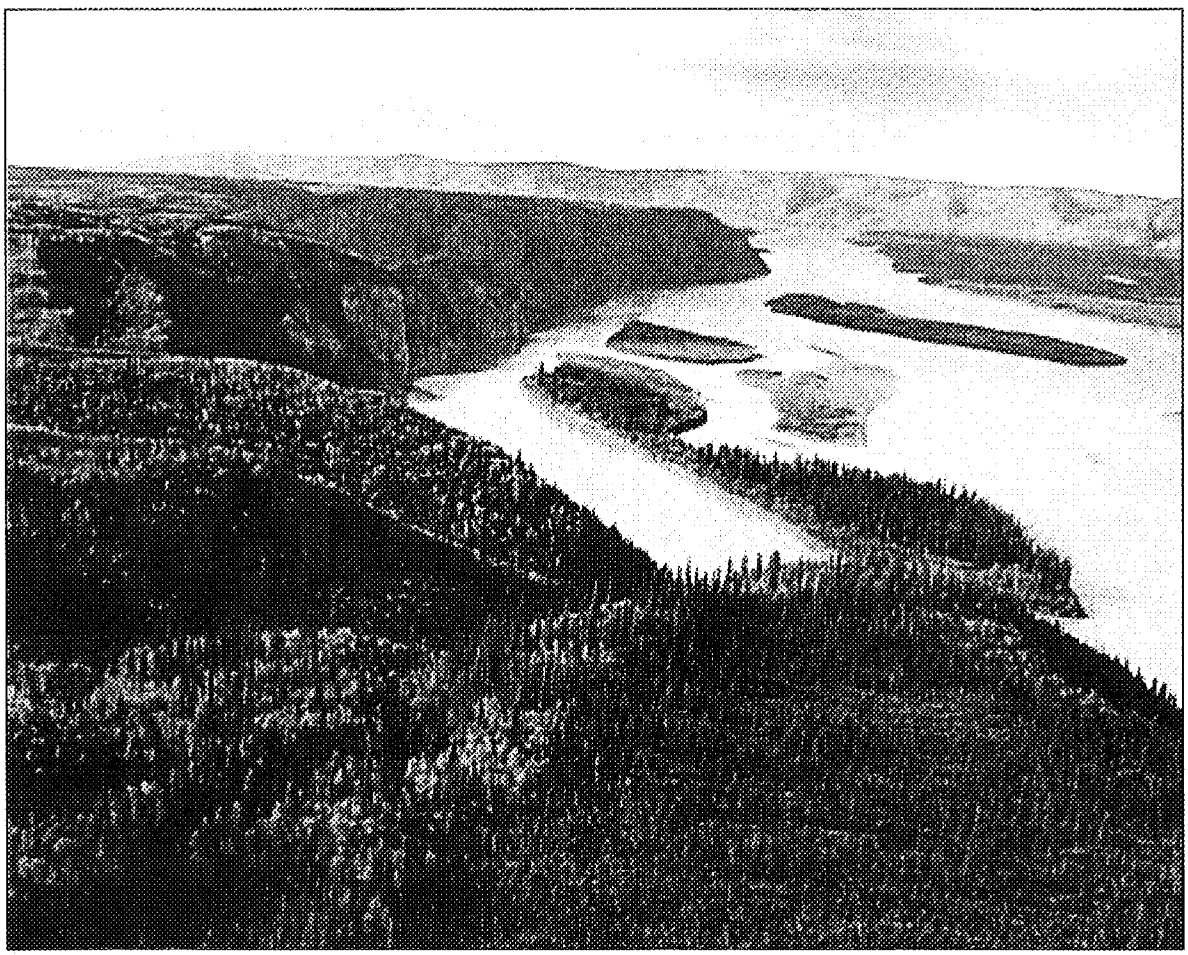
U.S. Department of the Interior
Bureau of Land Management

BLM-Alaska Technical Report 48
BLM/AK/ST-02/021+6500+931
September 2002

Ducks Unlimited, Inc.

Yukon-Charley/Black River/ Fortymile 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, and Ducks Unlimited, Inc. completed this project under a cooperative agreement.

Cover

The cover photo depicts the remoteness of the area and the need to use helicopters for data collection.

Technical Reports

Technical Reports issued by the Bureau of Land Management-Alaska present the results of research, studies, investigations, literature searches, testing, or similar endeavors on a variety of scientific and technical subjects. The results presented are final, or are a summation and analysis of data at an intermediate point in a long-term research project, and have received objective review by peers in the author's field.

The reports are available while supplies last from BLM External Affairs, 222 West 7th Avenue, #13, Anchorage, Alaska 99513 (907) 271-3318 and from the Juneau Minerals Information Center, 100 Savikko Road, Mayflower Island, Douglas, AK 99824, (907) 364-1553. Copies are also available for inspection at the Alaska Resource Library and Information Service (Anchorage), the United States Department of the Interior Resources Library in Washington, D. C., various libraries of the University of Alaska, the BLM National Business Center Library (Denver) and other selected locations.

A complete bibliography of all BLM-Alaska scientific reports can be found on the Internet at:
http://www.ak.blm.gov/affairs/sci_rpts.html.

Related publications are also listed at:
http://juneau.ak.blm.gov.

Yukon-Charley/Black River/Fortymile Earth Cover Classification

Technical Report 48
September 2002

U.S. Department of the Interior
National Park Service
Alaska Support Office
2525 Gambell St., Room 107
Anchorage, AK 99503

U.S. Department of the Interior
Bureau of Land Management
Alaska State Office
222 W. 7th Ave., No. 13
Anchorage, AK 99513

Ducks Unlimited, Inc.
3074 Gold Canal Drive
Rancho Cordova, CA 95670

Acknowledgments

This project was funded under a cooperative agreement between the United States Department of the Interior's, National Park Service (NPS) and Bureau of Land Management (BLM) and Ducks Unlimited, Inc (DU). This project was administered by Sara Wesser (NPS), John Payne (BLM) and Robb Macleod (DU).

Special thanks are extended to those who worked in the field. Those individuals include Dan Fehringer (DU), Lisa Fox (NPS), Scott Guyer (BLM), Jim Herriges (BLM), Nathan Jennings (DU), Beth Koltun (NPS), Fritz Reid (DU) and Gary Stewart (DU). Thanks to Joe Trudo, pilot from Trans-Alaska, Rey Madrid from Temsco, and Glen Bell from Tundra for safe air service. Thanks also to Bob McAlpin from Alaska Fire Service for help coordinating helicopter contracting, Kevin Fox (NPS) for ferrying cargo and personnel from Central to Coal Creek field camp, Dan Fehringer (DU) for image processing, Mark Pearson (Geo North, Inc.) for programming the Ducks Unlimited Field Form (DUFF) database, and Jing Huang (DU) for programming the accuracy assessment program.

Additionally, we would like to acknowledge the efforts of those who have technically reviewed this report. John Payne and Ed Bovy offered important suggestions.

Table of Contents

List of Figures

List of Tables

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 National Park Service (NPS) has also had an ongoing mapping effort for their lands with the goal of mapping all Parks in Alaska. The goal of this project was to continue the mapping effort for both the BLM and NPS while reducing the overall cost by simultaneously mapping the Yukon-Charley Rivers National Preserve its surrounding environs and the Black River/Fortymile River BLM lands. One Landsat Thematic Mapper (TM) satellite scene (Path 66, Row 14, acquired August 20, 1991, shifted 40% south) was used to classify the project area into 30 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. A helicopter was 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 record locations of new sites selected in the field. Data was collected on 316 field sites during a 10-day field season from August 3, 1997 through August 13, 1997. Approximately 40% (134) of these field sites were set aside for accuracy assessment. The field data collected in 1997 was supplemented with field data collected by the NPS in 1988 and 1990 for unrelated projects. The NPS data provided an additional 54 training sites and 112 accuracy assessment sites. Twenty-five accuracy assessment sites for earth cover classes not visited in the field (clear water, turbid water and snow) were obtained through photo interpretation. 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 of the major categories was 80%.

Introduction

In Alaska, most ground-based inventories of vegetation have been limited by accessibility to the area, or logistically restricted to a single large watersheds or several smaller watersheds. Aerial photography is available for much of Alaska, but is highly variable in scale and typically outdated which generally limits its usefulness for determining earth cover over large regional areas. In the last two decades, space-borne remote sensors (Landsat, *Systeme Pour l' Observation de la Terre*, European Remote Sensing Satellite-1, and others) have emerged as the best platforms for developing regional earth cover databases. Access to these large databases allow researchers, biologists and managers to define and map crucial areas for wildlife, do analysis of related habitats, plot movement patterns for large ungulates, generate risk assessments for proposed projects and provide baseline data to which wildlife and sociological data can be related.

A satellite inventory of earth cover serves many purposes. It provides baseline acreage statistics and corresponding maps for areas that currently lack or have outdated information for decision making. It is very useful for planning environmental impact statements, comprehensive management plans, and other regional studies that are mandated by the federal government. It can be integrated with other digital data sets into a geographic information system (GIS) to produce maps, overlays, and further analysis. It also helps researchers identify areas most important to specific species of interest and can guide biologically driven decisions on land use practices (Kempka *et al.* 1993). Knowledge of the size, shape, distribution and extent of earth cover types, when linked to species habitat and human activities, vastly improves our decision-making capabilities. The greater the area encompassed by earth cover information, in association with other digital base layers, the more regional, landscape-level assessment can be made and the more reliable land management decisions will become.

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 (Ritter *et al.* 1989). The initial mapping projects that were undertaken focused on mapping only the wetland types such as deep marsh, shallow marsh and aquatic classes (Ritter *et al.* 1989). It soon became apparent that mapping the entire landscape was more cost effective and most useful for habitat studies and wildlife management. Over the years, many refinements have been made to both the techniques of collecting field information and classifying the imagery. The BLM is currently in the process of mapping all of their lands in Alaska using this methodology. Many other agencies in Alaska (i.e. National Park Service, United States Fish and Wildlife Service, United States Forest Service, Alaska Department of Natural Resources and Alaska Department of Fish and Game) are also using similar techniques for mapping and wildlife analysis.

Landsat Thematic Mapper (TM) satellite imagery was chosen as the primary source for this mapping. Satellite imagery offers a number of advantages for a project of this size. It is a cost effective data source for regional mapping; can be processed using automated mapping techniques; and is collected on a repeat cycle, providing a standardized data source for future database updates (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 data can produce highly accurate classifications with a moderately detailed classification scheme.

