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Bureau of Land Management

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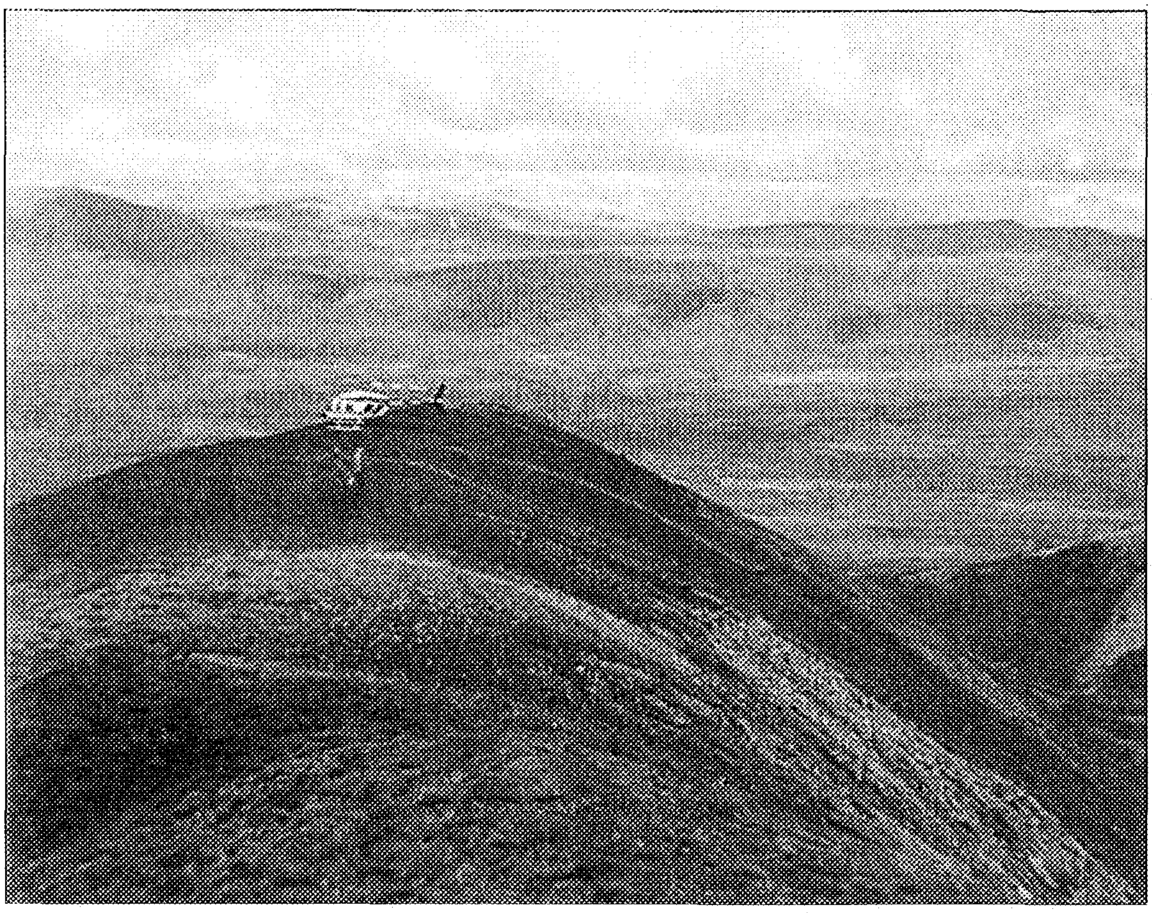
September 2002

Ducks Unlimited, Inc.

Steese-White Mountains 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.

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Abstract

The Bureau of Land Management (BLM) – Alaska and Ducks Unlimited, Inc. have been cooperatively mapping wetlands and associated uplands in Alaska using remote sensing and Geographic Information System technologies since 1988. The goal of this project was to continue the mapping effort for the BLM in the Steese National Conservation Area and the White Mountains National Recreational Area and its surrounding environs. Three Landsat Thematic Mapper (TM) satellite scenes 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. 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 411 field sites during a 12-day field season from July 18 through August 1, 1997. Forty-one (41%) percent (170) of these field sites were set aside for accuracy assessment. The field data collected in 1997 was supplemented with field data collected by the BLM in August 1998 and the Yukon Charley Project (1997). A modified supervised/unsupervised classification technique was performed to classify the satellite imagery. The most dominant earth cover classes were 39% open needleleaf, 13% woodland needleleaf and 10% mixed forest. The overall accuracy of the major categories was 81%.

Introduction

In Alaska, most ground-based inventories of vegetation have been limited by accessibility to the area, or logistically restricted to a single large 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 Thematic Mapper (TM), *SPOT (Systeme Pour l'Observation de la Terre*), European Remote Sensing Satellite (ERS-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, perform 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 (EIS), comprehensive management plans (CMP), 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 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 certain 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 useful to both managers and habitat studies. Over the years, many refinements have been made to both the techniques of collecting field information and processing 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 habitat analysis. Landsat Thematic Mapper (TM) satellite imagery was chosen as the primary source for this mapping effort. Satellite imagery offers a number of advantages for a project of this size. It is a cost effective data source for regional mapping, it 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 planned 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 an additional cooperative mapping project adjacent to the Steese and White Mountains area that encompasses the YUCH and adjacent BLM lands. It was 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 agencies of the Department of the Interior.

Project Objective

The objective of this project was to develop a baseline earth cover inventory using Landsat TM imagery for the Steese National Conservation Area and the White Mountains National Recreation Area. 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 the majority of two Landsat TM scenes, Paths 68 and 69, Row 14, with Path 70, Row 14 used to fill in clouded areas. The project area includes the political boundaries of the Steese National Conservation Area and the White Mountains National Recreational Area, plus a 10-km external buffer. This buffer was expanded to include lands that were of importance to the BLM Northern Field Office for wildlife management. Areas outside this buffer zone were classified in order to provide a more regional database and include adjacent wildlife habitats, but little field data was collected causing the accuracy in these areas to be unknown. All, or portions of the following United States Geological Survey (USGS) 1:250,000 scale quadrangles, were used: Livengood, Charley River, and Circle. Elevations range from 152 m (500 ft.) along the Yukon River to above 1753 m (5750 ft.) in the mountains along the southern boundary of the SNCA. The area is found within the boreal forest region that stretches through 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 temperatures reaching as low as –45°C (-50°F) in winter and up to 32° C (90°F) in summer.

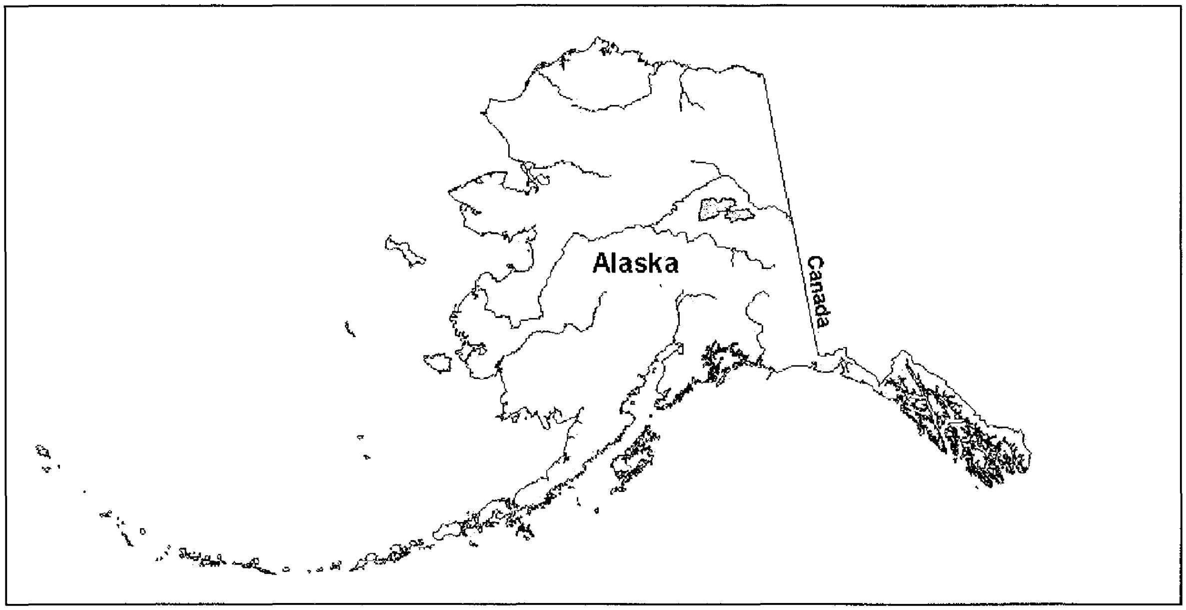


Figure 1. The project area for the Steese-White Mountains Project.

