater	9,102	0.3%
Clear Water	124,109	3.6%
Turbid Water	182,680	5.4%
Sparse Vegetation	7,752	0.2%
Rock/Gravel	25,374	0.7%
Non-vegetated Soil	7,386	0.2%
Other - Driftwood Piles	104	0.0%
Urban/Developed	629	0.0%
Cloud	117,746	3.5%
Cloud Shadow	8,245	0.2%
Terrain Shadow	10,916	0.3%
Fire Scar Regeneration	1,008	0.0%
Total	**3,409,990**	**100.0%**

Table C-6. Earth cover class acreages for native selected lands.

CLASSNAME	ACRES	%
Open Needleleaf	170,318	12.5%
Open Needleleaf - Lichen	50,885	3.7%
Woodland Needleleaf	58,467	4.3%
Woodland Ndl. - Lichen	24,148	1.8%
Closed Deciduous	73,366	5.4%
Open Deciduous	23,557	1.7%
Closed Mixed Ndl./Decid.	22,770	1.7%
Open Mixed Ndl./Decid.	79,799	5.9%
Tall Shrub	138,215	10.2%
Low Shrub	93,023	6.8%
Low Shrub - Lichen	28,531	2.1%
Low Shrub - Tussock Tundra	3,080	0.2%
Dwarf Shrub	109,128	8.0%
Dwarf Shrub - Lichen	81,882	6.0%
Low Shrub - Willow/Alder	38,348	2.8%
Wet Graminoid	20,380	1.5%
Wet Forb	210	0.0%
Lichen	30,276	2.2%
Moss	11,142	0.8%
Mesic/Dry Graminoid	35,752	2.6%
Mesic/Dry Forb	28	0.0%
Tussock Tundra	28,336	2.1%
Tussock Tundra - Lichen	47,458	3.5%
Aquatic Bed	357	0.0%
Emergent	6,402	0.5%
Saltwater	700	0.1%
Clear Water	38,614	2.8%
Turbid Water	29,739	2.2%
Sparse Vegetation	4,368	0.3%
Rock/Gravel	8,550	0.6%
Non-vegetated Soil	1,466	0.1%
Cloud	83,263	6.1%
Cloud Shadow	12,443	0.9%
Terrain Shadow	5,290	0.4%
Fire Scar Regeneration	14	0.0%
Total	**1,360,303**	**100.0%**

Table C-7. Earth cover class acreages for military lands.

CLASSNAME	ACRES	%
Open Needleleaf	948	10.8%
Open Needleleaf - Lichen	866	9.9%
Woodland Needleleaf	493	5.6%
Woodland Ndl. - Lichen	77	0.9%
Closed Deciduous	466	5.3%
Open Deciduous	436	5.0%
Closed Mixed Ndl./Decid.	242	2.8%
Open Mixed Ndl./Decid.	741	8.4%
Tall Shrub	603	6.9%
Low Shrub	885	10.1%
Low Shrub - Lichen	40	0.5%
Low Shrub - Tussock Tundra	9	0.1%
Dwarf Shrub	646	7.4%
Dwarf Shrub - Lichen	131	1.5%
Low Shrub - Willow/Alder	201	2.3%
Wet Graminoid	145	1.7%
Lichen	124	1.4%
Moss	50	0.6%
Mesic/Dry Graminoid	266	3.0%
Tussock Tundra	150	1.7%
Tussock Tundra - Lichen	133	1.5%
Emergent	16	0.2%
Saltwater	130	1.5%
Clear Water	79	0.9%
Turbid Water	704	8.0%
Sparse Vegetation	33	0.4%
Rock/Gravel	100	1.1%
Non-vegetated Soil	4	0.0%
Urban/Developed	67	0.8%
Total	**8,785**	**100.0%**

Table C-8. Earth cover class acreages for private lands.

CLASSNAME	ACRES	%
Open Needleleaf	69	3.6%
Woodland Needleleaf	87	4.5%
Woodland Ndl. - Lichen	5	0.3%
Closed Deciduous	48	2.5%
Open Mixed Ndl./Decid.	41	2.1%
Tall Shrub	236	12.3%
Low Shrub	231	12.0%
Low Shrub - Lichen	0	0.0%
Dwarf Shrub	124	6.5%
Dwarf Shrub - Lichen	29	1.5%
Wet Graminoid	549	28.6%
Lichen	9	0.5%
Moss	6	0.3%
Mesic/Dry Graminoid	1	0.1%
Tussock Tundra - Lichen	2	0.1%
Aquatic Bed	4	0.2%
Emergent	44	2.3%
Clear Water	435	22.6%
Rock/Gravel	1	0.1%
Cloud	0	0.0%
Total	**1,921**	**100.0%**

Appendix D. Plant Species by Frequency of Occurrence.