The BLM was planning on performing earth cover mapping for the Steese National Conservation Area (SNCA) and the White Mountains National Recreation Area (WMNRA) during the 1997-98 calendar year in cooperation with DU. Adjacent to the SNCA is the Yukon-Charley Rivers National Preserve (YUCH). Through a series of meetings and conferences, the BLM and National Park Service (NPS) embarked upon a cooperative mapping project adjacent to the Steese and White Mountains area that encompasses the YUCH and adjacent BLM lands. It is to the mutual benefit of the BLM and NPS to cooperatively develop maps of these areas thereby accruing considerable monetary savings, and promoting consistency in mapping efforts among sister Department of Interior agencies.

Project Objective

The objective of this project was to develop a baseline earth cover inventory using Landsat TM imagery for the Yukon-Charley Rivers National Preserve and Black River/Fortymile River BLM areas. 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

The project area (Figure 1) is located along the eastern border of Alaska and encompasses the area covered by one Landsat TM scene, path 66, row 14 shifted 40% south. Bounding coordinates for the study area are: UL – 66d 08' 14"N, 143d 37' 33"W; UR – 65d 33' 06"N, 139d 47' 41"W; LR – 64d 07' 58"N, 141d 12' 57"W; LL – 64d 41' 07"N, 144d 52' 23"W. This includes the town of Eagle, AK, the entire area of Yukon-Charley Rivers National Preserve, the Fortymile River area, portions of the Black River, a portion of Canada, and includes all or portions of the following United States Geological Survey (USGS), 1:250,000 scale quadrangles: Big Delta, Black River, Charley River, Circle, and Eagle. Elevations range from 550 feet along the Yukon River to over 6000 feet in the mountains within Yukon-Charley Rivers National Preserve. The area is found within the northern boreal forest region that stretches through northern Alaska and Canada. Major vegetative communities include open and woodland black spruce *(Picea mariana)* and white spruce (*Picea glauca*) forest, tussock tundra, low shrub tundra and dwarf shrub tundra. The climate is extreme, with winter temperatures reaching -70°F in winter and up to 90°F in summer.

Data Acquisition

One Landsat TM scene was purchased to cover the project area. The scene was

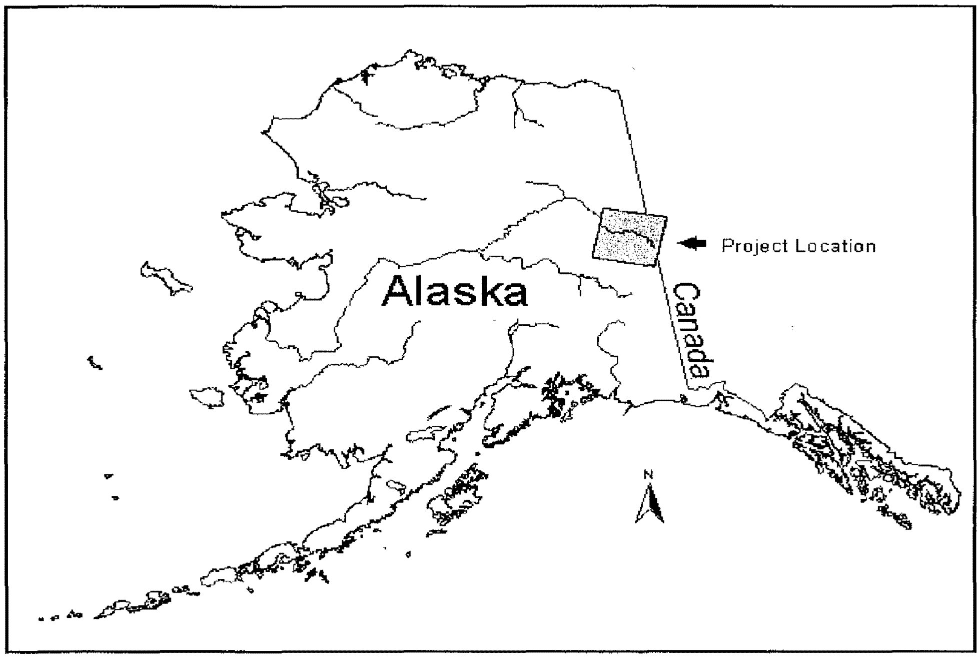


Figure 1. The project area for Yukon-Charley/Black River/Fortymile Mapping Project.

purchased from Earth Resource Observation Systems (EROS) data center in Albers Equal Area projection and was terrain corrected. The scene was Path 66, Row 14 (shifted 40% south) acquired on August 20, 1991. (Table 1, Figure 2). In addition, a spring image was purchased for the project area to help in the identification of certain earth cover types. The scene was Path 66, Row 14 (shifted 40% south) acquired on April 16, 1986 with an root mean squared error of 15.11 meters (Table 1, Figure 2). It was also purchased terrain corrected from EROS Data Center in Universal Transverse Mercator (UTM) Zone 7. This scene was re-projected into Albers Equal Area to conform to the NPS Standard.

Field data was collected over a 10-day period from August 3, 1997 to August 13, 1997. This data was supplemented with field data collected by in 1988 and 1990 for an unrelated project. The ancillary data used in this project included: National Aeronautics and Space Administration (NASA) 1:60,000 aerial photographs (color infrared transparencies from 1980,1981,1982,1984, and 1986, color infrared prints from 1984 and 1987), USGS 1:63,360 and 1:250,000 scale Digital Elevation Models (DEM), BLM's land status coverage and Intensive Management Areas polygons.

Table 1. The satellite imagery used for the Yukon-Charley/Black River/Fortymile Mapping Project.

SENSOR	PATH/ROW	% SHIFT	DATE	RMS ERROR
Landsat Thematic Mapper	66/14	40%	8/20/91	N/A
Landsat Thematic Mapper	66/14	40%	4/16/86	15.11 Meters

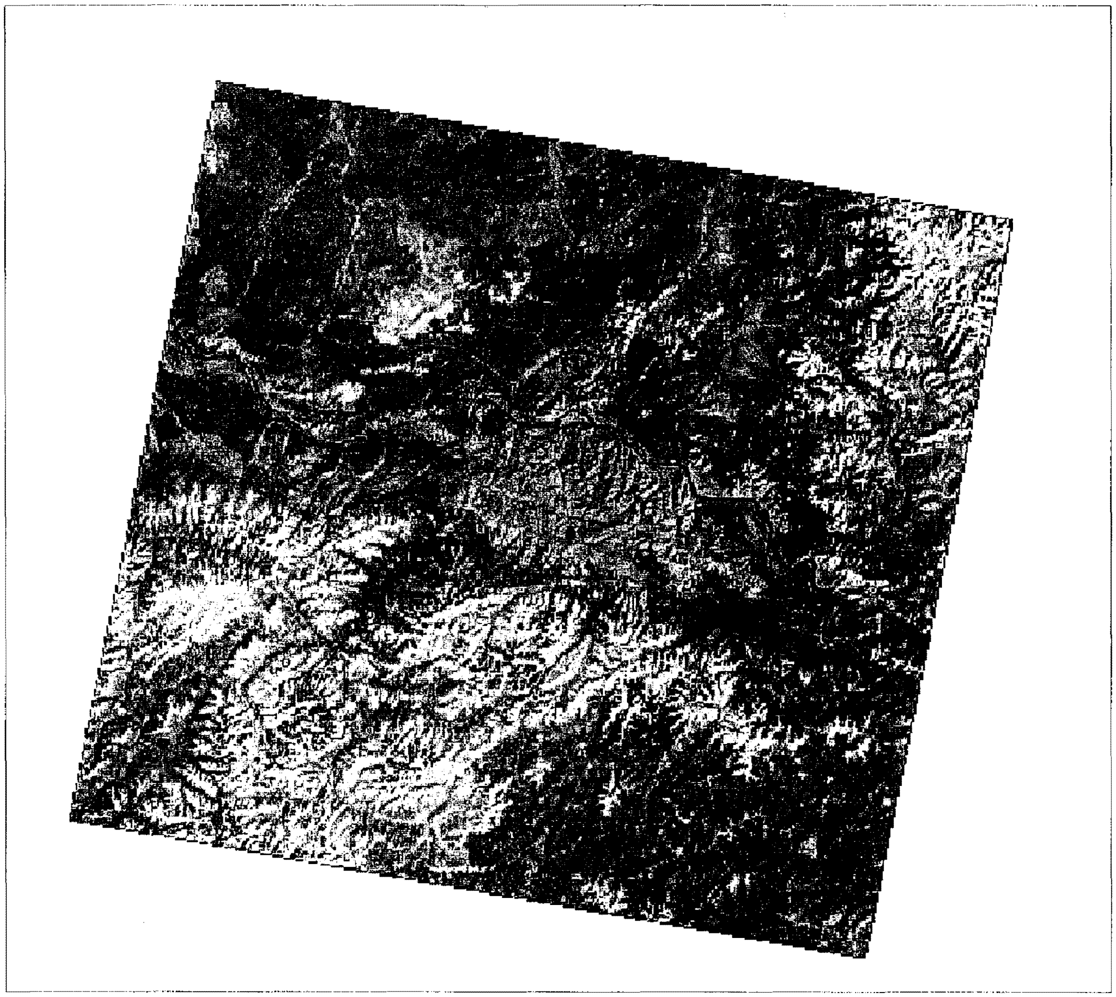


Figure 2. The imagery used in the Yukon-Charley/Black River/Fortymile Mapping Project.

Methods

Classification Scheme

The first step in any mapping project is the definition of a classification system that categorizes the features of the earth to be mapped. The system is derived by the anticipated uses of the map information and the features of the earth that can be discerned with the data (e.g., satellite imagery, aerial photography or field information) being used to create the map. A classification system has two critical components: (1) a set of labels (e.g., forest, shrub, water); and (2) a set of rules, or a system of assigning labels. It is important that the set of rules of the system for assigning labels be both mutually exclusive and totally exhaustive (Congalton 1991). In other words, any area to be classified should fall into one and only one category or class and every area should be included in the classification.

Until recently, the classification system for the BLM/DU earth cover projects was tailored to the needs of the area being studied. As the projects expanded in size and as other cooperators (i.e. United States Fish and Wildlife Service and National Park Service) began mapping and sharing data, the need to standardize the classification system arose so that data could be shared and utilized on a statewide basis. At the BLM Earth Cover Workshop in Anchorage, March 3-6, 1997, a classification system based on an existing vegetation classification (Viereck *et al.* 1992) was designed to address these needs. The goal of the classification system 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 agencies so a common integrated database can be built for the state of Alaska. Since the March 1997 meeting, the classification system has been revised due to small inconsistencies that were found during field data collection on the Steese/White, Yukon-Charley and Gulkana projects.