Data Acquisition

Three Landsat TM scenes were used to cover the project area. The scenes were purchased from Earth Resources Observation Systems (EROS) Data Center in the Universal Transverse Mercator (UTM) projection, zone 6 and were terrain corrected (Appendix A). The scenes were: Path 68, Row 14, acquired on August 10, 1994 and Path 69, Row 14, acquired on both June 22 and 29, 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 67, Row 14, acquired on April 7, 1986. Field data was collected over a 12-day period from July 18, 1997 to August 1, 1997. This data was supplemented with field data collected by the BLM in 1998. 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), United States Geological Survey (USGS)1:63,360 and 1:250,000 scale Digital Elevation Models (DEMs); and BLM and Alaska Department of Natural Resources (DNR) land status coverage.

Table 1. The satellite imagery used for the Seese-White Mountains Project.

SENSOR	PATH/ROW	DATE	RMS ERROR (m)
Landsat Thematic Mapper	67/14	4/7/86	26.83
Landsat Thematic Mapper	68/14	8/10/94	22.93
Landsat Thematic Mapper	69/14	6/22/91	24.71
Landsat Thematic Mapper	70/14	6/29/91	18.41

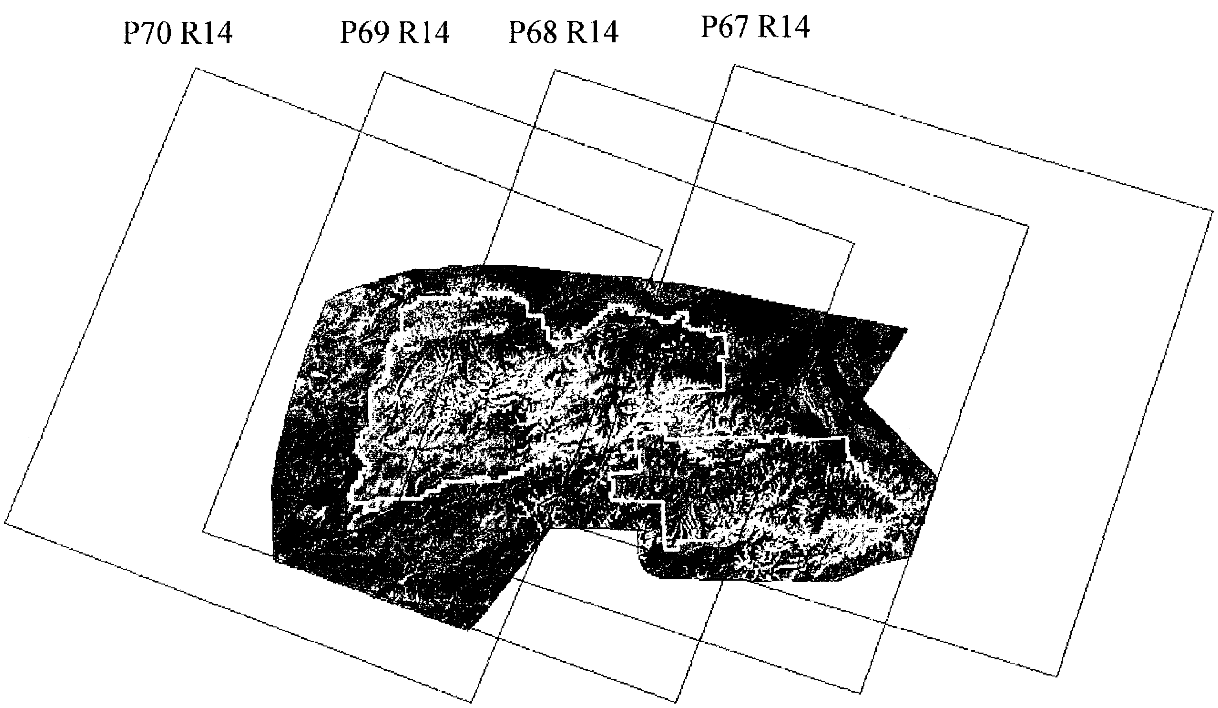


Figure 2. The imagery used for the Steese-White Mountains Project.

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 resulting 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 B) and written description were developed in order to eliminate any confusion in the classification. A few additional sub-classes not found in the regional classification scheme were added, while others were omitted. The additional classes are woodland needleleaf moss, wet sedge, 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. – 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 5 acres in area (e.g. – wet herbaceous, dry herbaceous and emergent). An asterisk (*) indicates the classe was not found in the final classification.

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

1.0 Forest
- 1.1 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 Bryoid*
    - 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 Steese-White Mountains Project.

C. SCHEME VALUE	CLASS VALUE	CLASS NAME
1.1	1	Closed Needleleaf
1.2	2	Open Needleleaf
1.21	3	Open Needleleaf Lichen
1.3	4	Woodland Needleleaf
1.31	5	Woodland Needleleaf - Lichen
*	6	Woodland Needleleaf – Moss
1.41	11	Closed Birch
1.44	12	Closed Mixed Deciduous
1.5	13	Open Deciduous
1.6	16	Closed Mixed Needleleaf/Deciduous
1.7	17	Open Mixed Needleleaf/Deciduous
2.1	20	Tall Shrub
2.24	21	Low Shrub
2.23	22	Low Shrub – Lichen
2.22	23	Low Shrub – Tussock Tundra
2.32	24	Dwarf Shrub
2.31	25	Dwarf Shrub Lichen
3.21	32	Wet Graminoid
3.32	41	Mesic/Dry Sedge Meadow
3.34	43	Mesic/Dry Graminoid
3.312	50	Tussock Tundra
3.311	51	Tussock Tundra – Lichen
4.1	60	Aquatic Bed
5.3	70	Water
5.1	72	Snow
6.1	80	Sparsely Vegetated
6.2	81	Rock/Gravel
9.1	92	Cloud
9.2	93	Cloud Shadow
*	94	Terrain Shadow
10	95	Other
*	96	Fire (Burned)

The first column in Table 3 represents the value from the classification scheme (Table 2); the second column represents the class value found in the final digital classified image; the third column represents the class name that corresponds to both numbers. An asterisk (*) indicates the class was mapped, but was not part of the original classification scheme (Appendix B).

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 evaluated by looking at 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 DEM's. If the image is of acceptable quality, it is then archived onto a CDROM and recorded into a database of available GIS data. The next step is to run an unsupervised classification to segment the image into spectrally similar areas that will be used for delineating potential field sites. A 30 class unsupervised classification is performed on the original imagery. Once this is complete, 30 field sites/class are delineated throughout the project area. The field sites need to cover the entire 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. Whenever possible, field sites are grouped in clusters in order to reduce the amount of helicopter ferrying time between sites. A tally of estimated number of field sites per class is kept until all of the classes are adequately sampled throughout the project area. The coordinates of the center points (collected in degrees decimal minutes, UTM, NAD27) of the field sites are generated and uploaded into a Y-code Rockwell Precision Lighweight Global Positioning System (GPS) Receiver (PLGR) to be used while field sampling. 1:63,360 scale quadrangle color infrared plots of the Landsat TM data are 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).