			# Sites on which Species Occurred			
Symbol	Species	Common_Name	All	Aniak	Unalakleet	INWR
MOXX	MOSS	MOSS	1045	294	400	351
LITT	LITTER	LITTER	933	357	503	73
LEPA11	LEDUM PALUSTRE	LABRADOR TEA	780	194	286	300
LIXX	LICHEN	LICHEN	704	89	319	296
BEGL	BETULA GLANDULOSA	BIRCH,DWARF ARCTIC	683	247	397	39
CAXX	CAREX SPP	SEDGE SPP	634	185	270	179
SAX_	SALIX SPP	WILLOW	605	228	206	171
EQXX	EQUISETUM SPP	HORSETAIL SPP	482	163	137	182
ALCR6	ALNUS CRISPA	ALDER,GREEN	472	129	158	185
VAUL	VACCINIUM ULIGINOSUM	BLUEBERRY,BOG	433	159	232	42
CACA4	CALAMAGROSTIS CANADENSIS	REEDGRASS,BLUEJOINT	413	179	180	54
PIMA	PICEA MARIANA	SPRUCE,BLACK	411	116	63	232
CWATER	CLEAR WATER	CLEAR WATER	364	140	83	141
BENA	BETULA NANA	BIRCH,SWAMP	334	7	12	315
PIGL	PICEA GLAUCA	SPRUCE,WHITE	333	94	185	54
LITT2	STANDING DEAD	STANDING DEAD	328	204	30	94
BEPA	BETULA PAPYRIFERA	BIRCH,PAPER	326	124	72	130
ERXX	ERIOPHORUM SPP	COTTON-GRASS	257	88	115	54
EMNI	EMPETRUM NIGRUM	CROWBERRY,BLACK	209	78	129	2
RUCH	RUBUS CHAMAEMORUS	CLOUDBERRY	161	11	148	2
GRASS	GRASS	GRASS	157	60	65	32
POPA14	POTENTILLA PALUSTRIS	CINQUEFOIL,MARSH	149	44	40	65
SPBE	SPIRAEA BEAUVERDIANA	SPIRAEA,BEAUVERED	146	51	95	0
EPAN2	EPILOBIUM ANGUSTIFOLIUM	FIREWEED	125	34	84	7
SADW	SALIX DW.	WILLOW, DWARF	125	41	84	0
ERVA4	ERIOPHORUM VAGINATUM	COTTON-GRASS,TUSSOCK	121	17	61	43
LALA	LARIX LARICINA	LARCH,AMERICAN	119	48	34	37
CAAQ	CAREX AQUATILIS	SEDGE,WATER	118	52	46	20
METR3	MENYANTHES TRIFOLIATA	BUCKBEAN	113	38	20	55
VAVI	VACCINIUM VITIS-IDAEA	CRANBERRY,MOUNTAIN	109	81	14	14
RUBUS	RUBUS SPP	RUBUS,SPP	101	79	11	11
POBA2	POPULUS BALSAMIFERA	POPLAR,BALSAM	100	23	10	67

Symbol	Species	Common_Name	# Sites on which Species Occurred All	Aniak	Unalakleet	INWR
ROCK	ROCK	ROCK	99	27	61	11
LIXX2	LICHEN YELLOW	LICHEN YELLOW	83	82	1	0
FEXX	FERN SPP	FERN SPP	82	71	1	10
DRXX	DRYAS SPP	MOUNTAIN-AVENS	70	14	52	4
POTR10	POPULUS TREMULOIDES	ASPEN,QUAKING	70	12	20	38
CHCA2	CHAMAEDAPHNE CALYCULATA	LEATHERLEAF	69	15	36	18
MYGA	MYRICA GALE	SWEETGALE	68	38	10	20
DRDI2	DRYOPTERIS DILATATA	WOODFERN,MOUNTAIN	58	0	58	0
ANPO	ANDROMEDA POLIFOLIA	ROSEMARY,BOG	55	0	22	33
POTEN	POTENTILLA SPP	CINQUEFOIL,SPP	52	28	7	17
PEFR5	PETASITES FRIGIDUS	COLTSFOOT,ARCTIC SWEET	51	7	43	1
PICEA	PICEA SPP	SPRUCE,SPP	44	22	0	22
ROAC	ROSA ACICULARIS	ROSE,PRICKLY	38	36	2	0
EQFL	EQUISETUM FLUVIATILE	HORSETAIL,WATER	36	0	22	14
LIXX3	LICHEN WHITE	LICHEN,WHITE	36	36	0	0
BARE	BARE GROUND	BARE GROUND	35	7	28	0
POTAM	POTAMOGETON SPP	PONDWEED,SPP	29	13	1	15
ARNIC	ARNICA SPP	ARNICA SPP	28	0	28	0
SATRE	SALIX TREE	WILLOW TREE	27	9	8	10
GRAV	GRAVEL	GRAVEL	26	14	12	0
RUMEX	RUMEX SPP	DOCK,SPP	23	11	11	1
SAXX	SAXIFRAGA SPP	SAXIFRAGE SPP	23	1	22	0
HELA4	HERACLEUM LANATUM	COW-PARSNIP	21	18	2	1
MUDX	MUD	MUD	21	12	6	3
NUPO	NUPHAR POLYSEPALUM	WATER LILY	21	7	0	14
IRSE	IRIS SETOSA	IRIS,BEACH-HEAD	20	5	11	4
LUPIN	LUPINUS SPP	LUPINE,SPP	18	4	14	0
SAND	SAND	SAND	16	12	3	1
CIMA2	CICUTA MACULATA	WATER-HEMLOCK,SPOTTED	15	0	0	15
ANLU	ANGELICA LUCIDA	ANGELICA,SEAWATCH	12	3	9	0
CIMA	CICUTA MACKENZIANA	WATER-HEMLOCK,MACKENZIE	12	8	4	0
COCA13	CORNUS CANADENSIS	BUNCHBERRY,CANADA	12	1	11	0
ACDE2	ACONITUM DELPHINIFOLIUM	MONKSHOOD,LARKSPUR-LEAF	11	2	9	0
SENEC	SENECIO SPP	GROUNDSEL,SPP	11		11	0
CATE11	CASSIOPE TETRAGONA	BELL-HEATHER,ARCTIC	10	1	8	1