The classification scheme consisted of 10 major categories and 27 subcategories (Table 2). A classification decision tree (Appendix A) and written description was developed in order to eliminate any confusion in the classification. A few additional sub-classes, were added to the regional classification scheme, while others were omitted. The additional classes are woodland needleleaf moss, terrain shadows and burned (Table 3). Each class was assigned a value or code that was used for the final classified file. When compared to the classification scheme developed at the BLM Earth Cover Workshop, some classes are missing. There are two reasons for the missing classes. First, not all of the cover types developed in the BLM Earth Cover Workshop are found in the project area (e.g. – urban, agriculture). Second, we were unable to collect an adequate number of field sites for some of the classes that were uncommon or, when found, were typically under five acres in area (e.g. – low shrub lichen, dwarf shrub lichen, emergent). An asterisk (*) indicates the class was not found in the final classification.

Table 2. The classification scheme developed at the BLM Earth Cover Workshop.

1.0 Forest
- 1.0 Closed Needleleaf
- 1.2 Open Needleleaf
  - 1.21 Open Needleaf Lichen
- 1.3 Woodland Needleleaf
  - 1.31 Woodland Needleaf Lichen
- 1.4 Closed Deciduous
  - 1.41 Closed Birch *
  - 1.42 Closed Aspen *
  - 1.43 Closed Cottonwood/Balsam Poplar *
  - 1.44 Closed Mixed Deciduous *
- 1.5 Open Deciduous
  - 1.51 Open Birch *
  - 1.52 Open Aspen *
  - 1.53 Open Cottonwood/Balsam Poplar *
  - 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 Willow/Alder Low Shrub
  - 2.22 Other Low Shrub/Tussock Tundra
  - 2.23 Other Low Shrub/Lichen
  - 2.24 Other Low Shrub
- 2.3 Dwarf Shrub
  - 2.31 Dwarf Shrub/Lichen
  - 2.32 Other Dwarf Shrub

3.0 Herbaceous
- **3.1** Byroad
  - 3.11 Lichen
  - 3.12 Moss
- 3.2 Wet Herbaceous
  - 3.21 Wet Graminoid
  - 3.22 Wet Forb
- 3.3 Mesic/Dry Herbaceous
  - 3.31 Tussock Tundra
    - 3.311 Tussock Tundra/Lichen
    - 3.312 Tussock Tundra Other
  - 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

Table 3. The classes mapped and assigned value for the Yukon-Charley/Black River/Fortymile Mapping Project.

VALUE	CLASS NAME
1	Closed Needleleaf
2	Open Needleleaf
3	Open Needleleaf Lichen
4	Woodland Needleleaf
5	Woodland Needleleaf - Lichen
6	Woodland Needleleaf – Moss
10	Closed Deciduous
13	Open Deciduous
16	Closed Mixed Needleleaf/Deciduous
17	Open Mixed Needleleaf/Deciduous
20	Tall Shrub
21	Low Shrub
22	Low Shrub – Lichen
23	Low Shrub – Tussock Tundra
24	Dwarf Shrub
32	Wet Graminoid
34	Wet Sedge
40	Dry Herbaceous
50	Tussock Tundra
51	Tussock Tundra – Lichen
60	Aquatic Bed
70	Clear Water
71	Turbid Water
72	Snow
80	Sparsely Vegetated
81	Rock/Gravel
92	Cloud
93	Cloud Shadow
94	Terrain Shadow
96	Fire (Burned)

Image Preprocessing

The first step that is taken when an image is received is to check the image for quality and consistency. Each band is looked at by displaying the image on screen and by viewing the histogram. Combinations of bands are then displayed to check for band to band registration and for clouds, shadows, and haze. The positional accuracy is checked using any available ancillary data such as adjacent imagery, hydrography, and DEMs. If the image is of acceptable quality, it is then archived onto a compact disk and recorded into a database of available GIS data.

The largest single expense for field data acquisition is helicopter time. In order to maximize the helicopter time budgeted for the project, field sites are delineated and plotted on the field maps before the fieldwork begins. The field sites need to cover the whole spectral variation of the imagery and extend throughout the project area to produce an adequate classification. In other words, it is important to have enough samples in each class to include the variation of spectral responses of the class throughout the entire image. For example, a shrub class in the southern part of the image may have a different spectral response than the same shrub class in the northern part of the image. The spectral response of the northern shrub may be confused with a deciduous class in the south. Therefore, it is important to have enough samples in each class to compensate for the spectral variation.

The field sites were delineated using an unsupervised clustering and seeding technique to initially generate spectrally unique areas within the study area. These spectrally unique areas were then refined and selected as sample sites for the fieldwork using aerial photography and a decision tree of the earth cover classification. Whenever possible, training sites were grouped in clusters in order to reduce the amount of ferrying time between sites. A tally of estimated number of field sites per class was kept until all of the classes were adequately sampled throughout the project area. The coordinates of the center points of the field sites were generated and uploaded into a military GPS unit (PLGR) to be used while field sampling. 1:63,360 scale quadrangle color infrared plots of the Landsat TM data were also produced for the placement of additional field sample sites and for navigational purposes.

Field Verification

The purpose of field data collection is to assess, measure, and document the on-the-ground vegetation variation within the project area. This variation will then be correlated with the spectral variation in the satellite imagery during the image classification process. Low-level helicopter surveys are a very effective method of field data collection since a much broader area can be covered with an orthogonal view from above, similar to a satellite sensor (Figure 3).

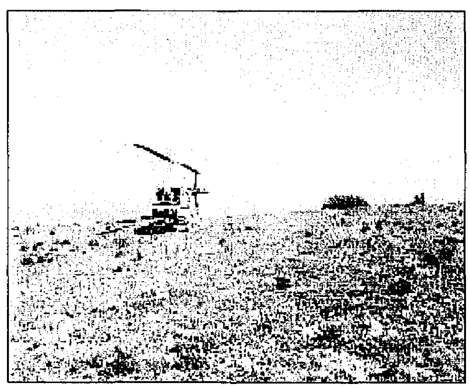


Figure 3. Data collection with helicopters effectively covers the extensive project area.

Helicopter surveys are sometimes the only alternative in Alaska due to large amounts of roadless areas that are difficult to access. The procedures for collecting field data have evolved into a very efficient and effective means of data collection. The navigator uses a PLGR GPS to locate the site and verifies the location on the field map. As the helicopter approaches the site at about 300 feet above ground level the navigator describes the site (Figure 4) and the biologist takes a picture with a digital camera. The pilot will then descend to approximately 5-10 feet above the vegetation and laterally move through the site so that the biologist can call out the vegetation to the recorder. The biologist will also take another picture with the digital camera for a close up view of the site. The pilot will then ascend to approximately 100 feet so that the biologist can call out the percentages of each species to the recorder. The navigator will then direct the pilot to the next site. On average, it normally takes about 6-10 minutes to collect all of the pertinent information for one site. In order to obtain a reliable and consistent field sample, a custom field data collection card (Kempka *et al.* 1994) was developed and used to record field information (Figure 5). A five-person helicopter crew was designated to perform the field assessment. Each crew consisted of a pilot, biologist, recorder, navigator and alternate. The navigator, who runs the GPS equipment and interprets the satellite image derived field maps, occupies the co-pilot seat. The biologist, the person most knowledgeable regarding the vegetation, and the recorder, who records species percentages and other data on the field form, occupy the remaining two seats in the back of the helicopter. The alternate is responsible for flight following, data entry of the previous day's work and substituting in case of sickness. On the first day of fieldwork, sampling was performed by landing the aircraft on the ground to verify and standardize the classification and sampling techniques. After the first day, the majority of the sites were observed without landing the helicopter to determine the percent cover for each species and an overall earth cover class. Ground verification was performed when identification of dominant vegetation and/or species was uncertain.

Figure 4. The navigator describes the site to the biologist.

Field Data Analysis

The field sites were entered into a customized database Ducks Unlimited Field Form (DUFF) designed by the BLM and DU and programmed by GeoNorth. The relational database is powered by *Standard Query Language Anywhere* (SQL) with a user interface programmed in Visual Basic. The user interface looks similar to the hard copy field card. It utilizes pull down menus and checks for data integrity (Figure 6). The database program also automatically calculates an overall class name for each site based on the recorded species and percentages of cover.

Rev 7/15/97

Steese/White-Yukon Charley Field Form

1997-YUCH - 1 - 319 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 Needleleaf Only)			

(Circle Lichen where present)

Forest	Forest	Shrub	Herbaceous	Herbaceous	Aquatic Veg/Water	Barren	Other
Closed Needleleaf	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		

%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

%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	

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

%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:

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

%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 in NEED. NPS

Figure 5. Field data collection form.

The digital images of the site are also recorded in the database and are accessible directly from the database. After each field session, the field data is entered into the customized database. The field sites can then be summarized by class name to ensure that adequate samples are obtained for the project. The class that the database assigns the field site is also compared to the class that the biologist assigned the site as an additional check for data integrity.

An ARC/INFO polygon coverage was generated for each site collected in the field. The pertinent attributes from the database were then related to the ARC/INFO coverage. A new attribute (Type) was added to the coverage indicating if the site was to be used as a training area or for accuracy assessment. Two separate coverages were created using the Type attribute to separate the training sites from the accuracy assessment sites. The coverage with all the field sites and the coverage with the accuracy assessment sites were stored in separate files. Only the coverage with the training sites was used in the classification process.

Classification

Every image is unique and presents it's own special problems in the classification process. The approach that was used in this project has been used and proven to be successful over many years (Figure 7). The image processor's site-specific experience and knowledge in combination with high quality ancillary data can overcome image uniqueness to produce a high quality and extremely useful product. Therefore, the image processor should be actively involved in the field data collection and hopefully have first hand knowledge of every training site.

Generation of New Bands

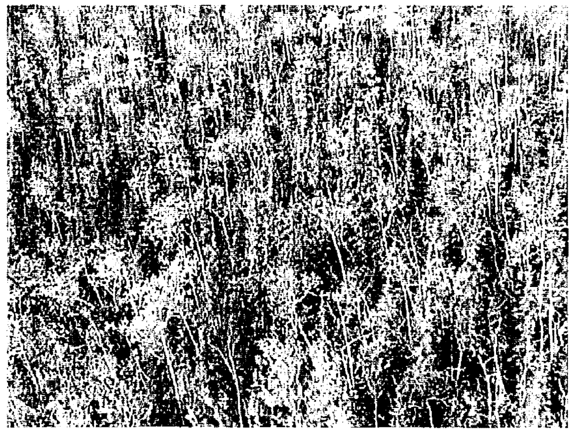
New bands can be derived from the raw data by simple operations like dividing one band by another or complex statistical computations like principle components transformations. The idea behind generating new bands is that unique information will be derived from the process and will enhance the classification. The possibilities of generating new bands from the raw imagery are infinite. A few of the more popular ones are principle components, tasseled cap, band ratios, and Normalized Difference Vegetation Index. It is beyond the scope of this project to generate and test every possible combination. However, based on past experience and other studies, one new band was generated from the raw Landsat TM data for this project. The new band was generated by dividing the digital number (DN) of band 4 by the DN of band 3. From past experience in Alaska and other vegetation studies the 4/3 ratio was chosen for this project (Kempka *et al.* 1995, Congalton *et al.* 1993). The 4/3 ratio typically reduces the shadow effects and enhances the differences between vegetation types. This new band was subset with the six raw bands to produce a seven band file to be used in the classification. The thermal band was not used in the classification.