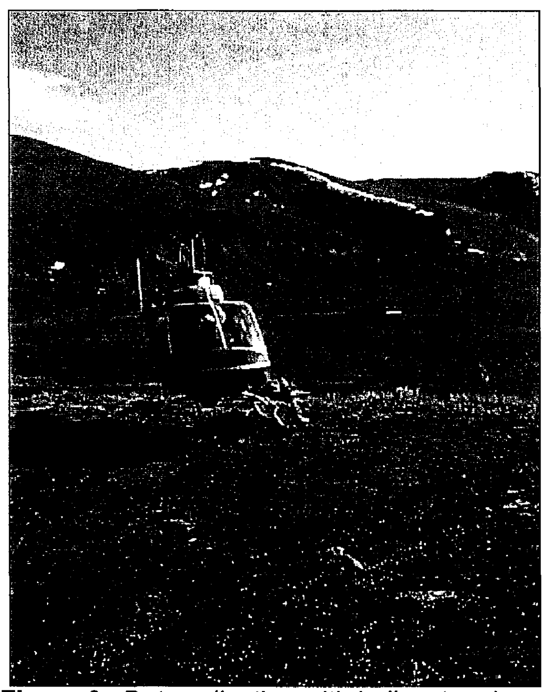
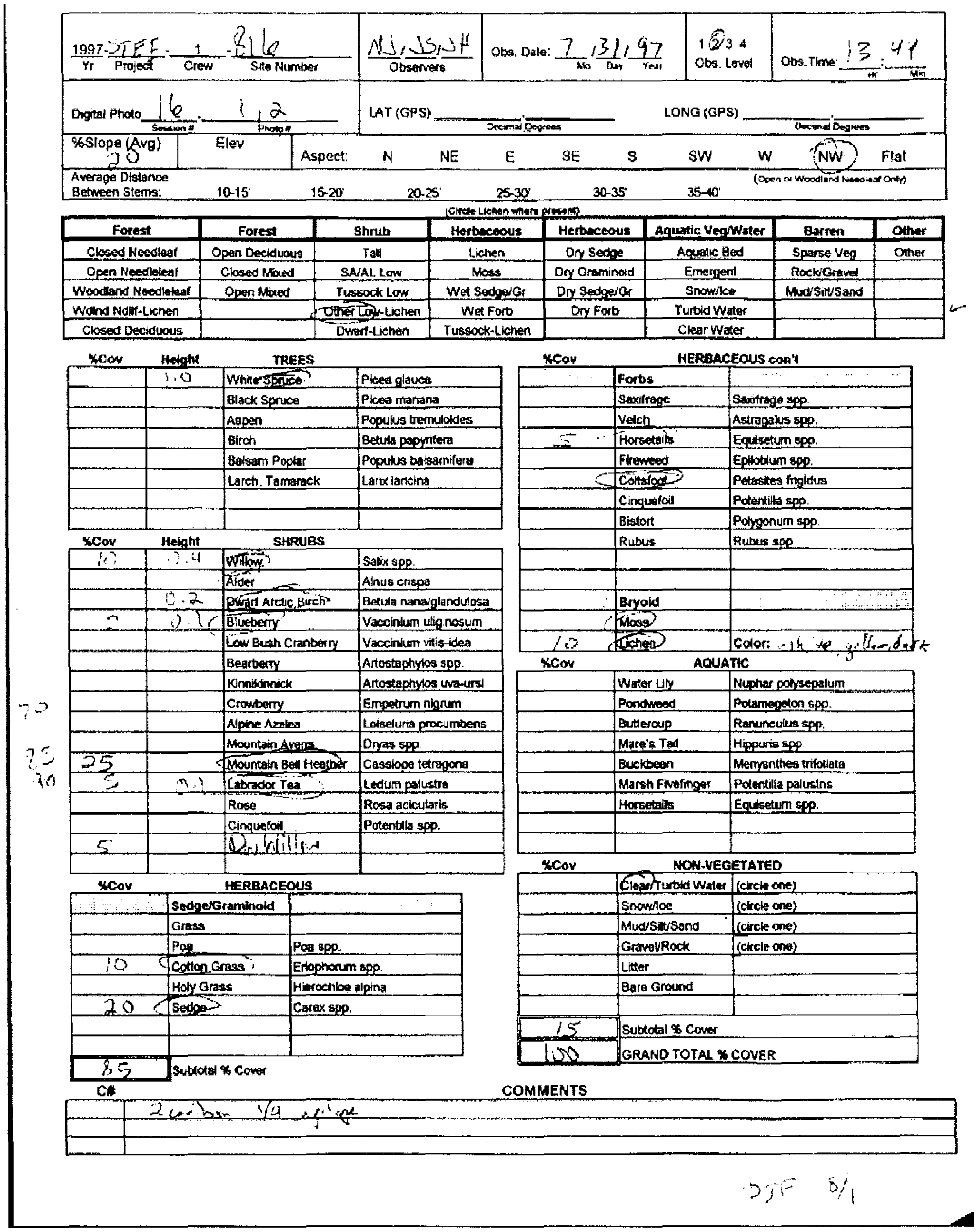


Figure 3. Data collection with helicopters is an effective way to cover broad and remote areas.

Helicopter surveys are sometimes the only alternative in Alaska due to a large amount of roadless areas that are difficult to access. 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 4).



1997-STEF-1-816 (Yr Project Crew Site Number) | Observers | Obs. Date: 7/31/97 (Mo Day Year) | 1 2 3 4 Obs. Level | Obs. Time 13:47 (Hr Min)

Digital Photo 16 (Session #) 1, 2 (Photo #) | LAT (GPS) (Decimal Degrees) | LONG (GPS) (Decimal Degrees)

%Slope (Avg) 20 | 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		

TREES

%Cov	Height		
	1.0	White Spruce	Picea glauca
		Black Spruce	Picea mariana
		Aspen	Populus tremuloides
		Birch	Betula papyrifera
		Balsam Poplar	Populus balsamifera
		Larch, Tamarack	Larix laricina

SHRUBS

%Cov	Height		
10	0.4	Willow	Salix spp.
		Alder	Alnus crispa
	0.2	Dwarf Arctic Birch	Betula nana/glandulosa
2	0.1	Blueberry	Vaccinium uliginosum
		Low Bush Cranberry	Vaccinium vitis-idea
		Bearberry	Artostaphylos spp.
		Kinnikinnick	Artostaphylos uva-ursi
		Crowberry	Empetrum nigrum
		Alpine Azalea	Loiseluria procumbens
		Mountain Avens	Dryas spp
25		Mountain Bell Heather	Cassiope tetragona
5	0.1	Labrador Tea	Ledum palustre
		Rose	Rosa acicularis
		Cinquefoil	Potentilla spp.
5		[illegible]	

HERBACEOUS

%Cov		
	Sedge/Graminoid	
	Grass	
	Poa	Poa spp.
10	Cotton Grass	Eriophorum spp.
	Holy Grass	Hierochloe alpina
20	Sedge	Carex spp.
85	Subtotal % Cover	

HERBACEOUS con't

%Cov		
	Forbs	
	Saxifrage	Saxifrage spp.
	Vetch	Astragalus spp.
5	Horsetails	Equisetum spp.
	Fireweed	Epilobium spp.
	Coltsfoot	Petasites frigidus
	Cinquefoil	Potentilla spp.
	Bistort	Polygonum spp.
	Rubus	Rubus spp
	Bryoid	
	Moss	
10	Lichen	Color: [illegible]

AQUATIC

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

C# | COMMENTS

Figure 4. Field data collection form.

A five-person helicopter crew was assigned to perform the field assessment (Figure 5). 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 is 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 are observed without landing the helicopter to determine the percent cover for each species and an overall earth cover class. Ground verification is performed when identification of dominant vegetation and/or species is uncertain.

Figure 5. The field crew documents the dominant vegetation at each site.

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 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. All observed species and taxa are identified to the extent possible from a helicopter. The ability to identify species is dependent on altitude of the helicopter above ground and other factors such as phenology and light conditions. 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.