Symbol	Species	Common_Name	# Sites on which Species Occurred All	Aniak	Unalakleet	INWR
LIXX6	LICHEN BROWN	LICHEN,BROWN	10	10	0	0
VIED	VIBURNUM EDULE	SQUASHBERRY	10	10	0	0
DIAPE	DIAPENSIA SPP	DIAPENSIA,SPP	8	0	8	0
EPXX	EPILOBIUM SPP	FIREWEED SPP	8	5	0	3
PELA	PEDICULARIS LABRADORICA	LOUSEWORT,LABRADOR	8	0	8	0
LEDE5	LEDUM DECUMBENS	LABRADOR-TEA,NARROW-LEAF	7	0	7	0
LIXX4	LICHEN GREEN	LICHEN,GREEN	7	7	0	0
SERO2	SEDUM ROSEA	STONECROP,ROSEROOT	7	0	7	0
TUWA	TURBID WATER	TURBID WATER	7	7	0	0
ASXX	ASTRAGALUS SPP	VETCH	6	1	5	0
CAQS	CAREX AQ. SPP.	CAREX NOT AQ	6	0	0	6
CARO2	CAMPANULA ROTUNDIFOLIA	BELLFLOWER,SCOTCH	6	0	5	1
LYCOP2	LYCOPODIUM SPP	CLUBMOSS,SPP	6	0	6	0
POAL5	POLYGONUM ALASKANUM	RHUBARB,ALASKA WILD	6	2	4	0
POLYG4	POLYGONUM SPP	BISTORT,SPP	6	6	0	0
PUKA	PUCCINELLIA KAMTSCHATICA	GRASS,ALASKA ALKALI	6	0	6	0
RUAR	RUBUS ARCTICUS	RASPBERRY,ARCTIC	6	0	6	0
CIDO	CICUTA DOUGLASII	WATER-HEMLOCK,WESTERN	5	1	4	0
COST4	CORNUS STOLONIFERA	DOGWOOD,RED-OSIER	5	5	0	0
EPLA	EPILOBIUM LATIFOLIUM	BEAUTY,RIVER	5	0	5	0
GEER2	GERANIUM ERIANTHUM	WOOLY GERANIUM	5	5	0	0
LIXX5	LICHEN ORANGE	LICHEN,ORANGE	5	5	0	0
POFR4	POTENTILLA FRUTICOSA	CINQUEFOIL,SHRUBBY	5	0	4	1
ARTEM	ARTEMISIA SPP	SAGE, SPP	4	0	4	0
CALA7	CAMPANULA LASIOCARPA	BELLFLOWER,COMMON ALASKA	4	0	4	0
HIPPU	HIPPURUS SPP	MARE'S-TAIL,SPP	4	1	0	3
LOPR	LOISELURIA PROCUMBENS	AZALEA, ALPINE	4	0	4	0
POAC	POLEMONIUM ACUTIFLORUM	JACOB'S-LADDER,STICKY TALL	4	1	3	0
POBI5	POLYGONUM BISTORTA	BISTORT,MEADOW	4	0	4	0
RANUN	RANUNCULUS SPP	BUTTERCUP,SPP	4	0	0	4
RIBES	RIBES SPP	CURRENT,SPP	4	0	4	0
SPARG	SPARGANIUM SPP	BURREED,SPP	4	0	0	4
VASI	VALERIANA SITCHENSIS	VALERIAN,SITKA	4	0	4	0
ALTRE	ALNUS SPP TREE	ALDER, TREE	3	2	1	0
DEAR4	DENDRANTHEMA ARCTICUM	DAISY,ARCTIC	3	0	3	0

Symbol	Species	Common_Name	# Sites on which Species Occurred All	Aniak	Unalakleet	INWR
GELI2	GEOCAULON LIVIDUM	TOADFLAX,NORTHERN RED-FRUIT	3	0	3	0
GRBU	GRAMINOID BURNED	GRAMINOID,BURNED	3	3	0	0
RUAR6	RUMEX ARCTICUS	DOCK,ARCTIC	3	2	1	0
VEVI	VERATRUM VIRIDE	FALSE-HELLEBORE,AMERICAN	3	3	0	0
BORO	BOSCHNIAKIA ROSSICA	GROUNDCONE,NORTHERN	2	0	2	0
CACA20	CASTILLEJA CAUDATA	INDIAN-PAINTBRUSH,PORT CLAREN	2	0	2	0
CAMPA	CAMPANULA SPP	CAMPANULA SPP	2	0	2	0
CEAR4	CERASTIUM ARVENSE	CHICKWEED,MOUSE-EAR	2	0	2	0
ELAR	ELYMUS ARENARIUS	LYME-GRASS,SEA	2	0	2	0
GEPR4	GERANIUM PRATENSE	CRANE'S-BILL,MEADOW	2	2	0	0
LISC3	LIGUSTICUM SCOTHICUM	LOVAGE,SCOTCH	2	0	2	0
MEPA	MERTENSIA PANICULATA	BLUEBELL,TALL	2	0	2	0
NUPHA	NUPHAR SPP	PONDLILY,SPP	2	0	0	2
PESU	PEDICULARIS SUDETICA	LOUSEWORT,SUDETAN	2	1	1	0
SILT	SILT	SILT	2	2	0	0
VAMI	VACCINIUM MICROCARPUS	BLUEBERRY	2	2	0	0
VILA6	VIOLA LANGSDORFFII	VIOLET,ALASKA	2	0	2	0
ALTE2	ALNUS TENUIFOLIA	ALDER,THIN-LEAF	1	0	1	0
ANMO9	ANTENNARIA MONOCEPHALA	PUSSYTOES	1	0	1	0
ANPA	ANEMONE PARVIFLORA	THIMBLE-WEED,SMALL-FLOWER	1	0	1	0
ARAR9	ARTEMISIA ARCTICA	SAGEBRUSH, BOREAL	1	1	0	0
ATDI	ATHYRIUM DISTENTIFOLIUM	FERN,ALPINE LADY	1	1	0	0
CAUN4	CASTILLEJA UNALASCHCENSIS	INDIAN-PAINTBRUSH,ALASKA	1	0	1	0
DEGL3	DELPHINIUM GLAUCUM	LARKSPUR,TOWER	1	1	0	0
DROB	DROSERA X OBOVATA	SUNDEW	1	0	0	1
EQPA	EQUISETUM PALUSTRE	HORSETAIL,MARSH	1	0	1	0
FOXX	FORB SPP	FORB SPP	1	0	1	0
GRXX	GRAMINOID SPP	GRAMINOID SPP	1	0	0	1
LOPE	LOLIUM PERENNE	RYEGRASS,PERENNIAL	1	0	1	0
MIAR3	MINUARTIA ARCTICA	STITCHWORT,ARCTIC	1	0	1	0
MIGR	MICROSTERIS GRACILIS	PHLOX,FALSE	1	1	0	0
MOLA6	MOEHRINGIA LATERIFLORA	SANDWORT,GROVE	1	0	1	0
NVSO	NON VEG SOIL	NON VEG SOIL	1	1	0	0
PAFI3	PARNASSIA FIMBRIATA	GRASS-OF-PARNASSUS,FRINGED	1	0	1	0
PAMA5	PAPAVER MACOUNII	POPPY,MACOUN'S	1	0	1	0