Removal of Clouds and Shadows

The clouds and cloud shadows are removed from the image before the classification is started. This process eliminates the confusion that is caused between the clouds and cloud shadows and other vegetation types. They are removed using an unsupervised classification and manual on-screen editing. The clouds are separated from the shadows and the two classes are recoded to their respective class number.

Field SiteYUCH319 – Closed Mixed Needleleaf/Deciduous

High site photo.



Low site photo.

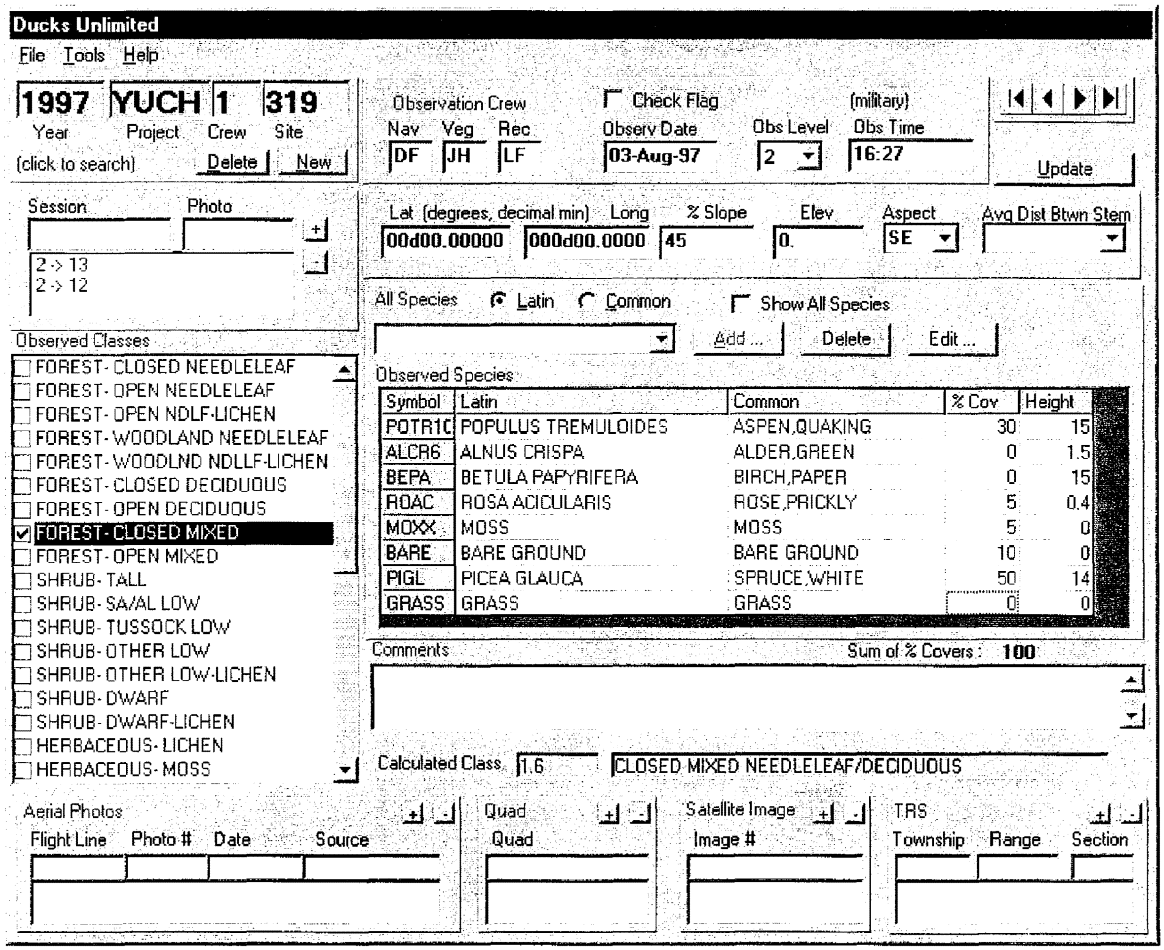


Figure 6. The custom database and user interface for field data entry (DUFF).

The cloud/shadow layer is then combined with the rest of the classified image during the last step in the classification process.

Seeding Process

The field sites that were designated as training areas were "seeded" (generate statistics from the imagery) in ERDAS, Inc. Imagine (Imagine) software using spectral bounds as the limit for seed growth. The standard deviations of the seeded areas were kept to about 3 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. These classes were easily recognized on the imagery and aerial photography. 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 is generated using the six raw bands and the 4/3 ratio. One hundred and fifty signatures are derived from the unsupervised classification using the ISODATA program in Imagine. The output of this process is a signature file similar to that of the seeding process only it contains the 150 unsupervised signatures. A maximum likelihood classification of the 150 unsupervised signatures is 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 approach is an iterative process because all of the supervised signatures are not going to cluster perfectly with the unsupervised signatures the first time. The unsupervised signatures that match well with the supervised signatures were inspected 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. This classification approach provides three major benefits: (1) it aids in the labeling of the unsupervised classes by grouping them with known supervised training sites; (2) it helps identify classes that possess no spectral uniqueness, (i.e. training sites that are spectrally inseparable); and (3) identifies areas of spectral reflectance present in the imagery that have not been represented by a training site.

Editing and Modeling

The final step of the classification process was to model the remaining confusion and make final edits. There may be a few problem areas in the classification that the spectral data can not separate, but a simple model can take care of the problem. For instance, water may be classified where there are terrain shadow effects, which can be easily modeled out of the classification using DEMs. In the end, there may be a few problems in the classification which can not be addressed with either spectral separation

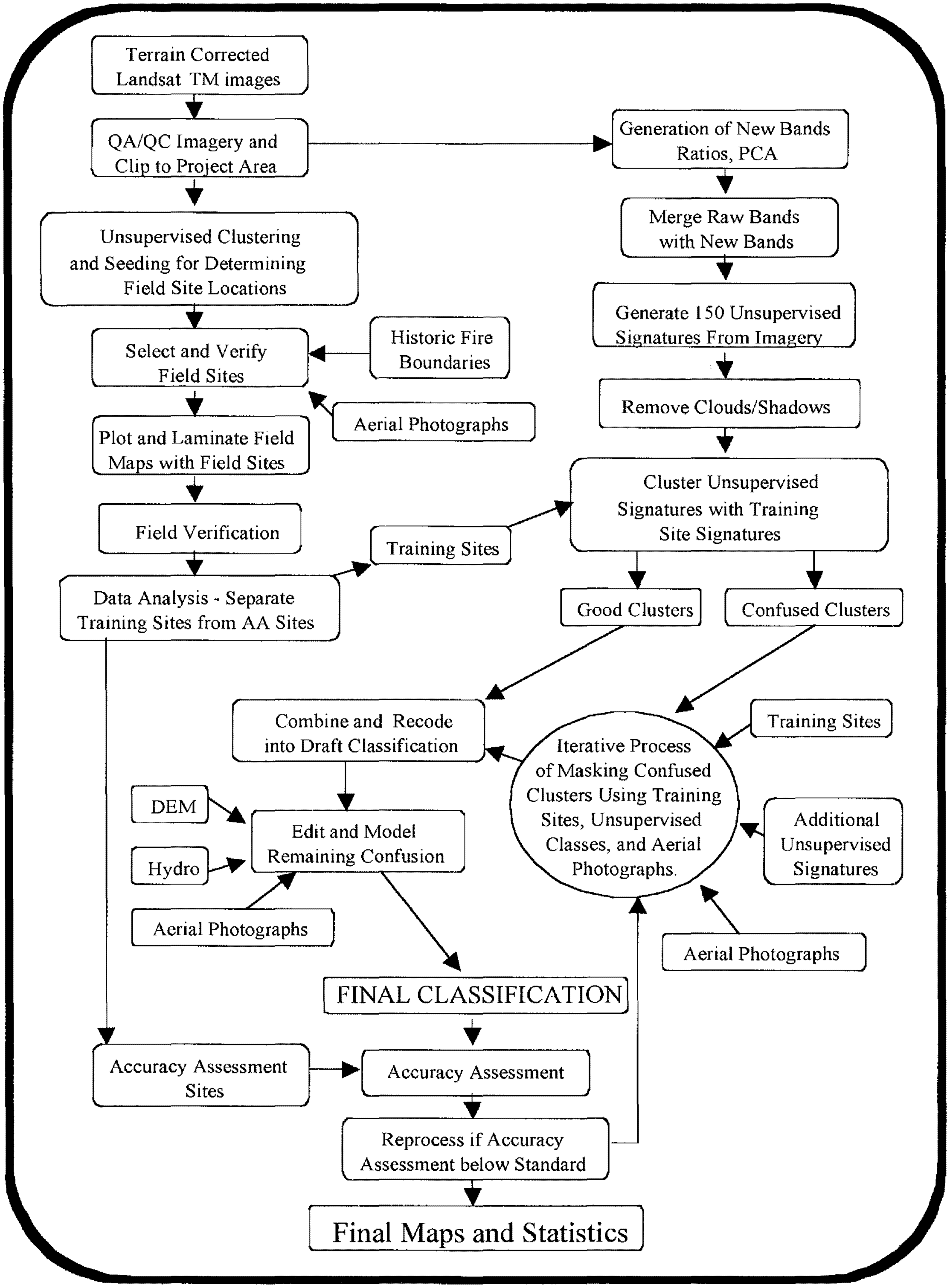


Figure 7. Image processing flow diagram.

or modeling. When this happens, the image processor must use aerial photographs and on screen digitizing to remedy the situation.

Accuracy Assessment

The purpose of quantitative accuracy assessments is the identification and measurement of map errors. There are 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). There are many factors to consider when designing an accuracy assessment. These include how to determine the sample size, how to allocate this sample, and which sampling scheme to employ. 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 is 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 the sample size is determined, it then must be allocated among the categories in the map. A strictly proportional allocation is possible. However, the smaller categories in aerial extent will have only a few samples that may severely hamper future 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.