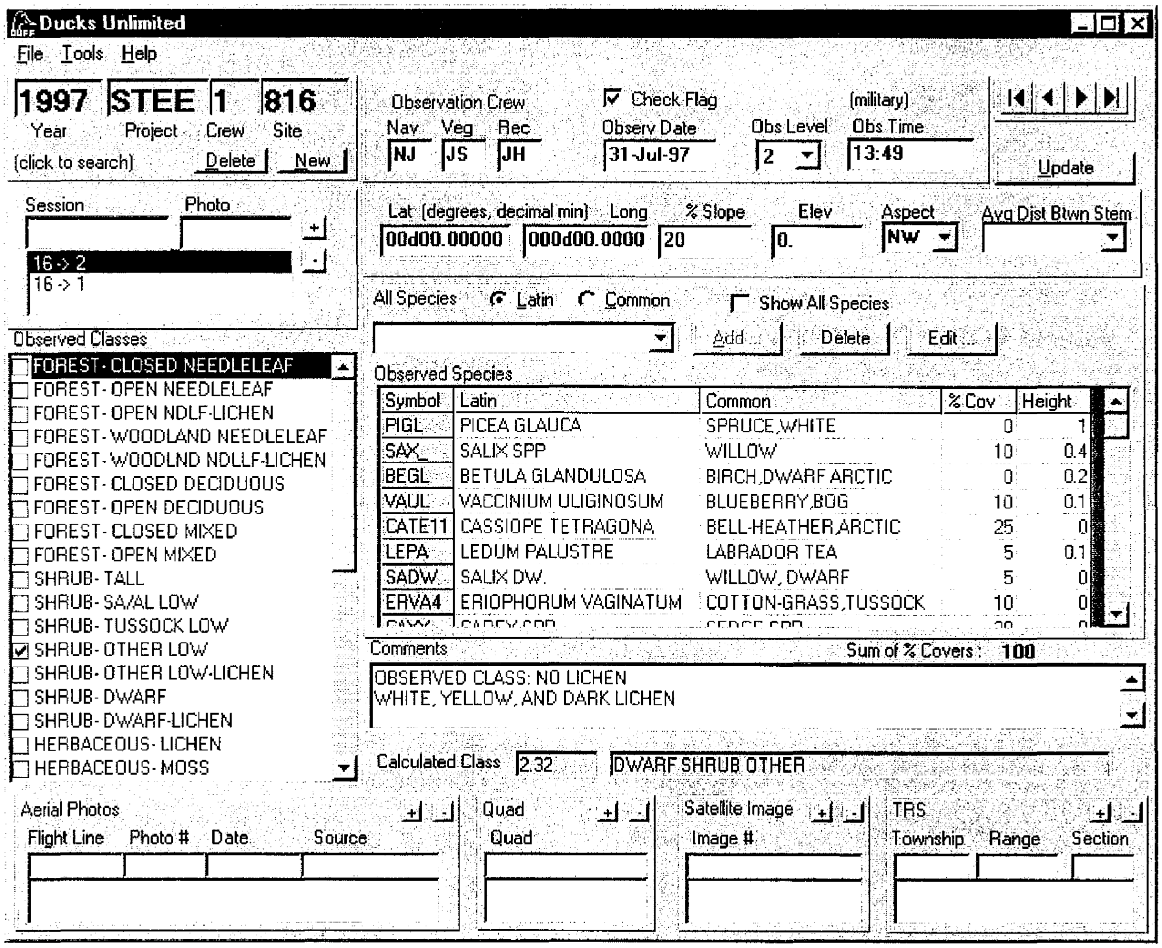
Field Data Analysis

The field sites are entered into a customized database Ducks Unlimited Field Form (DUFF) designed by the BLM and DU and developed by GeoNorth. The relational database is powered by *Sybase SQL Anywhere* software 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).

Field Site STEE816 – Dwarf Shrub Other

High site photo.

Low site photo.



DUFF screen capture.

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

The database program also automatically calculates an overall class name for each site based on the recorded species and percentages of cover. 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 to is also compared to the class that the biologist assigned the site, as an additional check for data integrity. The calculated class is the class name assigned to the site (Figure 7 and 8).

View Statistics

Calc Class	Count
CLOSED MIXED DECIDUOUS	3
CLOSED NEEDLELEAF	8
WOODLAND NEEDLELEAF	5
LOW SHRUB TUSSOCK TUNDRA	3
DWARF SHRUB OTHER	24
LOW SHRUB OTHER	8
TALL SHRUB	4
CLOSED BIRCH	9
LOW SHRUB LICHEN	1
OPEN POPLAR	1
ROCK/GRAVEL	7
OPEN NEEDLELEAF	10
CLOSED MIXED NEEDLELEAF/DECIDUOUS	2
SPARSE VEGETATION	2
DWARF SHRUB LICHEN	1
OPEN NEEDLELEAF LICHEN	1
MESIC/DRY SEDGE MEADOW	3
OPEN MIXED NEEDLELEAF/DECIDUOUS	2
WET FORB	1
TUSSOCK TUNDRA	1
OPEN BIRCH	1

97 Sites

Close

Figure 7. Summary of collected field sites for path 68.

View Statistics

Calc Class	Count
DWARF SHRUB OTHER	36
CLOSED NEEDLELEAF	13
OPEN NEEDLELEAF	39
WOODLAND NEEDLELEAF	20
WOODLAND NEEDLELEAF LICHEN	7
OPEN NEEDLELEAF LICHEN	15
OPEN MIXED DECIDUOUS	3
LOW SHRUB OTHER	32
TALL SHRUB	28
LOW SHRUB TUSSOCK TUNDRA	10
TUSSOCK TUNDRA	14
DWARF SHRUB LICHEN	16
CLOSED MIXED NEEDLELEAF/DECIDUOUS	6
CLOSED BIRCH	15
LOW SHRUB LICHEN	16
LICHEN	3
LOW SHRUB WILLOW/ALDER	5
OTHER	2
TUSSOCK TUNDRA LICHEN	6
EMERGENT VEGETATION	3
CLOSED MIXED DECIDUOUS	7
ROCK/GRAVEL	5
MESIC/DRY SEDGE MEADOW	4
SPARSE VEGETATION	5
MESIC/DRY GRAMINOID	1
MESIC/DRY FORB	1
OPEN ASPEN	1
OPEN BIRCH	2
OPEN MIXED NEEDLELEAF/DECIDUOUS	1

316 Sites

Close

Figure 8. Summary of collected field sites for path 69.

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

Classification

Every image is unique (e.g. spectral and spatial differences resulting from different dates of imagery and/or sensors) and presents it's own special problems in the classification process. The approach that is used in this project has been used and proven to be successful over many years (Figure 9). The image processor's site-specific experience and knowledge in combination with high quality ancillary data can overcome some of the spectral and spectral differences to produce a high quality and extremely useful product. Therefore, the image processor should be actively involved in the field data collection and gain 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 such as 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 image enhancements are principle components, tasseled cap, band ratios and Normalized Difference Vegetation Index (NDVI). 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 combined 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 recorded to their respective class number. 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 are designated as training areas were "seeded" (generate statistics from the imagery) in ERDAS Imagine software using spectral bounds as the limit for seed growth. The standard deviations of the seeded areas are kept to a maximum of three

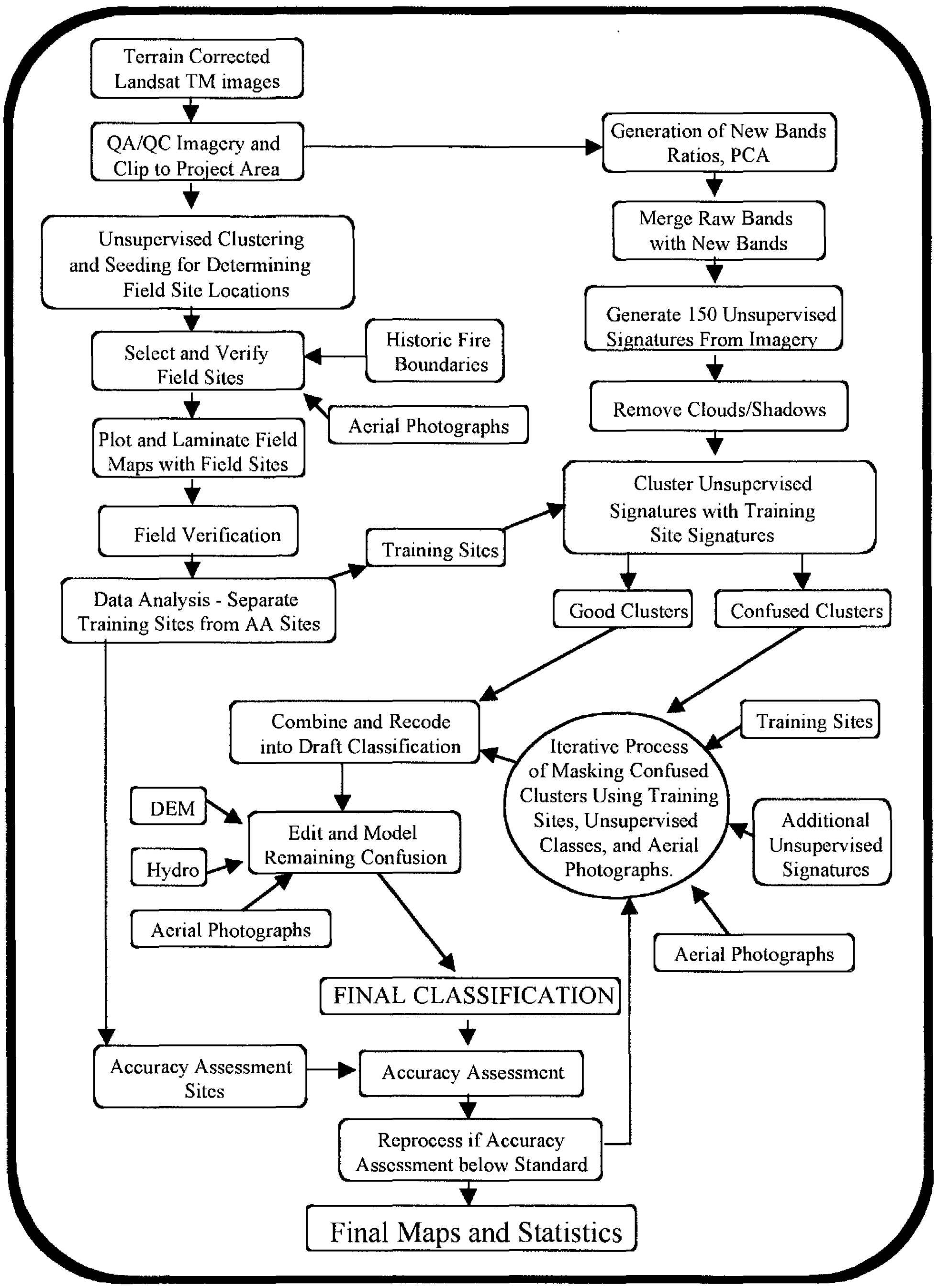


Figure 9. Image processing flow diagram

(3) and all seeded areas are required to be over 15 pixels 1.5 ha (3.75 acres) in size. Along with the field training areas, additional "seeds" were generated for water. These classes are easily recognized on the imagery and aerial photography. The output of the seeding process in ERDAS 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 ERDAS Imagine. The output of this process is a signature file similar to that of the seeding process except that 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) is 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 are 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 are inspected and removed from the classification process. The remaining confused clusters are grouped into general categories (forest, shrub, non-vegetation, etc.) and re-run through the process. This process is repeated until all of the spectral classes are 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) it 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 is to create spatial models of the remaining confused areas and make final edits. In some areas the classification cannot be separated using only the spectral data, but writing a simple spatial model can eliminate much of the confusion. For instance, water may be classified where there are terrain shadows. By using DEMs to generate a slope file and then running a spatial model to locate water on high slopes, the areas where water is classified incorrectly can be relabeled a more appropriate class such as shrub or trees. In other areas of the classified image, neither spectral data nor spatial models will suffice to correct classification errors. In these cases, reference to air photos and manual editing are needed.