Symbol	Species	Common_Name	# Sites on which Species Occurred All	Aniak	Unalakleet	INWR
PAPA8	PARNASSIA PALUSTRIS	GRASS-OF-PARNASSUS,NORTHERN	1	0	1	0
PEDIC	PEDICULARIS SPP	LOUSEWORT SPP	1	1	0	0
PEPA4	PEDICULARIS PARVIFLORA	LOUSEWORT,SMALL-FLOWER	1	0	1	0
PHLOX	PHLOX SPP	PHLOX SPP	1	1	0	0
RUAC2	RUMEX ACETOSA	SORREL,GARDEN	1	0	1	0
SAAL	SALIX ALAXENSIS	WILLOW,FELT-LEAF	1	1	0	0
SAHI3	SAXIFRAGA HIRCULUS	SAXIFRAGE,YELLOW MARSH	1	1	0	0
SAPL2	SALIX PLANIFOLIA	WILLOW,DIAMOND-LEAF	1	0	0	1
SIAL2	SISYMBRIUM ALTISSIMUM	MUSTARD,TALL TUMBLE	1	0	1	0
SOLID	SOLIDAGO SPP	GOLDENROD SPP	1	0	0	1
SPRO	SPIRANTHES ROMANZOFFIANA	LADIES'-TRESSES,HOODED	1	0	1	0
VAAL	VACCINIUM ALASKAENSE	BLUEBERRY,ALASKA	1	0	1	0
VAOX	VACCINIUM OXYCOCCOS	CRANBERRY,SMALL	1	0	1	0

Appendix E. Accuracy Assessment Error Matrices

Table E-1. Error Matrix for Aniak Project Area.

Reference Label (columns); Map Label (rows)

Class	Open Needleleaf	Open Needleleaf Lichen	Woodland Needlelef	Closed Birch	Open Mixed Ndl./Decid.	Tall Shrub	Low Shrub	Low Shrub Lichen	Dwarf Shrub	Dwarf Shrub Lichen	Wet Graminoid	Lichen	Moss	Mesic/Dry Graminoid	Emergent Vegetation	Clear Water	Sparse Vegetation	Rock/Gravel	Non-Vegetated Soil	Total	User's Accuracy +/-0%	User's Accuracy +/- 5%
Open Needleleaf	**4**				0,1															5	80%	80%
Open Needleleaf Lichen	0,1																			1	0%	0%
Woodland Needlelef			**5**		0,1		1,1													8	63%	75%
Closed Birch				**4**																4	100%	100%
Open Mixed Ndl./Decid.					**3**															3	100%	100%
Tall Shrub					0,1	**9**					0,1									11	82%	82%
Low Shrub							**5**								0,1					6	83%	83%
Low Shrub Lichen								**1**												1	100%	100%
Dwarf Shrub									**5**											5	100%	100%
Dwarf Shrub Lichen										**8**										8	100%	100%
Wet Graminoid											**4**				1,0					5	80%	80%
Lichen												**2**								2	100%	100%
Moss													**5**							5	100%	100%
Mesic/Dry Graminoid										0,1										1	0%	0%
Emergent Vegetation															**1**					1	100%	100%
Clear Water																	0,1			1	0%	0%
Sparse Vegetation																	**1**			1	100%	100%
Rock/Gravel												0,1						**6**	0,1	8	75%	75%
Non-Vegetated Soli																				0	----	----
Total	5	0	5	4	6	9	7	1	5	9	5	3	5	0	3	0	2	6	1	76		
Producer's +/- 0%	80%	----	100%	100%	50%	100%	71%	100%	100%	89%	80%	67%	100%	----	33%	----	50%	100%	0%		**83%**	
Producer's +/- 5%	80%	----	100%	100%	50%	100%	86%	100%	100%	89%	80%	67%	100%	----	67%	----	50%	100%	0%			

Total # of Training Sites:	76
Diagonal Total:	63
Off-diagonal Total:	13
Off-diagonal Acceptable:	2
Overall Accuracy +/- 0% variation:	**83%**
Overall Accuracy +/- 5% variation:	**86%**

Table E-2. Error Matrix for Unalakleet Project Area.

Reference Class (columns); Map Class (rows)

Class	Open Needleleaf	Open Ndl. - Lichen	Woodland Ndl.	Closed Deciduous	Open Deciduous	Open Mixed Ndl./Decid.	Tall Shrub	Low Shrub	Low Shrub - Lichen	Dwarf Shrub	Dw. Shrub - Lichen	Low Shrub - Willow/Alder	Wet Graminoid	Lichen	Moss	Dry Graminoid	Tussock Tundra	Tuss. Tundra - Lichen	Sparsely Vegetated	Rock/Gravel	Total	User's Accuracy +/- 0%	User's Accuracy +/- 5%
Open Needleleaf	**22**		3,1			1,1															28	79%	93%
Open Ndl. - Lichen	0,1																				1	0%	0%
Woodland Ndl.			**2**			1,0		0,1													4	50%	75%
Closed Deciduous				**5**																	5	100%	100%
Open Deciduous							0,1	0,1													2	0%	0%
Open Mixed Ndl./Decid.						**3**															3	100%	100%
Tall Shrub			1,1	0,1			**15**			0,1		0,1				0,1					21	71%	76%
Low Shrub								**12**								0,1					13	92%	92%
Low Shrub - Lichen											0,1			0,3							4	0%	0%
Dwarf Shrub										**11**	1,1		0,1		0,1						15	73%	80%
Dw. Shrub - Lichen										1,0	**13**			0,1							15	87%	93%
Low Shrub - Willow/Alder							0,1					**7**	0,1								9	78%	78%
Wet Graminoid													**5**		1,1						7	71%	86%
Lichen										0,1			0,1	**5**							7	71%	71%
Moss			0,1												**5**						6	83%	83%
Dry Graminoid								0,2							0,1	**3**					6	50%	50%
Tussock Tundra										2,0											2	0%	100%
Tuss. Tundra - Lichen														0,1							1	0%	0%
Sparsely Vegetated										1,0											1	0%	100%
Rock/Gravel										1,0											1	0%	100%
Total	23	0	9	6	0	6	17	16	0	18	16	8	8	10	9	5	0	0	0	0	**151**		
Producer's Accuracy +/- 0%	96%	----	22%	83%	----	50%	88%	75%	----	61%	81%	88%	63%	50%	56%	60%	----	----	----	----		**71.5%**	
Producer's Accuracy +/- 0%	96%	----	67%	83%	----	83%	88%	75%	----	83%	88%	88%	63%	50%	67%	60%	----	----	----	----			**80.1%**