Error Matrix

The standard method for assessing the accuracy 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. The individual accuracy of each category are 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. It is important to note that the error matrix and accuracy assessment is based on the assumption that the reference data is 100% correct. This assumption is not always true, especially when the reference data is derived from aerial photographs.
In addition to clearly showing errors of omission and commission, the error matrix can be used to compute overall accuracy, producer's accuracy, and user's accuracy (Story and Congalton 1986). Overall accuracy is simply the sum to 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. Producer's and user's accuracies are ways of representing

individual category accuracy instead of just the overall classification accuracy.

Kappa Analysis

A Cohen's coefficient of agreement (Kappa) analysis is performed on the error matrix as a further measure of accuracy (Congalton 1991). Kappa is a measure of overall agreement in the error matrix after chance agreement is removed from consideration. In other words, Kappa attempts to provide a better measure of agreement by adjusting the overall accuracy for chance agreement or that agreement that might be contributed solely by chance matching of the two maps. The result of the Kappa analysis is the KHAT statistic. Landis and Koch (1977) characterized the possible ranges for KHAT into three groupings: a value greater then 0.80 (i.e., 80%) represents strong agreement; a value between 0.40 and 0.80 (i.e., 40 - 80%) represents moderate agreement; and a value below 0.40 (i.e., 40%) represents poor agreement. In addition to calculating KHAT, confidence intervals can be calculated using the approximate large sample variance. The large sample variance can then be used to test if the agreement between the classification and reference data is significantly different from zero or a random classification with the Z statistic. The Z statistic in the Kappa analysis can also be used to test if a classification is significantly different from another classification. A "Z", statistics of 1.98 or less means that the classification is not significantly different from a random classification at the 99% confidence level.

Accuracy Assessment Software

In order to automate the accuracy assessment process, a program was developed in Visual Basic to format the data, calculate the statistics for each individual accuracy assessment polygon, flag mixed sites and generate the error matrix and statistics. The program uses three input files to perform the analysis. The first input file is a text file of the results of a summary routine in Imagine using the classification and rasterized version of the accuracy assessment sites. The second input is a list of site numbers and an associated label (class name). This file is used in the class listing to compare reference and classified values. The third input is a list of class names, total number of sites and total number of classes used in the classification and defines the error matrix. After the three files are input, the program generates a listing of accuracy assessment sites along with the assigned class value for both the reference data and classification. The class value that is assigned for the classification is based on the majority rule. The next column in the listing includes a "classified correctly" value from 1 to 3 that describes the degree of homogeneity of the classification that occurred in that particular site. A value of 1 means that the majority class percentage in the site is greater than or equal to 60%, a value of 2 means that the majority class percentage in the site is less than or equal to 40%, and a value of 3 means that the majority class percentage in the site is greater than 40% and less then 60%. Additional columns in the listing are the percentage and number of pixels by class that fell within the accuracy assessment site in descending order. The table is used to analyze the mixed classes and to clear up any confusion between the accuracy assessment site and the classification. The table also helps to identify any non-map errors in the accuracy assessment such as registration problems and labeling errors. The next step in the program calculates the error matrix and Kappa statistics for the classification. The program generates an error matrix based on the reference value and the classification value that was generated in the previous step. The error matrix was then used to compute the Kappa statistics. The error matrix and Kappa statistics were used to report the final accuracy of the classification and are produced for the final report.

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 make 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. For this project, the fieldwork for obtaining the training sites for classifying the imagery and the reference data for the accuracy assessment was accomplished at the same time. Special care was taken during the preprocessing 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 (50) for the accuracy assessment. The primary objective for this project was to create the best possible earth cover map. In the classes that were not well sampled, few if any filed sites were withheld for the accuracy assessment. This means that there is little measure of confidence for those classes in the accuracy assessment. However, withholding a percentage of sites for the accuracy assessment does give us some confidence in the classification and guides the image processor to certain areas of confusion in the classification.

Some Considerations

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 20, 1991, the aerial photographs spanned a seven-year period from 1980 through 1987, the field data was collected in August 1997, and the intensive management area data was collected in 1988 and 1990. Differences due to environmental changes from the different sources may have a major impact on the accuracy assessment. 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 error (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.

Results

Field Verification

Field data were collected on a total of 316 field sites during the 10-day field season from August 3, 1997 through August 13, 1997 (Table 4.). Approximately 40% (134) of these sites were reserved for accuracy assessment. The sites from the 1997 fieldwork were supplemented with existing data from 166 field sites visited by the NPS in 1988 and 1990 for projects unrelated to this. The NPS data provided an additional 54 training sites and 112 accuracy assessment sites. Twenty-five accuracy assessment sites for earth cover classes not visited in the field (clear water, turbid water and snow) were obtained through photo interpretation. A Bell Jet Ranger helicopter was used to gain access to the field sites. Field camps and fuel were based out of the Coal Creek Research Camp maintained by the NPS.

Classification

Classification of 30 earth cover classes was attempted. Many of these classes were inadequately represented in the field data available for training and accuracy assessment. As a result, classes with an inadequate sample size were grouped up into the next hierarchical cover type for accuracy assessment of the classification. This grouping resulted in 21 accuracy assessment classes (Table 5). The area and percent area was calculated for each of the 30 earth cover classes (Table 6) as well as for the grouped accuracy assessment classes (Table 7). A metadata file was also created for use with distributing the classified data (Appendix B). The result of the Landsat TM classification is shown in Figure 8.

Table 4. The number of field samples and number withheld for accuracy assessment.

	1997 Field Sites	NPS IMA Data	Photo Sites	Total
Training	182	54	0	236
Accuracy Assessment	134	112	25	271
Total	316	166	25	507

Table 5. The classes used in the accuracy assessment.

VALUE	CLASS NAME	GROUPED CLASSES
1	Closed Needleleaf	
2	Open Needleleaf	Open Needleleaf - Lichen
4	Woodland Needleleaf	Woodland Needleleaf - Lichen and Moss
10	Deciduous	Closed Deciduous, Open Deciduous
16	Mixed Needleleaf/Deciduous	Closed Mixed Ndl./Decid., Open Mixed Ndl./Decid.
20	Tall Shrub	
21	Low Shrub	Low Shrub - Other, Lichen, and Tussock
24	Dwarf Shrub	
31	Wet Herbaceous	
40	Dry Herbaceous	
50	Tussock Tundra	Tussock Tundra - Lichen
70	Clear Water	
71	Turbid Water	
72	Snow	
80	Sparsely Vegetated	
81	Rock/Gravel	
94	Terrain Shadow	
95	Fire (Burned)	

Table 6. The area and percent area of the 30 classified earth cover classes.

CLASS#	CLASS NAME	ACRES	% AREA
1	Closed Needleleaf	42,936.69	0.5%
2	Open Needleleaf	3,271,781.61	41.8%
3	Open Needleleaf - Lichen	2,301.34	0.0%
4	Woodland Needleleaf	1,223,988.91	15.6%
5	Woodland Needleleaf - Lichen	39,649.91	0.5%
6	Woodland Needleleaf - Moss	8,774.59	0.1%
10	Closed Deciduous	311,919.00	4.0%
13	Open Deciduous	32,725.65	0.4%
16	Closed Mixed Needleleaf/Deciduous	327,268.25	4.2%
17	Open Mixed Needleleaf/Deciduous	303,513.58	3.9%
20	Tall Shrub	65,452.41	0.8%
21	Low Shrub	692,623.65	8.8%
22	Low Shrub - Lichen	826.64	0.0%
23	Low Shrub - Tussock Tundra	316,287.95	4.0%
24	Dwarf Shrub	293,156.86	3.7%
32	Wet Graminoid	3,416.65	0.0%
34	Wet Sedge	649.17	0.0%
40	Dry Herbaceous	40,151.86	0.5%
50	Tussock Tundra	65,494.66	0.8%
51	Tussock Tundra - Lichen	3,446.23	0.0%
60	Aquatic Bed	108.31	0.0%
70	Clear Water	22,124.97	0.3%
71	Turbid Water	46,037.54	0.6%
72	Snow	7,893.24	0.1%
80	Sparse Vegetation	156,671.27	2.0%
81	Rock/Gravel	171,814.15	2.2%
92	Cloud	1,630.82	0.0%
93	Cloud Shadow	604.69	0.0%
94	Terrain Shadow	295,415.06	3.8%
96	Fire (Burn)	80,332.19	1.0%
Total		7,828,997.87	100.0%

Table 7. The area and percent area of the 21 accuracy assessment classes.

CLASS#	CLASS NAME	ACRES	% AREA
1	Closed Needleleaf	42,936.69	0.5%
2	Open Needleleaf	3,274,082.96	41.8%
4	Woodland Needleleaf	1,272,413.42	16.3%
10	Deciduous	344,644.64	4.4%
16	Mixed Needleleaf/Deciduous	630,781.83	8.1%
20	Tall Shrub	65,452.41	0.8%
21	Low Shrub	1,009,738.24	12.9%
24	Dwarf Shrub	293,156.86	3.7%
31	Wet Herbaceous	4,065.82	0.1%
40	Dry Herbaceous	40,151.86	0.5%
50	Tussock Tundra	68,940.89	0.9%
60	Aquatic Bed	108.31	0.0%
70	Clear Water	22,124.97	0.3%
71	Turbid Water	46,037.54	0.6%
72	Snow	7,893.24	0.1%
80	Sparse Vegetation	156,671.27	2.0%
81	Rock/Gravel	171,814.15	2.2%
92	Cloud	1,630.82	0.0%
93	Cloud Shadow	604.69	0.0%
94	Terrain Shadow	295,415.06	3.8%
96	Fire (Burn)	80,332.19	1.0%
Total		7,828,997.87	100.0%