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 on average for each map category. 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 a real extent will have only a few samples that may severely impede 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. (See the Alaska Perspective section for the approach used in this project).

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 data. The matrix shows 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 (Lilles and Kiefer 1994). An error matrix is an effective way to represent accuracy in that the individual accuracy of each category is 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 to. 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. Producer's accuracy is a measure of how well the reference pixels for a given cover type are classified. User's accuracy (a measure of commission error) indicates the probability that a pixel classified into a given cover type is representative of that type (i.e. classified correctly).

Kappa Analysis

A Kappa analysis is performed on the error matrix as a further measure of accuracy (Congalton 1991). Cohen's coefficient of agreement (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 the agreement that resulted by chance when matching 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 statistic of 1.98 or less means that the classification is not significantly different from a random classification at the 99% confidence level. The confidence intervals should be considered when using the classified data for other analysis. This provides additional information to individual and overall class accuracies.

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 showing the results of a summary routine in ERDAS Imagine using the classification and rasterized version of the accuracy assessment sites. The second input is a list of site numbers and their 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 which defines the error matrix.
After the input of these three files, 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 (i.e. the class that contains the most pixels for a given polygon). 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 assists in the identification 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 (majority class) that was generated in the previous step. The error matrix is then used to compute the Kappa statistics. The error matrix and Kappa statistics are used to report the final accuracy of the final classification published in 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 much of Alaska, but most are at a scale that make it difficult, if not impossible, to distinguish some vegetation classes. Ideally, fieldwork should be performed during one summer, the classification should be performed during the subsequent winter, and the reference data would be collected during the next summer. This procedure should 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 high 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 had a low number of samples, 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.

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 June 22 and 29, 1991, and August 10, 1994; the aerial photographs spanned a seven year period from 1980 through 1987 and the field data was collected in August 1997 and 1998. 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. As a result, the stated accuracies in the error matrix are most likely overestimated.

Results

Field Verification

Field data was collected on a total of 413 field sites during the 12 day field season from July 18, 1997 through August 1, 1997 (Table 4). Figure 8 shows the spatial distribution of the training and accuracy assessment sites. Approximately 41% (170) of these sites were reserved for accuracy assessment. Nineteen accuracy assessment sites for water were obtained through photo interpretation. Twenty-five sites for rock/gravel were digitized from polygons and notes taken while en route to field sites. Seventy-nine other sites from the Yukon Charley Project were used as additional training sites for classifying the Path 68, Row 14 image. A Bell Jet Ranger helicopter was used to gain access to the field sites. Field camps and fuel were based out of Fairbanks at the BLM-Alaska Northern Field Office and Central, Alaska. The participants in the field data collection were Nathan Jennings (DU), Jim Herriges (BLM), Jim Sisk (BLM), Dan Fehringer (DU), and Jacqui Frair (BLM/DU).

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

	1997 Field Sites	Photo/Yukon Charley Sites		Total
Training	241		79	320
Accuracy Assessment	170	44		214
Total	411	123		534

Shrub Percentage Cutoff Issue

During planning meetings and post-field work processing, the percentage of shrub that should be used to label field polygons to a shrub class had been widely discussed and changed several times between 25% and 40% shrub. Although the shrub issues were not entirely settled, fieldwork was conducted assuming a 25% cutoff while the DUFF program was using a 40% shrub cutoff calculation. Image processing began using the same assumption, but midway through the project (prior to the 1998 field season) the shrub percentage was finally changed to 25% as a result of additional conversations with the BLM, NPS and DU.

The conclusions drawn from the signature analysis conducted by DU indicated that a 40% shrub cutoff would probably not produce significantly different results from shrubs calculated at a 25% cutoff. Consequently, the processing that had already been completed on the shrubs and herbaceous classes needed to be redone. This involved reprogramming the DUFF program to reflect a 25% shrub cutoff level, changing the training and accuracy assessment layers, computing new signature files, rerunning the multiple iterations of the cluster analysis routines, and combining the modified shrub and herbaceous data with the other earth cover classes. Although this analysis required a significant amount of

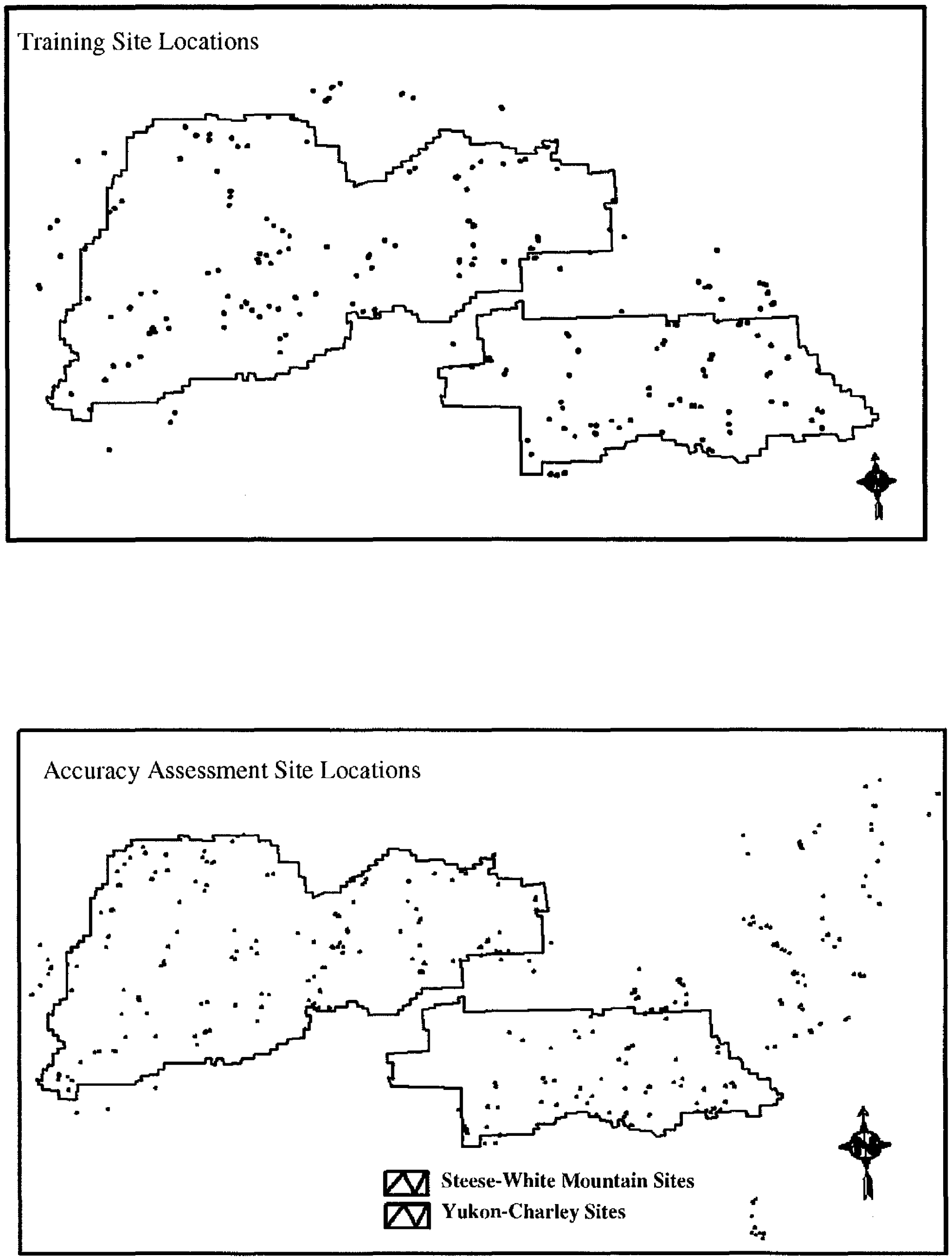


Figure 10. The spatial distribution of the field sites for the Steese-White Mountain Project.

time to complete all parties agreed that the analysis provided insight into the complexities of classifying the shrub and herbaceous categories from satellite remotely sensed data and allowed past and future work to be integrated more efficiently.