Total # of Training Sites:	151
Diagonal Total:	108
Off-diagonal Total:	56
Off-diagonal Acceptable:	13
Overall Accuracy +/- 0% variation:	72%
Overall Accuracy +/- 5% variation:	80%

Table E-3. Error Matrix for INWR Project Area.

Reference Class

Map Class

Class	Open Needleleaf	Open Ndl. Lichen	Woodland Needleleaf	Wdlnd. Ndl. Lichen	Closed Deciduous	Cl. Mixed Ndl./Dec.	Op. Mixed Ndl./Dec.	Tall shrub	Low Shrub - Other	Low Shrub - Tussock	Dwarf Shrub	Dw. Shrub - Lichen	Wet Graminoid	Lichen	Moss	Dry Graminoid	Emergent Vegetation	Clear Water	Turbid Water	Total	User's Accuracy +/-0%	User's Accuracy +/- 5%
Open Needleleaf	**17**	1,0	1,0	0,1			0,1													21	81%	90%
Open Ndl. Lichen	0,2	**19**		1,0			0,1					0,2	0,1		0,1					27	70%	74%
Woodland Needleleaf	0,1	0,1	**13**	0,2					0,1		0,1									19	68%	68%
Wdlnd. Ndl. Lichen			1,0	**8**					0,1											10	80%	90%
Closed Deciduous			0,1		**18**			0,1												20	90%	90%
Cl. Mixed Ndl./Dec.						**7**	1,3													11	64%	73%
Op. Mixed Ndl./Dec.		0,1				1,1	**6**													9	67%	78%
Tall shrub								**14**			1,0					0,1				16	88%	94%
Low Shrub - Other				0,1			0,1	0,1	**17**		0,1		0,1							22	77%	77%
Low Shrub -Tussock												0,1								1	0%	0%
Dwarf Shrub				0,1							**14**	0,1	0,2		0,1					19	74%	74%
Dw. Shrub - Lichen			0,1									**7**		1,1		0,1				11	64%	73%
Wet Graminoid								0,1					**13**		0,1		3,0			18	72%	89%
Lichen														**3**	0,2					5	60%	60%
Moss											1,0				**21**					22	95%	100%
Dry Graminoid																**3**				3	100%	100%
Emergent Vegetation																	**15**			15	100%	100%
Clear Water													0,1				0,1	**10**		12	83%	83%
Turbid Water																			**6**	6	100%	100%
Total	20	22	17	14	18	9	13	17	19	0	18	11	18	5	26	5	19	10	6	267		
Producer's +/- 0%	85%	86%	76%	57%	100%	78%	46%	82%	89%	-----	78%	64%	72%	60%	81%	60%	79%	100%	100%		**79.0%**	
Producer's +/- 5%	85%	91%	88%	64%	100%	89%	54%	82%	89%	-----	89%	64%	72%	80%	81%	60%	95%	100%	100%			**83.5%**

Total # of Training Sites:	267
Diagonal Total:	211
Off-diagonal Total:	56
Off-diagonal Acceptable:	12
Overall Accuracy +/- 0% variation:	**79%**
Overall Accuracy +/- 5% variation:	**84%**

Appendix F. Innoko Earth Cover Mapping Image File Metadata

Filename:inno_earthcov
Filetype:Arc/Info Grid

Metadata:

- Identification_Information
- Data_Quality_Information
- Spatial_Reference_Information
- Entity_and_Attribute_Information
- Metadata_Reference_Information

Identification_Information:
  Citation:
    Citation_Information:
      Originator:Ducks Unlimited,Inc.
      Publication_Date:111501
      Publication_Time:
      Title: inno_earthcov
      Edition:
      Geospatial_Data_Presentation_Form:map
  Description: Innoko Earth Cover Classification
    Abstract:
      The Bureau of Land Management (BLM) – Alaska and Ducks Unlimited, Inc. (DU) have been cooperatively mapping wetlands and associated uplands in Alaska using remote sensing and GIS technologies since 1988. The goal of this project was to continue the mapping effort by mapping the Innoko National Wildlife Refuge (INWR) and surrounding BLM, Native, and State lands—hence called the Innoko Project (approximately 22 million acres). Because the entire project area was so large, three sub-project areas were defined: the Innoko National Wildlife Refuge (INWR), the Unalakleet area, and the Aniak area. Sub-project boundaries were delineated using several factors, including acquisition dates of available Landsat images, limitations in field logistics, geographic features, and political boundaries (i.e. - mapping the entire INWR in one sub-project area). Fieldwork, image classification, and accuracy assessment were completed independently for each of the sub-project areas. The digital maps produced for the three areas were mosaicked post-classification to produce a earth cover map for the entire Innoko project area. A total of six Landsat TM satellite scenes (2 for INWR: Path 76, Rows 15 and 16 acquired August 26, 1991; 3 for the Unalakleet area: Path 77 Rows 15-17 acquired August 8, 1995; and 1 for the Aniak portion: Path 76 Row 17 acquired August 26, 1991) were used to classify the project area into 33 earth cover categories. An unsupervised clustering or seeding technique was used to determine the location of field sites and a custom field data collection card and digital database were used to record field information. Helicopters were utilized to gain access