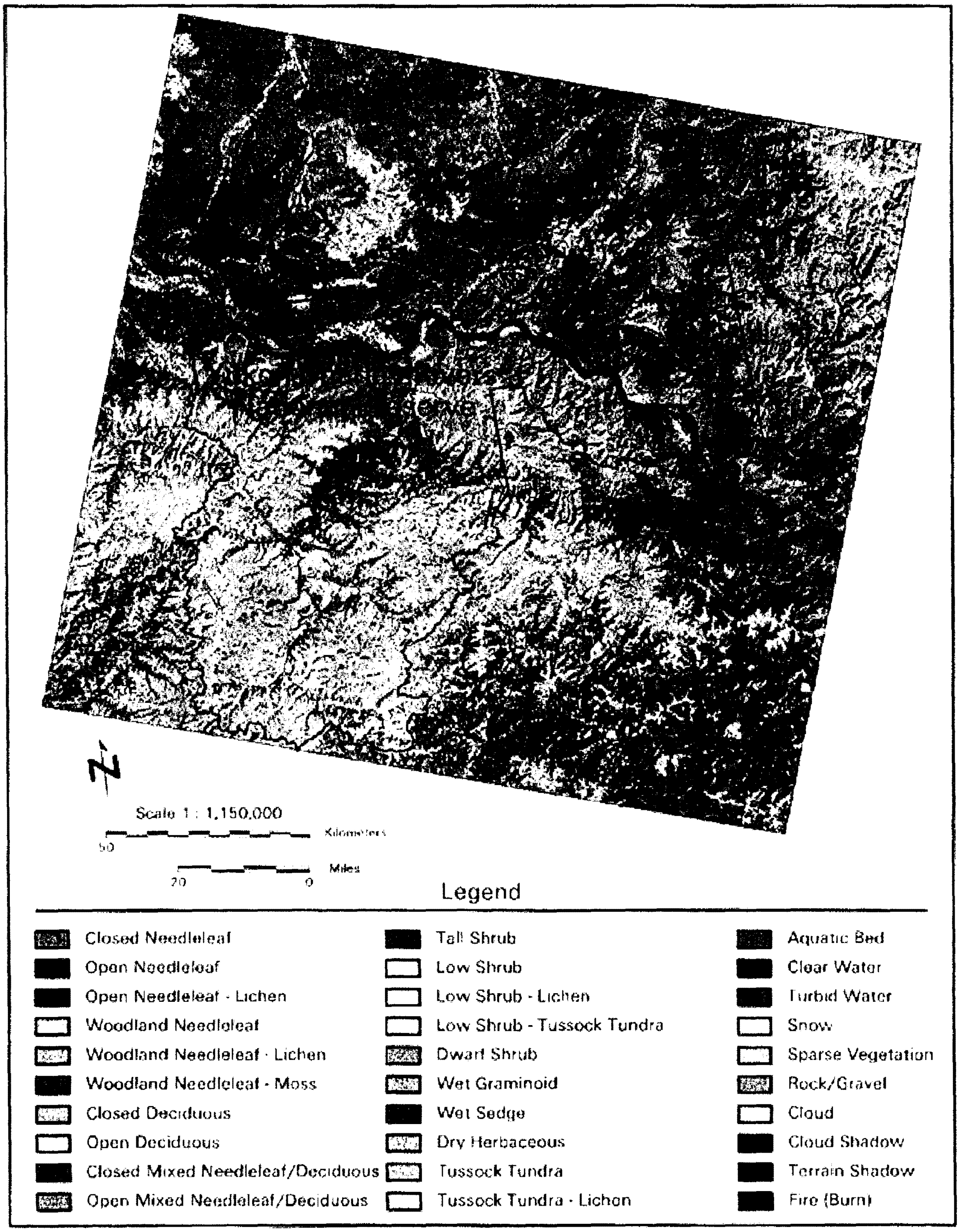


Figure 7. Results of the Yukon-Charley/Black River/40 Mile classification.

Figure 8. Results of the Yukon-Charley/Black River/Fortymile classification.

Modeling

Modeling of several classes was performed using a shaded relief image and an elevation zone image derived from USGS DEMs. 1:63,360 scale DEMs were used when available and 1:250,000 scale DEMs were used for the remainder of the imagery. The shaded relief image was created in Imagine using the solar azimuth and solar elevation listed in the header file for the TM image.

The terrain shadow class is entirely the result of modeling. In the initial 150 class unsupervised classification, the first 6 classes showed heavy confusion between terrain shadows, water, open needleleaf and closed needleleaf classes. Where the shaded relief image indicated heavy shadowing, these classes were modeled to terrain shadow. The remaining areas in these 6 classes were then run through an iteration of the combined supervised/unsupervised classification method to classify the water, open needleleaf and closed needleleaf areas. During post classification editing procedures, some editing was performed to re-label areas initially modeled to terrain shadow.

Modeling was also performed on the open and closed deciduous classes. Even after several iterations of the supervised/unsupervised classification process, visual inspection of the classified map indicated that tall shrub areas at high elevations were being classified as open deciduous and closed deciduous. A model was written to re-label all pixels over 3000 feet elevation that were classed as open or closed deciduous into the tall shrub class. The 3000 feet elevation break was determined through visual inspection of the image, notes taken on field maps, and photo interpretation. Although open and closed deciduous classes can and do occur over 3000 feet in the study area, it is uncommon, and more errors would have occurred by leaving these pixels labeled as open and closed deciduous.

Light shadowing caused problems on north slopes, particularly in areas of relatively higher elevations. Typically these shadowed areas would class as large expanses of open or woodland needleleaf. Although the open and woodland needleleaf classes are commonly found in these areas, large portions of the shaded areas should have been labeled as tall shrub, low shrub, low shrub tussock, tussock tundra and dwarf shrub. The shaded relief model was used to 'flag' open and woodland needleleaf classes in shadowed areas at elevations over 3000 feet. These pixels were then masked out of the image and run through an unsupervised classification to label non-forest pixels. This process worked very well, but shadowed non-forest classes were still occasionally labeled as open or woodland needleleaf in shadowed areas.

Editing

Editing was performed on all classes to various extents depending on how well the iterative classification process worked for each. The woodland needleleaf lichen and woodland needleleaf moss classes in particular were heavily edited. Although these classes could be visually identified on the imagery, unsupervised classes that included the woodland needleleaf moss and woodland needleleaf lichen sub-classes in one portion of the image would always class woodland needleleaf (no lichen or moss) in other portions of the image. Areas of interest were digitized around the areas containing the lichen and moss sub-classes, and these areas were re-coded accordingly.

The wet sedge and aquatic bed classes were also the result of editing. The wet sedge class was edited in the same manner as the woodland needleleaf moss and woodland needleleaf lichen classes. The aquatic bed class is limited to areas along the flats of the Yukon River and corresponds to areas where field notes were taken from the helicopter indicating the presence of aquatic plants on lakes and ponds.

Accuracy Assessment

The overall accuracy of the grouped classes was 80% and the overall accuracy of the subclasses was 71% (Table 8). The error matrices for both the grouped classes and for all classes are located in Appendix C, tables 1 and 2 respectively. The error matrices present values for user's accuracy, producer's accuracy and Kappa statistic for each class.

Accuracy of Grouped Classes

For the grouped classes, the closed needleleaf, open needleleaf, woodland needleleaf, and deciduous classes all exceeded 70% accuracy (Appendix C, table C-1) and all but woodland needleleaf exceeded 80%. The lower accuracy of the woodland needleleaf classes is not surprising. The sparse tree crown cover in this class results in a large portion of its spectral signature consisting of the shrub and herbaceous cover in the understory. Because of this it is often confused with the shrub and herbaceous classes.

The lowest accuracy is found in the tall shrub class. This class had a limited number of training sites, and is often found in narrow strips in riparian areas. Both of these difficulties made it a problematic cover type to classify. The mixed needleleaf/deciduous class also showed lower accuracy, around 65%. As expected, the confusion here was with the pure forested classes.

Accuracy of Detailed Classes

Accuracy of the closed needleleaf and open needleleaf classes remained above 70% (Appendix C, table C-2) when looking at the ungrouped classes. Confusion between the open and closed deciduous classes resulted in lower accuracy for these classes when they were split out from the grouped deciduous class. Lowest accuracy was again seen in the shrub and herbaceous classes.

Table 8. Results of the accuracy assessment for the Yukon-Charley/Black River/Forty mile Mapping Project.

	Overall Accuracy	KHAT Accuracy
Grouped classes	80%	77%
All Classes	72%	69%

Of particular interest in the ungrouped classes are the woodland needleleaf lichen and woodland needleleaf moss classes. Both these classes have high user's accuracy. Because these classes were mostly edited into the maps, they are usually correct when they appear on the map. However, it was impossible to accurately edit the entire scene when adding these classes. For this reason, there will be areas in the map that should be labeled as woodland needleleaf lichen and woodland needleleaf moss but are not. These errors of omission are evident when you examine the producer's accuracy for the woodland needleleaf lichen class.

Final Products

The primary product of this project is a digital database of the 30 earth cover classes for the Yukon-Charley/Black River/Fortymile project. Hard copy maps of the classification and raw imagery were also created of the entire project area at a scale of 1:63,360. A small scale plot of the entire project area was also produced. In addition, the field database program with the digital images of the sites were delivered. An ArcView project was also created that showcases the classification, raw imagery and field data in a user-friendly system.

Conclusion

The Bureau of Land Management – Alaska and Ducks Unlimited, Inc. have been cooperatively mapping wetlands and associated uplands in Alaska using remote sensing and graphic information system technologies since 1988. This project continued with the mapping effort for the Yukon-Charley/Black River/Fortymile project using Landsat Thematic Mapper satellite scene, Path 66, Row 14 acquired August 20, 1991. The project area was classified into 30 earth cover categories. The overall classification accuracy of 17 major (lumped) categories was 80%. The digital database of the classification was the primary product of this project along with hard copy maps of the classification, a complete field database and program, and an ArcView project.

Literature Cited

Chuvieco, E. and R.G. Congalton. 1988. Using cluster analysis to improve the selection for training statistics in classifying remotely sensed data. Photogrammetric Engineering and Remote Sensing. 54:1275-1281.

Congalton, R. and K. Green. 1993. A practical look at the sources of confusion in error matrix generation. Photogrammetric Engineering & Remote Sensing; Vol. 59, No. 5, pp. 641-644.

Congalton, R.G., K. Green and J. Teply. 1993. Mapping old growth forest on national forest and park lands in the Pacific Northwest from Remotely sensed data. Photogrammetric Engineering and Remote Sensing. 59:529-535.

Congalton, R.G. 1991. A review of assessing the accuracy of classifications of remotely sensed data. Remote Sensing of Environment. 37:35-46.

Gopal, S. and C. Woodcock. 1992. Accuracy assessment of the Stanislaus vegetation map using fuzzy sets. *In* Remote Sensing and Natural Resource Management. Proceedings of the Fourth Forest Service Remote Sensing Applications Conference. American Society for Photogrammetry and Remote Sensing. pp. 378-394.

Kempka, R.G., R.D. Macleod, J. Payne; F.A. Reid, D.A. Yokel, G.R. Balogh. 1995. National Petroleum Reserve Alaska landcover inventory: exploring arctic coastal plain using remote sensing. Proceedings of GIS95. Vancouver, BC. March 1995. pp 788-798.

Kempka, R.G., B.S. Maurizi, F.A. Reid, R.C. Altop and J.W. Denton. 1994. Standardizing reference data collection for satellite land cover mapping in Alaska. Proceedings of GIS94, Vancouver, British Columbia. February 1994. pp 419-426.