Classification

The result of the Landsat TM classification is shown in Figure 11. Classification of 35 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. Twenty classes were used in the full accuracy assessment classes; 14 classes were used for the grouped accuracy assessment (Table 5). The area and percent area was calculated for each of the 35 earth cover classes (Table 6) as well as for the grouped classes (Table 7). A metadata file was also created for use with distributing the classified data (Appendix C).

Modeling

Modeling of several classes was performed using an elevation zone image derived from 1:63,360 scale USGS digital elevation models (DEMs). The elevation zone image was created in ERDAS Imagine by recording the metric values to a corresponding English unit (ft).

In the initial 150-class unsupervised classification, the first five classes showed heavy confusion between terrain shadows, water, open needleleaf and closed needleleaf classes. By visually inspecting the steep terrain in the Steese-White Mountains Project area, which fell into one of these five classes, a label of terrain shadow was given. The remaining areas in these five classes were then run through an iteration of the combined supervised/unsupervised classification method to classify the water, open needleleaf and closed needleleaf areas.

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 914 meters (3000 ft.) elevation that were classed as open or closed deciduous into the tall shrub class. The 914-meters (3000 ft.) 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 914 meters (3000 ft.) 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 northwest slopes, particularly in areas of relatively higher elevations. Typically these shadowed areas would classify 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. An aspect model was used to 'flag' open and woodland needleleaf classes on slopes facing the north west. These pixels were then masked out of the image and run through an unsupervised classification to label non-forest pixels. This process worked

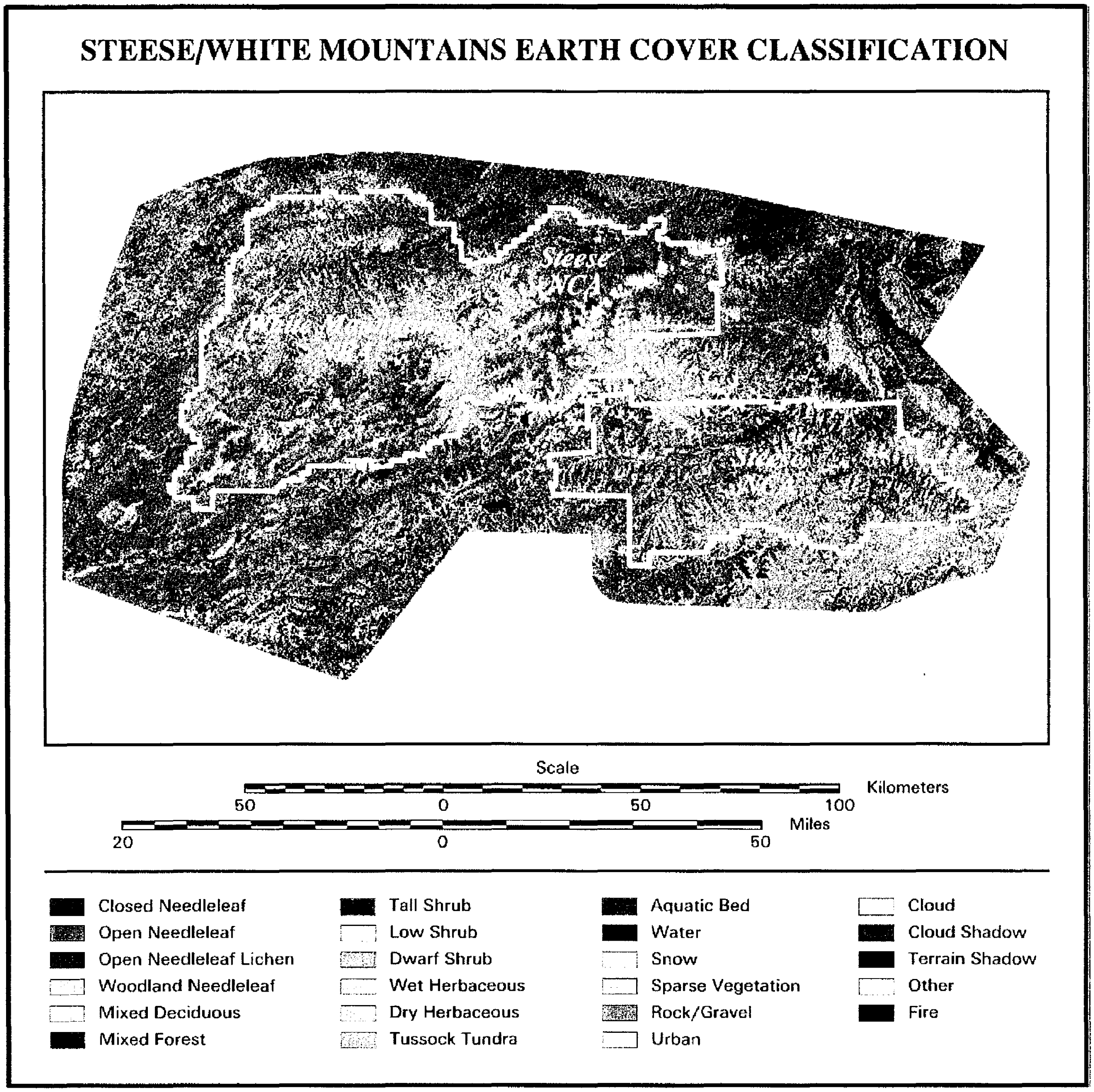


Figure 11. Results of the Steese-White Mountains classification.

Table 5. The classes used in the accuracy assessment.

VALUE	CLASS NAME	GROUPED CLASSES
1	Closed Needleleaf	Closed Needleleaf
2	Open Needleleaf	Open Needleleaf
3	Open Needleleaf Lichen	Open Needleleaf Lichen
4	Woodland Needleleaf	Woodland Needleleaf
11	Closed Birch	
12	Closed Mixed Deciduous	Closed Deciduous
13	Open Deciduous	
16	Open Mixed Needleleaf/Deciduous	Mixed Forest
17	Closed Mixed Needleleaf/Deciduous	
20	Tall Shrub	Tall Shrub
21	Low Shrub	Low Shrub (Other, Lichen, Tussock)
22	Low Shrub Lichen	
23	Low Shrub Tussock Tundra	
24	Dwarf Shrub	Dwarf Shrub (Other, Lichen)
25	Dwarf Shrub Lichen	
50	Tussock Tundra	Tussock Tundra (Other,Lichen)
70	Water(Clear, Turbid)	Water(Clear, Turbid)
80	Sparse Vegetated	Sparse Vegetated
81	Rock/Gravel	Rock/Gravel
96	Fire (Burned)	Fire (Burned)

Table 6. The area and percent area of the 35 classified earth cover classes.

CLASS#	CLASS NAME	ACRES	%AREA
1	Closed Needleleaf	216761.73	3.70%
2	Open Needleleaf	2288242.39	39.06%
3	Open Needleleaf Lichen	76599.07	1.31%
4	Woodland Needleleaf	711959.56	12.15%
5	Woodland Needleleaf Lichen	28120.74	0.48%
6	Woodland Needleleaf Moss	19239.39	0.33%
11	Closed Birch	64847.71	1.11%
12	Closed Mixed Deciduous	162449.54	2.77%
13	Open Deciduous	14596.23	0.25%
15	Open Mixed Deciduous	37307.65	0.64%
16	Closed Mixed Needleleaf/Deciduous	208196.19	3.55%
17	Open Mixed Needleleaf/Deciduous	373678.09	6.38%
20	Tall Shrub	384675.07	6.57%
21	Low Shrub	265337.03	4.53%
22	Low Shrub Lichen	77048.08	1.32%
23	Low Shrub Tussock Tundra	54936.01	0.94%
24	Dwarf Shrub	269777.37	4.61%
25	Dwarf Shrub Lichen	11766.92	0.20%
32	Wet Graminoid	995.00	0.02%
34	Wet Sedge	234.40	0.00%
41	Mesic/Dry Sedge	261.31	0.00%
43	Mesic/Dry Graminoid	18.01	0.00%
50	Tussock Tundra	125827.98	2.15%
51	Tussock Tundra Lichen	7658.17	0.13%
60	Aquatic Bed	427.22	0.01%
70	Water	21661.94	0.37%
72	Snow	4425.66	0.08%
80	Sparse Vegetation	29511.15	0.50%
81	Rock/Gravel	87793.32	1.50%
90	Urban	18300.44	0.31%
92	Cloud	19801.61	0.34%
93	Cloud Shadow	22373.60	0.38%
94	Terrain Shadow	12198.59	0.21%
95	Other	11506.72	0.20%
96	Fire	230362.52	3.93%
TOTAL		5,858,896.42	100%

Table 7. The area and percent area of the 23 grouped earth cover classes.