to field sites throughout the project area. Global positioning system (GPS) technology was used both to navigate to pre-selected sites and to record locations of new sites selected in the field. Data were collected on 1,544 field sites during a 17-day field season from July 17, 1998 through August 2, 1998. A modified supervised/unsupervised classification technique was performed to classify the satellite imagery. The classification scheme for the earth cover inventory was based on Viereck *et al.* (1992) and revised through a series of meetings coordinated by the BLM – Alaska and DU. The overall accuracy at the +/-5% level of variation for each project area was 86%, 80%, and 84% for the Aniak, Unalakleet, and Innoko NWR areas, respectively. The cooperators in this project were the Bureau of Land Management-Alaska, the U.S. Fish and Wildlife Service, and Ducks Unlimited, Inc.

Purpose:

The objective of this project was to develop a baseline earth cover inventory using Landsat TM imagery for the INWR, the BLM's Unalakleet area lands, and surrounding Native, State, and Federal lands. More specifically, this project purchased, classified, field verified, and produced high quality, high resolution digital and hard copy resource base maps. The result of this project is an integrated GIS database that can be used for improved natural resources planning.

Time_Period_of_Content:
  Time_Period_Information:
    Multiple_Dates/Times:
    Single_Date/Time:
      Calendar_Date:08261991
    Single_Date/Time:
      Calendar_Date:08081995
  Currentness_Reference:11/2001
Status:
  Progress:complete
  Maintenance_and_Update_Frequency:none
Spatial_Domain:
  Bounding_Coordinates:
    West_Bounding_Coordinate:-163.418
    East_Bounding_Coordinate:-155.811
    North_Bounding_Coordinate:65.154
    South_Bounding_Coordinate:60.517
Keywords:
  Theme:
    Theme_Keyword_Thesaurus:
    Theme_Keyword:Land Cover Classification
    Theme_Keyword:Earth Cover Classification
    Theme_Keyword:Landsat TM
  Place:
    Place_Keyword_Thesaurus:
    Place_Keyword:Innoko NWR
    Place_Keyword:Unalakleet
    Place_Keyword:Alaska

Temporal:
Temporal_Keyword_Thesaurus:
Temporal_Keyword:1991
Temporal_Keyword:1995
Point_of_Contact:
Contact_Information:
Contact_Organization:Ducks Unlimited, Inc.
Contact_Person:
Contact_Position:GIS Manager
Contact_Address:
Address_Type:
Address:3074 Gold Canal Drive
City:Rancho Cordova
State_or_Province:California
Postal_Code: 95670
Country:U.S.A
Contact_Voice_Telephone: (916)852-2000
Data_Quality_Information:
Attribute_Accuracy:
Attribute_Accuracy_Report:See Final Report
Quantitative_Attribute_Accuracy_Assessment:
Attribute_Accuracy_Value:
Attribute_Accuracy_Explanation:
Lineage:
Source_Information:
Source_Citation:
Citation_Information:
Originator:EROS Data Center
Publication_Date: 1991 and 1995
Publication_Time:
Title: Landsat5 TM Imagery From Path 76, Rows 15-17 acquired 08/26/91 and Path 77, Rows 15-17 acquired 08/08/95
Edition:
Geospatial_Data_Presentation_Form: remote sensing image
Source_Scale_Denominator:
Type_of_Source_Media:
Source_Time_Period_of_Content:
Time_Period_Information:
Multiple_Dates/Times:
Single_Date/Time:
Calendar_Date:1991
Single_Date/Time:
Calendar_Date:1995
Process_Step:
Process_Discription:See "Innoko Earth Cover Classification" report
Source_Used_Citation_Abbreviation:

Process_Date:1998-2001
Process_Time:
Source_Produced_Citation_Abbreviation:
Spatial_Data_Organization_Information:
Indirect_Spatial_Reference:
Direct_Spatial_Reference_Method:Raster
Raster_Object_Information:
Raster_Object_Type:Pixel
Row_Count:18364
Column_Count:11415
Vertical_Count:
Spatial_Reference_Information:
Horizontal_Coordinate_System_Definition:
Geographic:
Latitude_Resolution:
Longitude_Resolution:
Geographic_Coordinate_Units:
Planar:
Map_Projection:
Map_Projection_Name:
Albers_Conical_Equal_Area:
1st_Standard_Parallel:65
2nd_Standard_Parallel:55
Longitude_of_Central_Meridian:-154
Latitude_of_Projection_Origin:50
False_Easting:
False_Northing:
Geodetic_Model:
Horizontal_Datum_Name: NAD27 (Alaska)
Ellipsoid_Name:Clarke 1866
Semi-major_Axis:
Denominator_of_Flattening_Ratio:
Metadata_Reference_Information:
Metadata_Date:11/15/2001
Metadata_Review_Date:
Metadata_Future_Review_Date:
Metadata_Contact:
Contact_Information:
Contact_Person_Primary:
Contact_Person:
Contact_Organization:
Contact_Organization_Primary:
Contact_Organization: Ducks Unlimited
Contact_Person:
Contact_Position:GIS Manager
Contact_Address:

Address_Type:
Address: 3074 Gold Canal Drive
City:Rancho Cordova
State_or_Province:California
Postal_Code: 95670
Country:U.S.A
Contact_Voice_Telephone: (916)852-2000
Contact_TDD/TTY_Telephone:
Contact_Facsimile_Telephone:
Contact_Electronic_Mail_Address:
Hours_of_Service:
Contact_Instructions:
Metadata_Standard_Name:Innoko Earth Cover Classification Metadata
Metadata_Standard_Version:
Metadata_Time_Convention:
Metadata_Access_Constraints:
Metadata_Use_Constraints:
Metadata_Security_Information:
Metadata_Security_Classification_System:
Metadata_Security_Classification:
Metadata_Security_Handling_Description:
Metadata_Extensions:
Online_Linkage:
Profile_Name:

Appendix G. Innoko Earth Cover Mapping Field Sites Metadata

Filename:inno_fld_sts
Filetype:Arc/Info coverage

Metadata:

Identification_Information
Data_Quality_Information
Spatial_Reference_Information
Entity_and_Attribute_Information
Metadata_Reference_Information

Identification_Information:
  Citation:
    Citation_Information:
      Originator:Ducks Unlimited, Inc.
      Publication_Date:11/15/2001
      Publication_Time:
      Title:inno_fld_sts
      Edition:
    Geospatial_Data_Presentation_Form:map
  Description:
    Abstract:
      The field data collected for the Innoko Earth Cover Mapping Project is included on the final products CD's. inno_fld_sts is an Arcinfo coverage of all sites that were visited in the field. inno_fld_sts includes site information about each polygon. Three DBASE files (inno_photo.dbf, inno_site_species.dbf, and inno_species.dbf) are also included on the final products CD's. All three of these files can be linked to the ArcInfo polygon coverage to provide the complete database of information collected for each fieldsite. The links are made by the duff.avx ArcView extension included on the final products CD's.
    Purpose:
      The objective of this project was to develop a baseline earth cover inventory using Landsat TM imagery for the INWR, the BLM's Unalakleet area lands, and surrounding Native, State, and Federal lands. More specifically, this project purchased, classified, field verified, and produced high quality, high resolution digital and hard copy resource base maps. The result of this project is an integrated GIS database that can be used for improved natural resources planning.
  Time_Period_of_Content:
    Time_Period_Information:
      Single_Date/Time:
        Calendar_Date:11/2001
    Currentness_Reference:11/2001
  Status:

Progress:complete
Maintenance_and_Update_Frequency:none
Spatial_Domain:
Bounding_Coordinates:
West_Bounding_Coordinate:-162.193
East_Bounding_Coordinate:-155.278
North_Bounding_Coordinate:64.867
South_Bounding_Coordinate:60.526
Keywords:
Theme:
Theme_Keyword_Thesaurus:
Theme_Keyword:Field Sites
Theme_Keyword:ArcInfo Coverages
Theme_Keyword:Land Cover Classification
Theme_Keyword:Earth Cover Classification
Place:
Place_Keyword_Thesaurus:
Place_Keyword:Innoko National Wildlife Refuge
Place_Keyword:Unalakleet
Place_Keyword:Alaska
Stratum:
Stratum_Keyword_Thesaurus:
Stratum_Keyword:
Temporal:
Temporal_Keyword_Thesaurus:
Temporal_Keyword:2001
Access_Constraints:
Use_Constraints:
Point_of_Contact:
Contact_Information:
Contact_Person_Primary:
Contact_Person:
Contact_Organization:
Contact_Organization_Primary:
Contact_Organization: Ducks Unlimited, Inc.
Contact_Person:
Contact_Position: GIS Manager
Contact_Address:
Address_Type:
Address: 3074 Gold Canal Drive
City:Rancho Cordova
State_or_Province: California
Postal_Code: 95670
Country:U.S.A.
Contact_Voice_Telephone: 916 852-2000
Contact_TDD/TTY_Telephone:

Contact_Facsimile_Telephone:
Contact_Electronic_Mail_Address:
Hours_of_Service:
Contact_Instructions:
Data_Quality_Information:
Attribute_Accuracy:
Attribute_Accuracy_Report:See Final Report
Lineage:
Source_Information:
Source_Citation:
Citation_Information:
Originator:Ducks Unlimited, Inc.
Publication_Date: 2000
Publication_Time:
Title:ArcInfo polygon coverage for Innoko earth cover mapping field sites and associated Dbase files.
Edition:
Geospatial_Data_Presentation_Form:ArcInfo polygon coverage. DBASE files.
Process_Step:
Process_Description:See "Innoko Earth Cover Classification"
Source_Used_Citation_Abbreviation:
Process_Date:1998-2001
Process_Time:
Source_Produced_Citation_Abbreviation:
Process_Contact:
Contact_Information:
Contact_Person_Primary:
Contact_Person:
Contact_Organization:
Contact_Organization_Primary:
Contact_Organization: Ducks Unlimited, Inc.
Contact_Person:
Contact_Position: GIS Manager
Contact_Address:
Address_Type:
Address: 3074 Gold Canal Drive
City:Rancho Cordova
State_or_Province: California
Postal_Code: 95670
Country:U.S.A
Contact_Voice_Telephone: 916-852-2000
Contact_TDD/TTY_Telephone:
Contact_Facsimile_Telephone:
Contact_Electronic_Mail_Address:
Hours_of_Service:
Contact_Instructions:

Cloud_Cover:
Spatial_Reference_Information:
Horizontal_Coordinate_System_Definition:
Planar:
Map_Projection:
Map_Projection_Name:
Albers_Conical_Equal_Area:
1st_Standard_Parallel:65
2nd_Standard_Parallel:55
Longitude_of_Central_Meridian:-154
Latitude_of_Projection_Origin:50
False_Easting:
False_Northing:
Planar_Coordinate_Information:
Planar_Coordinate_Encoding_Method:
Coordinate_Representation:
Abscissa_Resolution:
Ordinate_Resolution:
Geodetic_Model:
Horizontal_Datum_Name:NAD27 (Alaska)
Ellipsoid_Name:Clarke1866
Semi-major_Axis:
Denominator_of_Flattening_Ratio:
Entity_and_Attribute_Information:
Overview_Description:
Entity_and_Attribute_Overview:
See Appendix L in "Innoko Earth Cover Classification Final Report" or see Fielddata_documentation.doc on final deliverable CD.
Entity_and_Attribute_Detail_Citation:
Metadata_Reference_Information:
Metadata_Date:11/2001
Metadata_Review_Date:
Metadata_Future_Review_Date:
Metadata_Contact:
Contact_Information:
Contact_Person_Primary:
Contact_Person:
Contact_Organization:Bureau of Land Management Alaska
Contact_Organization_Primary:
Contact_Organization:
Contact_Person:
Contact_Position:
Contact_Address:
Address_Type:
Address:222 West 7th avenue
City:Anchorage