Kempka, R.G., F.A. Reid, and R.C. Altop. 1993. Developing large regional databases for waterfowl habitat in Alaska using satellite inventory techniques: a case study of the Black River. Proceedings of GIS93, Vancouver, British Columbia. February 1993. pp 1-11.

Landis, J. and G. Koch. 1977. The measurement of observer agreement for categorical data. Biometrics. Vol. 33, pp. 159-174.

Lillesand, T. and R. Kiefer. 1994. Remote sensing and image interpretation. Wiley and Sons, Inc., New York. 750pp.

Ritter, R.A., G.T. Koeln, and C. Altop 1989. A comparison of a Landsat Thematic Mapper derived waterfowl habitat inventory to digital national wetlands inventory data. Final report to the Bureau of Land Management from Ducks Unlimited.

Story, M. and R.G. Congalton. 1986. Accuracy assessment: A user's perspective. Photogrammetric Engineering and Remote Sensing. Vol. 16, No. 5, pp. 529-535.

Tortora, R. 1978. A note on sample size estimation for multinomial populations. The American Statistician. Vol. 43, No. 9, pp. 1135-1137.

Viereck, L.A., C.T. Dyrness, A.R.Batten and K.J. Wenzlick. 1992. The Alaska vegetation classification. Gen. Tech. Rep. PNW-GTR-286. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 278 p.

Appendices

Appendix A Decision tree for classification scheme.

Description of Classes

The following is a discussion of each of the earth cover types classified in the Yukon-Charley/Black River/Fortymile Mapping Project. The first number indicates the class number from the BLM earth cover classification scheme. The second number, in parenthesis, indicates the class number in the classified digital map.

1.0 Forest
Needleleaf and deciduous Trees-
The needleleaf species generally found are white spruce (*Picea glauca*) and black spruce (*Picea mariana*). White spruce tends to occur on warmer sites with better drainage, while black spruce dominates poorly drained sites, and thus is more common in the interior of Alaska. The needleleaf classes include both white and black spruce.

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

1.1 (1) Closed Needleleaf
At least 60% of the cover is trees, and ≥75% of the trees are needleleaf trees. Closed needleleaf sites are rare because even where stem densities are high, the crown closure remains low. Generally, closed needleleaf sites are found only along major rivers.

1.2 (2) Open Needleleaf
25-59% of the cover is trees, and ≥75% of the trees are needleleaf. This class is very common throughout the interior of Alaska. A wide variety of understory plant groups were present, including low and tall shrubs, forbs, grasses, sedges, horsetails, mosses and lichens.

1.21 (3) Open Needleleaf Lichen
25-59% of the cover is trees, ≥75% of the trees are needleleaf, and ≥ 20% of the understory is lichen. This class is less common than either open needleleaf or woodland needleleaf lichen.

1.3 (4) Woodland Needleleaf
From 10-24% of the cover is trees, and ≥75% of the trees are needleleaf. This is a fairly common class but the understory is extremely varied and includes most of the shrub, herbaceous or graminoid types present in the study area.

1.31 (5) Woodland Needleleaf Lichen
From 10-24% of the cover is trees, ≥75% of the trees are needleleaf, and ≥ 20% of the understory is lichen. This class is more common than open needleleaf lichen. The lichen often occurs in small round patches between trees. Within the study area, this class was generally found along ridgetops or on riparian benches.

1.31b (6) Woodland Needleleaf Moss
From 10-24% of the cover is trees, ≥75% of the trees are needleleaf, and ≥ 20% of the understory is moss. Although this class was not included in the classification scheme developed at the BLM Earth Cover Workshop, there was enough evidence of the class in the Thematic Mapper(TM) imagery and in field notes that an attempt was made to classify it.

1.4 (10) Closed Mixed Deciduous
At least 60% of the cover is trees, and ≥75% of the trees are deciduous. Occurs in stands of limited size, generally on the floodplains of major rivers, but occasionally on hillsides, riparian gravel bars, or bordering small lakes. This class may include paper birch (*Betula papyrifera*), aspen (*Populus tremuloides*) or cottonwood (*Populus balsamifera* and *Populus trichocarpa*).

1.5 (13) Open Mixed Deciduous
From 25-59% of the cover is trees, and ≥75% of the trees are deciduous. There is generally a needleleaf component to this class even though it is less than 25%. This a relatively uncommon class.

1.6 (16) Closed Mixed Needleleaf/Deciduous
At least 60% of the cover is trees, but neither needleleaf nor deciduous trees make up ≥75% of the tree cover. This class was uncommon and found mainly along major river channels.

1.7 (17) Open Mixed Needleleaf/Deciduous
From 25-59% of the cover is trees, but neither needleleaf nor deciduous trees make up ≥75% of the tree cover. This class is more common than the similar class, open deciduous, and can be found mainly on hill slopes or bordering lakes.

2.0 Shrub
The tall and low shrub classes are dominated by willow species (*Salix* spp.), dwarf birch (*Betula nana* and *Betula glandulosa*) and *Vaccinium* species, with alder (*Alnus* spp.) being somewhat less common. However, the proportions of willow to birch and the relative heights of the shrub species vary widely, making it difficult sometimes to determine whether a site is tall or low shrub. As a result, the height of the shrub species making up the largest proportion of the site dictates whether the site is called a low or tall shrub. The shrub heights will only be 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 includes a variety of forbs and graminoids. The species composition of this class varies widely from site to site and may include rare plant species. It is nearly always found on hilltops or mountain plateaus, and may include some rock.

2.1 (20) Tall Shrub
Shrubs make up 25-100% of the cover, and the shrub height is ≥1.3 meters. This class generally has a major willow component

that is mixed with dwarf birch and/or alder, but can also be dominated by nearly pure stands of alder. It is found most often in wet draws, at the head of streams, or on the slopes of mountains and hills.

2.22 (23) Low Shrub/Tussock Tundra
Shrubs make up 25-100% of the cover, the shrub height is .25-1.3 meters, and ≥35% of the cover is made up of tussock forming cottongrass *(Eriophorum vaginatum)*. This class is found in extensive patches in flat, poorly drained areas. It is generally made up of cottongrass, ericaceous shrubs, willow species, other graminoids and an occasional black spruce.

2.23 (22) Low Shrub/Lichen
Shrubs make up 25-100% of the cover, the shrub height is .25-1.3 meters, and ≥20% of the cover is made up of lichen. This class is found at mid- to high elevations. The shrub species in this class are nearly always dwarf birch.

2.24 (21) Low Shrub
Shrubs make up 25-100% of the cover, the shrub height is .25-1.3 meters. This is the most common low shrub class. It is generally composed of dwarf birch, willow species, *Vaccinium* species and *Ledum* species.

2.31 (24) Dwarf Shrub
Shrubs make up 25-100% of the cover, and the shrub height is ≤.25 meters. This class is generally made up of dwarf ericaceous shrubs and *Dryas* species, but often includes a variety of forbs and graminoids, and some rock. It is nearly always found at higher elevations on hilltops, mountain slopes and plateaus.

<u>3.0 Herbaceous</u>
The classes in this category include bryoids, forbs and graminoids. Bryoids and forbs are present as a component of most of the other classes but rarely appear in pure stands. Graminoids such as *Carex* spp., *Eriophorum* spp., or bluejoint grass (*Calamagrostis canadensis*) can dominate a community.

3.11 Lichen
Composed of ≥40% herbaceous species and between 5 and 25% water, and ≥ 60% lichen species. This class was not found in patches large enough to map in this study area.

3.12 Moss
Composed of ≥40% herbaceous species and between 5 and 25% water, and ≥60% moss species. This class was not found in patches large enough to map in this study area.

3.21 (32) Wet Graminoid
Composed of ≥40% herbaceous species and between 5-25% water, where ≥60% of the herbaceous cover was graminoid. This class represents wet or seasonally flooded sites. It is often present in stands too small to be mapped at the current scale.

3.21b (34) Wet Sedge
Composed of ≥40% herbaceous species where ≥50% of the herbaceous cover was sedges, and between 5 and 25% water, or ≥20% of the site was *Carex aquatilis*. This class generally occurs in low, barely sloping areas, and represents wet or seasonally flooded sites. It is often present in stands too small to be mapped at the current scale.

3.31 (50) Tussock Tundra
Composed of ≥40% herbaceous species and ≤25% water, where ≥50% of the herbaceous cover was graminoid, and ≥35% of the graminoid cover is made up of tussock forming cottongrass (*Eriophorum vaginatum*). Tussock tundra often includes ericaceous shrubs, willow species, forbs, bryoids and other graminoids, and is usually found at lower elevations in flat, poorly drained areas.

3.311 (51) Tussock Tundra/Lichen
Composed of ≥40% herbaceous species and ≤25% water, where ≥50% of the herbaceous cover was graminoid, and ≥20% of the cover is lichen, and ≥35% of the graminoid cover is made up of tussock forming cottongrass (*Eriophorum vaginatum*). Tussock tundra often includes ericaceous shrubs, willow species, forbs and other graminoids, and is usually found at lower elevations in flat, poorly drained areas. This class includes a major component of lichen.

3.3 (40) Mesic/Dry Herbaceous
Composed of ≥40% herbaceous species and ≤5% water, excluding tussock forming cottongrass (*Eriophorum vaginatum)* and *Carex aquatilis*. This class is made up of both mesic/dry graminoid and forb communities. These communities are uncommon in the study area and too few sites were visited to make up separate mesic/dry graminoid and mesic/dry forb classes.

4.0 Aquatic Vegetation
The aquatic vegetation is divided into aquatic bed and emergent classes. The aquatic bed class is dominated by plants with leaves that float on the water surface, generally pond lilies (*Nuphar polysepalum*). The emergent vegetation class is composed of species that are partially submerged in the water, and may include freshwater herbs such as horsetails (*Equisetum* spp.) marestail (*Hippuris spp.*) and buckbean (*Menyanthes trifoliata*).

4.1 (60) Aquatic Bed
Aquatic vegetation makes up ≥20% of the cover, and ≥20% of the vegetation is composed of plants with floating leaves. This class is found in shallow water and is generally dominated by pond lilies.

4.2 (61) Emergent Vegetation
Aquatic vegetation makes up ≥20% of the cover, and ≥20% of the vegetation is composed of plants other than pond lilies. Generally includes freshwater herbs such as horsetails (*Equisetum* spp.), marestail (*Hippuris spp.*) or buckbean (*Menyanthes trifoliata*) and is found in shallow water in small ponds or along the edges of large water bodies. This class was not found in patches large enough to map in this study area.