CLASS#	CLASS NAME	ACRES	% AREA
1	Closed Needleleaf	216,761.73	3.70%
2	Open Needleleaf	2,288,242.39	39.06%
3	Open Needleleaf Lichen	76,599.07	1.31%
4	Woodland Needleleaf	759,319.69	12.96%
12	Deciduous	279,201.13	4.77%
16	Mixed Forest	581,874.28	9.93%
20	Tall Shrub	384,675.07	6.57%
21	Low Shrub	397,321.12	6.78%
24	Dwarf Shrub	281,544.29	4.81%
31	Wet Herbaceous	1,229.40	0.02%
40	Dry Herbaceous	279.33	0.00%
50	Tussock Tundra	133,486.15	2.28%
60	Aquatic Bed	427.22	0.01%
70	Water	21,661.94	0.37%
72	Snow	4,425.66	0.08%
80	Sparse Vegetation	29,511.15	0.50%
81	Rock/Gravel	87,793.32	1.50%
90	Urban	18,300.44	0.31%
92	Cloud	19,801.61	0.34%
93	Cloud Shadow	22,373.60	0.38%
94	Terrain Shadow	12,198.59	0.21%
95	Other	11,506.72	0.20%
96	Fire	230,362.52	3.93%
TOTAL		5,858,896.42	100%

very well, but shadowed non-forest classes were still occasionally labeled as open or woodland needleleaf in shadowed areas.

Editing

Manual editing was performed on all classes to various extents depending on how well the iterative classification process worked for each. Essentially, manual editing consists of digitizing an Area Of Interest (AOI) around the pixels in question, then using a recoding tool to change the class value of the questionable pixels to a new class value. These areas were changed based primarily on air photo interpretation, field notes and the analyst's experience in the field.

The woodland needleleaf lichen, woodland needleleaf moss and the wet sedge 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. The wet sedge class was based purely on visual inspection and experience from being in the field. Areas of interest (AOIs) were digitized around the areas visually appearing to be the woodland needleleaf lichen and moss, and wet sedge sub-classes, and these AOIs were recorded accordingly.

The mesic/dry graminoid, and aquatic bed classes were also entirely the result of manual editing. 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. Based on field notes recorded on the field maps, the mesic/dry graminoid/sedge classes were only noted in higher elevations in the central part of the western image (69/14) and in a small area in the eastern image (68/14). All of the mesic/dry graminoid/sedge training sites in the western image were confused with dwarf shrub and thus were manually edited to reflect the proper class. Notes, air photo interpretation, and models were inadequate to determine the full extent of this class. For the eastern image, the mesic/dry graminoid/sedge pixels were classified with no manual editing, however, the extent of this class is not fully recognized.

Accuracy Assessment

To achieve the map accuracy stated below, several iterations of intermediate classifications were performed. At no time during the classification process was the physical location of the accuracy assessment polygon used to determine which classes were problematic, however, the information conveyed by the error matrix provided some insight as to which classes were being misclassified with other cover types. After analyzing the error matrix, decisions could be made on where to focus further image processing. This is an accepted and practiced method for further improving a classification of remotely-sensed data. Approximately eight intermediate accuracy assessments were reviewed to complete the final classified image.

The overall accuracy of the grouped classes was 81% and the overall accuracy of the subclasses was 78% (Table 8). The error matrices for both the grouped classes and for all classes are located in Appendix D, Tables 1 and 2, respectively. Error matrices for Path 68, Row 14 and Path 69, Row 14 can be found in Appendix D, Tables 3 and 4, respectively. The error matrices represent values for user's accuracy, producer's accuracy and Kappa statistic for each class. The accuracy assessment that was performed included information from all three dates of imagery, with the majority being from Paths 68 and 69, Row 14. Path 70, Row 14 was used to fill in for clouded areas in Path 69. From visually inspecting the classification, the western part of the classification differs significantly from the eastern section. This results from a lack of information of particular earth cover types, such as low shrub lichen, dwarf shrub lichen, and tussock tundra lichen.

As the final classification shows, part of the image essentially does not have a recognized lichen component for the shrub and herbaceous classes that the western section of the project area does; this is not to say that the lichen component is not present in the project area. An explanation for this could be as simple as the vegetation caller identifying a slightly different lichen percentage in the Path 68, Row 14 image than in the Path 69 image. Even if the percentage calls were 5% off, this could mean a difference between the presence and absence of a strong lichen component. No error analysis has been performed to check the consistency of calls made from the helicopter and actual percent cover, which makes it difficult to determine the amount of error in the overall classification. Another possibility could be a difference in image date. The image date for Path 68, Row 14 was August 10, 1994. Compared to the Path 69, Row14 image, the differences in sun angle and acquisition time for the Path 68, Row14 image could obscure minor spectral differences that may be more apparent in the Path 69, Row14 image.

Accuracy of Individual Scenes

A detailed accuracy assessment of Path 68, Row14 and Path 69, Row 14 can be found in Appendix D-3 and D-4. The following sections comment on the results of the accuracy assessment for both the grouped and detailed classes.

Accuracy of Grouped Classes

The majority of the classes exceeded 70% accuracy (Appendix D, Table 1). The classes with an accuracy < 70% result from a small number of accuracy assessment sites or where a large number of accuracy assessment sites were included in a particular class (e.g. mixed needleleaf/deciduous and tussock tundra). The 100% accuracy for open needleleaf lichen is overly optimistic since there were only six accuracy assessment sites for open needleleaf lichen--the spectral variability of this class is most likely not recognized from only six sites. The same optimism likely exists for the closed needleleaf class. Almost all of the field sites visited for closed needleleaf occurred near large rivers. Closed needleleaf areas not neighboring rivers mostly occur outside the original Steese-White Mountain Project area. Thus, the classifier seemed to classify the closed needleleaf sites near rivers well, but the areas outside the Steese-White boundary may not follow the same trend. These areas were not heavily edited since no ancillary data existed. The low shrub class appeared to be the most variable; the error matrix shows confusion between open needleleaf, woodland needleleaf, mixed forest, tall shrub, dwarf shrub and tussock tundra. The low shrub class in particular is very common within the Steese-White Mountains Project Area and is usually associated with other vegetation communities, especially tussock tundra and more open needleleaf stands.

The dwarf shrub class was another class that showed confusion between several different cover types, especially rock/gravel and sparse vegetation. This confusion is not surprising since many of the high elevation

Table 8. The accuracy assessment for the Steese-White Mountains Project.

	Overall Accuracy	KHAT Accuracy
P68 R14, all classes	72%	68%
P69 R14, all classes	80%	79%
All Classes	78%	67%
Grouped Classes	81%	79%

areas consist of shrub species that only occur a few centimeters above rocks on the slopes. To separate out the dwarf shrub from the rock/gravel areas, additional rock/gravel sites derived from field notes and locations were used for accuracy assessment. The navigator recorded these additional sites while the rest of the field crew was surveying the current field. Although these additional sites are based on a single observation without knowing the species composition, the sites were found to be useful in the classification. As shown in the accuracy assessment, the classifier seemed to perform well for the information collected for rock/gravel.

Accuracy of Detailed Classes

The closed birch and closed mixed deciduous seemed to be confusing, which is very common, since most of the closed mixed deciduous sites have a strong component of birch. However, the cluster analysis indicated that particular unsupervised classes were being separated between closed birch and closed mixed deciduous sites. As a result, the two classes were left as separate classes in the final classification.

The majority of confusion between classes exists between individual low shrub and dwarf shrub subclass types. As mentioned above, the low shrub type tends to have associations with other vegetation communities such as tussock tundra and lichen. The dwarf shrub type tends to have associations with lichen and various graminoids. Depending on factors such as quantity of lichen and/or tussock tundra, grasses and forbs, and the presence of precipitation during the time of image acquisition, the low shrub class can be confused with areas that are predominantly herbaceous or have a significant percentage of lichen. The same holds true for dwarf shrub. Because these cover types occur on different slopes, aspects and elevations, and because of the inherent difficulty in 1:60,000 air photo interpretation, these types become challenging to classify and model.

The final classified map includes more discriminated classes than assessed classes. Every attempt was made to keep as much detail in the classification as possible. As noted from above, classes such as woodland needleleaf moss, wet graminoid, wet sedge, mesic/dry sedge, and tussock tundra lichen are present in the final classification, but as a result of too few field sites, an accuracy assessment was not performed on these classes. In these instances, all of the field sites were used as training sites.