State_or_Province:Alaska
Postal_Code:99513
Country:U.S.A
Contact_Voice_Telephone:
Contact_TDD/TTY_Telephone:
Contact_Facsimile_Telephone:
Contact_Electronic_Mail_Address:
Hours_of_Service:
Contact_Instructions:
Metadata_Standard_Name:
Metadata_Standard_Version:
Metadata_Time_Convention:
Metadata_Access_Constraints:
Metadata_Use_Constraints:
Metadata_Security_Information:
Metadata_Security_Classification_System:
Metadata_Security_Classification:
Metadata_Security_Handling_Description:
Metadata_Extensions:
Online_Linkage:
Profile_Name:

Appendix H. Attribute Definitions and Descriptions.

Field Site Polygon Coverage Attribute Table:
inno_fld_sts.pat:

Field	Width	Output	Type	#Decimals	Description
AREA	4	12	F	-	ArcInfo internal fields
PERIMETER	4	12	F	-	ArcInfo internal fields
coverage#	4	5	B	-	ArcInfo internal fields
coverage-ID	4	5	B	-	ArcInfo internal fields
SITE_NUM	4	4	I	-	Field site number
YEAR	4	4	I	-	Year of field data collection.
AREA_NAME	10	10	C	-	Name of project area.
CREW_NUM	1	1	I	-	Id number of crew that collected data (1 = Aniak, 2 = Unalakleet, 3 = INWR)
OBS_NAV	2	2	C	-	Navigator initials for field data collection
OBS_VEG	2	2	C	-	Vegetation caller initials for field data collection
OBS_REC	2	2	C	-	Recorder initials for field data collection
OBS_DATE	8	8	D	-	Date of field data collection
PERCNT_SLP	3	3	I	-	Percent slope of site
ASPECT_DIR	2	2	C	-	Aspect of site (8 compass points – N,NE,E,etc., FL=Flat)
LATITUDE	10	10	N	5	Latitude of polygon labelpoint – Decimal Degrees
LONGITUDE	11	11	N	5	Longitude of polygon labelpoint – Decimal Degrees
OBS_LEVEL	1	1	I	-	Observation level, where: 1 = site visited on the ground,

					2 = viewed from above (ie from helicopter), 3 = viewed from a distance, 4 = viewed on air photos.
STEM_DIST	2	2	I	-	Distance between tree stems (applies to Open or Woodland Needleaf only). 0 = n/a 1 = 10'-15' 2 = 15'-20' 3 = 20'-25' 4 = 25'-30' 5 = 30'-35' 6 = 35'-40' 7 = >40'
OBS_ID	2	2	I	-	Id of site class as observed by the vegetation caller.
MAJ_OBS	20	20	C	-	Level 1 class of classification hierarchy.
OBS_CLASS	25	25	C	-	Vegetation caller's observed class for site.
COMMENTS	200	200	C	-	Notes made by vegetation caller while at the site.
CALC_CLASS	50	50	C	-	Classification of site as calculated using the project decision tree
CALC_CL_ID	6	6	N	3	ID number of calculated class
AA_FLAG	1	1	I	-	Indicates if site was used as accuracy assessment or training data. 0 = site used for training. 1 = site used for accuracy assessment.

<u>Data exported from Ducks Unlimited Field Form Software</u>:

INNO_SITE_PHOTO.dbf Dbase IV file containing site photo information.

YEAR	Year of field data collection
AREA_NAME	Name of project area

CREW_NUM	Id number of crew that collected data (1 = Aniak, 2 = Unalakleet, 3 = INWR)
SITE_NUM	Field site number; relates to SITE_NUM of field site polygon coverage in a one-to-many relationship (i.e. each site may have multiple photos).
SESS_NUM	Session number for field data collection. Photos are uniquely numbered within each session.
PHOTO_NUM	Photo number. Photos are numbered consecutively within each session.

INNO_SITE_SPECIES.dbf. Dbase IV file containing species composition information for each site. Each record describes an individual species observed at a site. Each site can have multiple records in this table, depending on how many different species were observed within the site.

YEAR	Year of field data collection
AREA_NAME	Name of project area
CREW_NUM	Id number of crew that collected data (1 = Aniak, 2 = Unalakleet, 3 = INWR)
SITE_NUM	Field site number; relates to SITE_NUM of field site polygon coverage in a one-to-many relationships. Each site may have multiple species records in this table.
SYMBOL	Species code - usually a combination of the first two letters of the genus and first two letters of the species.
PCT_COVER	Percent cover of the species at site observed by the vegetation caller. Percent cover for each site sums to 100%. Typically estimated in 5% increments. 0% or <NULL> represents presence of species at <5% cover.
HEIGHT	Height (meters) of tree or shrub species at site as estimated by the vegetation caller.

INNO_SPECIES.dbf

SYMBOL	Species code - usually a combination of the first two letters of the genus and first two letters of the species.
FAMILY	Plant family.
SPECIES	Plant genus and species.
AUTHOR	Author citation for species information.
COMMON	Common name.
ALT_NAME	Alternate name.
GENERAL	General plant type; used to pipe information correctly through the decision tree.
SPECIFIC	Specific plant type; used to pipe information correctly through the decision tree.

NOTE: The data in the inno_species.dbf and inno_site_species.dbf Dbase IV files are based on the PLANTS National Database developed by the National Resource Conservation Service. Edits have been made to some species codes to facilitate use of the data with the DUFF data entry program. Also species have been added to the list as necessary when compiling field data. Non-vegetated identifiers (Rock, Sand, Litter, etc.) have also been added.