5.0 Water
Water classes include snow, ice and clear and turbid water. The distinction between clear and turbid water is relative, but deep open water is usually clear, while shallow or particulate heavy water is usually classed as turbid. In this area, the Yukon River is classed as turbid water. Other rivers, creeks, and lakes/ponds are classed as clear water.

5.1 (72) Snow
Composed of ≥50% snow.

5.2 (73) Ice
Composed of ≥50% ice.

5.3 (70) Clear Water
Composed of ≥80% clear water.

5.4 (71) Turbid Water
Composed of ≥80% turbid water.

6.0 Barren
This class includes sparsely vegetated sites, such as abandoned gravel pits or riparian gravel bars, along with non-vegetated sites, such as barren mountaintops or glacial till.

6.1 (80) Sparse Vegetation
At least 50% of the area is barren, but vegetation makes up ≥20% of the cover. This class is often found on riparian gravel bars, on rocky or very steep slopes and in

abandoned gravel pits. The plant species are generally herbs, graminoids and bryoids, and may include rare species.

6.2 (81) Rock/Gravel
At least 50% of the area is barren, ≥50% of the cover is composed of rock and/or gravel, and vegetation makes up less than 20% of the cover. This class is most often made up of mountaintops, talus slopes or glaciers.

6.3 (82) Non-vegetated Soil
At least 50% of the area is barren, ≥50% of the cover is composed of mud, silt or sand, and vegetation makes up less than 20% of the cover. This type is generally found along shorelines or rivers. This class was not found in patches large enough to map in this study area.

(90) Urban
At least 50% of the area is urban. This class was not found in the study area.

(91) Agriculture
At least 50% of the area is agricultural. This class was not found in the study area.
(92) Cloud
At least 50% of the cover is made up of clouds.

(93) Cloud Shadow
At least 50% of the cover is made up of cloud shadows.

(94) Terrain Shadow
At least 50% of the cover is made up of terrain shadows.

(96) Burned
This class includes areas that have recently burned (within 2-3 years), or older burned areas that have retained enough standing dead trees to cause spectral confusion with recent burns. They typically contain a shrub (low and/or tall) or herbaceous understory and a snag overstory.

Appendix B

Earth Cover Classification Metadata

Metadata Information System (MIS): YUCH_EARTHCOV

GENERAL DESCRIPTION

Coverage/Image Name: YUCH_EARTHCOV

Description: 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 technologies since 1988. The National Park Service (NPS) has also had an ongoing mapping effort for their lands with the goal of mapping all the parks in Alaska. The goal of this project was to continue the mapping effort for both the BLM and NPS while reducing the overall cost by simultaneously mapping the Yukon-Charley Rivers National Preserve, its surrounding environs and the Black River/Fortymile River BLM lands. One Landsat Thematic Mapper satellite scene (Path 66, Row 14, acquired August 20, 1991, shifted 40% south) was used to classify the project area into 30 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. A helicopter was utilized to gain access to field sites throughout the project area. Global positioning system technology was used both to navigate to pre-selected sites and record locations of new sites selected in the field. Data was collected on 316 field sites during a 10-day field season from August 3, 1997 through August 13, 1997. Approximately 40% (134) of these field sites were set aside for accuracy assessment. The field data collected in 1997 was supplemented with field data collected by the NPS in 1988 and 1990 for an unrelated projects. The NPS data provided an additional 54 training sites and 112 accuracy assessment sites. Twenty-five accuracy assessment sites for earth cover classes not visited in the field (clear water, turbid water and snow) were obtained through photo interpretation. 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 of the major categories was 80%. The cooperators in this project included: National Park Service, Bureau of Land Management-Alaska, and Ducks Unlimited, Inc.

Scale: 30-meter pixel resolution. Classes assumed accurate at a 5 acre minimum mapping unit or larger.

Date of Image: August 20,1991

Date of Mapping: August, 1997 – June, 1998

PROJECTION INFORMATION

Projection: Albers Conical Equal Area

Spheroid: Clarke 1866
Units: meters
Parameters:

1st standard parallel:	55d 00' 00"
2nd standard parallel:	65d 00' 00"
longitude of central meridian	154d 00' 00" W
latitude of origin of projection:	50d 00' 00"
false easting:	0.00
false northing:	0.00

SOURCE INFORMATION

Landsat TM scene purchased and terrain corrected by EROS data center, Sioux Falls, ND.

CONTACT INFORMATION

Ducks Unlimited Inc.
Western Regional Office
3074 Gold Canal Dr.
Rancho Cordova, CA 95670

Bureau of Land Management
Alaska State Office
222 West 7th Avenue, #13
Anchorage, AK 99513-7599
907-271-3431

Appendix C

Error Matrices

C-1. Error matrix for grouped earth cover classes.

Class	Closed Needleleaf	Open Needleleaf	Woodland Needleleaf	Deciduous	Mixed Ndl./Decid.	Tall Shrub	Low Shrub	Dwarf Shrub	Dry Herb.	Tussock Tundra	Clear Water	Turbid Water	Snow	Sparsely Vegetated	Rock/ Gravel	Terrain Shadow	Burned	Total	User's Accuracy	Low L	Upper L	Kappa	Variance
Cl. Ndl.	**4**																	4	100	95	100	1	
Open Ndl.	1	**48**	2		2	1	2											56	85.71	76.19	95.23	0.8182	
Wdlnd Ndl.		5	**26**		2		3			1								37	70.27	55	85.54	0.6601	
Deciduous		1		**21**	2													24	87.5	73.44	100	0.8617	
Mixed Ndl./Dec.		2		2	**10**	1												15	66.67	41.48	91.86	0.6458	
Tall Shrub				1		**2**												3	66.67	6.66	100	0.6565	
Low Shrub		2	6	2		4	**47**	2	1	1								65	72.31	61.12	83.5	0.6558	
Dwarf Shrub							1	**8**		1								10	80	53.21	100	0.7899	
Dry Herb.								1										1	0	0	20	-0.0112	
Tussock Tundra									1	**7**								8	87.5	62.08	100	0.8702	
Clear Water											**15**							15	100	98.67	100	1	
Turbid Water												**5**						5	100	96	100	1	
Snow													**5**					5	100	96	100	1	
Sparse Veg.								2						**7**	1			10	70	39.6	100	0.692	
Rock/Gravel															**5**			5	100	96	100	1	
Terrain Shadow									1									1	0	0	20	0	
Burn																	**7**	7	100	97.14	100	1	
Total	5	58	34	26	16	8	53	13	3	10	15	5	5	7	6	0	7	271					
Producer's	80	82.76	76.47	80.77	62.5	25	88.68	61.54	0	70	100	100	100	100	83.33	-----	100		80.07				
Low L	40.94	72.69	61.62	64.85	37.53	0	79.77	33.56	0	39.6	98.67	96	96	97.14	50.17	-----	97.14			75.13			
Upper L	100	92.83	91.32	96.69	87.47	57.51	97.59	89.52	6.67	100	100	100	100	100	100	-----	100				85.01		
Kappa	1	0.8182	0.6601	0.8617	0.6458	0.6565	0.6558	0.7899	-0.011	0.8702	1	1	1	0.692	1	0	1					0.7711	
Variance																							0.0008

C-2. Error matrix for all earth cover classes.

Class	Closed Ndl.	Open Ndl.	Open Ndl. Lichen	Wdlnd. Ndl.	W. Ndl. Lichen	W. Ndl. Moss	Closed Dec.	Open Dec.	Cl. Mixed Ndl./Decid.	Op. Mixed Ndl./Decid.	Tall Shrub	Low Shrub	Low Sh. Tussock	Dwarf Shrub	Dry Herb.	Tussock Tundra	Tu.Tundra Lichen	Clear Water	Turbid Water	Snow	Sparse Veg.	Rock/ Gravel	Terrain Shadow	Burned	Total	User's	Low L	Upper L	Kappa	Variance
Closed Needleleaf	4																								4	100	95	100	1	
Open Needleleaf	1	45	4	1	1				1	1	1	2													57	78.95	68.02	89.88	0.7383	
Open Ndl. Lichen																									0	-----	-----	-----	-----	
Woodland Needleleaf		4	1	19	3				1	1		1	2			1									33	57.58	40.11	75.05	0.5364	
Wdlnd. Ndl. Lichen				1	4																				5	80	40.94	100	0.7931	
Wdlnd. Ndl. Moss						2																			2	100	90	100	1	
Closed Dec.		1					16	2	2																21	76.19	57.02	95.36	0.7419	
Open Dec.							2	1																	3	33.33	0	93.34	0.3208	
Cl. Mixed Ndl./Decid.							1	1	6	1															9	66.67	33.65	99.69	0.6526	
Open Mixed Ndl./Dec.		1							1	2	1														5	40	0	86.94	0.3887	
Tall Shrub							1				2														3	66.67	6.66	100	0.6565	
Low Shrub		1		1							2	13	7	1											25	52	31.62	72.38	0.4755	
Low Sh. Tussock		1		1	1		1	1			2	5	21		1	1									35	60	43.2	76.8	0.5502	
Dwarf Shrub												1		9			1								11	81.82	57.21	100	0.809	
Dry Herb.														1											1	0	0	20	-0.0112	
Tussock Tundra												1			1	6	1								9	66.67	33.65	99.69	0.6565	
Tuss. Tundra Lichen																									0	-----	-----	-----	-----	
Clear Water																		15							15	100	98.67	100	1	
Turbid Water																			5						5	100	96	100	1	
Snow																				5					5	100	96	100	1	
Sparse Veg.														2							7	1			10	70	39.6	100	0.692	
Rock/ Gravel																						5			5	100	96	100	1	
Terrain Shadow															1										1	0	0	20	0	
Burned																								7	7	100	97.14	100	1	
Total	5	53	5	23	9	2	21	5	11	5	8	23	30	13	3	8	2	15	5	5	7	6	0	7	271					
Producer's	80	84.91	0	82.61	44.44	100	76.19	20	54.55	40	25	56.52	70	69.23	0	75	0	100	100	100	100	83.33	----	100		71.59				
Low L	40.94	74.9	0	66.25	9.75	90	57.02	0	23.31	0	0	35.39	52.93	42.6	0	42.49	0	98.67	96	96	97.14	50.17	----	97.14			66.04			
Upper L	100	94.92	4	98.97	79.13	100	95.36	59.06	85.79	86.94	57.51	77.65	87.07	95.86	6.67	100	10	100	100	100	100	100	----	100				77.14		
Kappa	1	0.7383	----	0.5364	0.7931	1	0.7419	0.3208	0.653	0.3887	0.6565	0.4755	0.5502	0.809	-0.011	0.6565	----	1	1	1	0.692	1	0	1					0.6872	
Variance																														0.0009