When reviewing accuracy assessment, the confidence intervals should be noted. Too often, the overall accuracy assessment is noted and users assume that each class will share the same accuracy. Particular attention should be given to the individual class accuracies, their respective confidence intervals and Kappa values. As a rule of thumb, the stated accuracy is typically optimistic, especially when few sites are available for assessing accuracy. The accuracy assessment performed only applies to the area within 10 kilometers of the Steese-White Mountains boundaries. No field data was collected outside this project boundary and air photos were not available. In addition, the project area was enlarged after the field work was completed to include areas that are important for moose and caribou habitat.

Final Products

The primary product of this project is a digital database of the 35 earth cover classes for the Steese-White Mountains Mapping

Project. Also included in the data base is the site information for the Yukon Charley-Black River/40 Mile Project. Fifteen hard copy 1:63,360 scale maps of the classification, as well as a map of the full project area, were produced. In addition, the field DUFF database program with the digital images of the sites was delivered. An ArcView project was also created that showcases the classification, raw imagery and field data in a user-friendly system.

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 with the mapping effort for the Steese National Conservation Area and White Mountains National Recreational Area project using Landsat Thematic Mapper satellite scene, Paths 68 and 69 Row 14, August 10, 1994 and June 22, 1991, respectively and Path 70 Row 14, June 29, 1991. The project area was classified into 35 earth cover categories. The overall classification accuracy of the14 major (lumped) categories was 81%. 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 DUFF program and an ArcView project.

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Appendices

Appendix A - Metadata for TM imagery

The metadata for each of the Landsat TM images can be found on the raw imagery dataset. The raw data is in generic binary format (band sequential, BSQ) and was purchased through EROS Data Center in Sioux Falls, South Dakota. Each band is a separate file with an additional header file that contains rows, columns, bands, RMS error, pixel size, etc.

Appendix B - Decision tree for classification scheme.

Description of Classes

The following is a discussion of each of the earth cover types classified in the Steese-White Mountains 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 and black spruce. 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, aspen and cottonwood. Cottonwoods are found only in river valleys and on alluvial flats. Under some conditions, willow and alder 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 often very extensive, deciduous and mixed deciduous/coniferous stands are generally more limited in size. However, extensive stands of pure deciduous trees occur on floodplains and in ancient oxbows of major rivers.

Besides the general descriptions of the forest types, two caveats to the decision tree need to be noted. willow and alder species are considered shrubs if their heights are < 4 m and trees if they are ≥ 4 m. The height constraint is based on discussions with the BLM and NPS regarding the ecological significance of willow and alder height as it relates to moose use. Once the canopy of the willow and alder is out of reach of browsing moose, the species are considered trees, if not they are considered shrub. In addition, if spruce species are < 1 m, they are considered shrub. While in the field (1997), a strong mix of shrubs and black spruce of 1 m occurred together and thus the area was considered to function as a shrub stand rather than an open needleleaf stand.

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. Only a few sites of closed needleleaf were found along the Birch Creek, however, this class is widely found outside the project area. The acreage for this class is most likely overestimated, but since no field data were collected outside the project area, the closed needleleaf was left unedited.

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. This class composes approximately 39% of the area classified for the Steese-White Mountains. Much of the confusion with this class occurred on NW slopes where terrain shadows were prevalent.

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. In the Steese-White Mountains project area, the open needleleaf lichen class is most likely under estimated. During the classification process, it was found on several of the air photos that lichen was obviously present in needleelaf areas that were being classified as open needleleaf. In such cases, this class was manually edited when open needlelaf was classified in areas that appeared as open needlelaf lichen on air photos. In some cases the edits are noticeable on the final classification.

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. This class composed approximately 12% of the final classified map. A portion of this class may be considered low shrub and can account for the low percentage of low shrub types.

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 north-facing slopes or on riparian benches. This class follows a similar trend as the open needleleaf lichen class. Areas were found on the air photo to have a strong lichen component, but the analyst was not as confident to call such areas woodland needleleaf lichen since some areas were difficult to determine height of vegetation types in these areas using 1:60K scale photos.

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 TM imagery and in field notes that an attempt was made to classify it. This cover type was only found on the Path 68, Row 14 image SW of the Yukon River; only a small percentage of the final map has this class.

1.4 (12) 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, or cottonwood.

1.41 (11) Closed Birch
Enough field data were collected for closed birch and closed mixed to try and separate these cover types. This class follows similar trends as the closed mixed deciduous class with the only difference being dominated by birch. Despite the cover type being classed, there is still some confusion with other deciduous types as well as mixed forest.

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 is 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. This class did compose approximately 4% of the map area and is most commonly found outside the Steese-White Mountains project area. The mixed forest types (both open and closed) combined did not have enough data to do a strong accuracy assessment.

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 Needleaf/Deciduous, and can be found mainly on hill slopes or bordering lakes. This class made up approximately 6% of the scene, again, much of the class found outside the project area.

2.0 Shrub

The tall and low shrub classes are dominated by willow species, dwarf birch (*Betula nana* and *B. glandulosa*), *Ledum* species, 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 is usually composed of dwarf ericaceous shrubs, dwarf willow species, 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. Sometimes dwarf birch and low willow species, growing in a very short or decumbent form was included in dwarf shrub (i.e. an extra low, low shrub class).

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. Some confusion probably occurs with low shrub and deciduous classes and is most likely over represented in the classified map.

2.22 (23) Low Shrub/Tussock Tundra

Shrubs make up 25-100% of the cover, the shrub height is >0.25-1.3 meters, and ≥35% of the cover is made up of tussock forming Cotton Grass *(Eriophorum vaginatum)*. This class is found in extensive patches in flat or poorly drained areas. It is generally made up of cotton grass, ericaceous shrubs, willow species, other graminoids, and an occasional black spruce. This class and the tussock tundra class probably have more confusion than indicated in the accuracy assessment and can account in part why the low shrub class percentage is low.

2.23 (22) Low Shrub/Lichen
Shrubs make up 25-100% of the cover, the shrub height is 0.25-1.3 meters, and ≥20% of the cover is made up of lichen. This class is found at mid-high elevations. The shrub species in this class are nearly always dwarf birch. This class is probably more widely spread than indicated on the map and presents some confusion between dwarf shrub/lichen and tussock tundra.

2.24 (21) Low Shrub
Shrubs make up 25-100% of the cover; the shrub height is 0.25-1.3 meters. This is the most common low shrub class. It is generally composed of dwarf birch, willow species, *Vaccinium* species, and *Ledum* species. As indicated from above some confusion exists between low shrub subtypes, dwarf shrub, and tussock tundra.

2.32 (24) Dwarf Shrub
Shrubs make up 25-100% of the cover, and the shrub height is ≤0.25 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.

2.31 (25) Dwarf Shrub Lichen
This class is similar in composition to dwarf shrub with the exception of the presence of ≥20% lichen. This class shows some confusion with dwarf shrub, tussock tundra and accounts for the majority of confusion and inability to classify mesic/dry herbaceous types adequately.

3.0 Herbaceous
The classes in this category include bryoids (moss and lichen), 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 <25% water, and ≥ 50% of herbaceous is 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 <25% water, and ≥50% of herbaceous is 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 ≥50% 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, where ≥50% of the herbaceous cover was sedges, 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; however, a couple of small, unique patches of *Carex aquatilis* was found north of the SNCA and southwest of the Yukon River. This area appears to be located in a low flat drainage area from some neighboring lakes. Although there was no recorded information about this area, the best guess of the vegetation type was *Carex aquatilis* (Wet Sedge).

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 cotton grass (*Eriophorum vaginatum*). Tussock tundra often includes other graminoids, ericaceous shrubs, willow species, forbs, moss/lichen, and is usually found at lower elevations in flat or greatly sloping, poorly drained areas. This class presented confusion with low shrub, low shrub tussock tundra, and dwarf shrub types and was difficult to interpret when using 1:60K scale air photos for the classification process.

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 cotton grass. Tussock tundra often includes ericaceous shrubs, willow species, forbs and other graminoids, and is usually found at lower elevations in poorly drained areas. This class includes a major component of lichen. Although this class is present in the final classification map, it is most likely under represented as a result of being confused with dwarf shrub lichen, difficulty in air photo interpreation, and lack of field notes on these areas.

3.3 (40) Mesic/Dry Herbaceous
Composed of ≥40% herbaceous species and ≤5% water, excluding tussock tundra sites. 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. Mesic/dry sedge meadow (41) and mesic/dry graminoid (43) were found in small patches near mountain tops. In the western image (69/14) this class was completely manually edited as a result of having the training sites being confused with dwarf shrub, dwarf shrub lichen, and sparse vegetation sites. In the eastern image (68/14) the mesic/dry herbaceous types did a better job of separating out as a separate type, but still its extent is most likely under represented as a result of the confusion between dwarf shrub, dwarf shrub lichen, and sparse vegetation types.

<u>4.0 Aquatic Vegetation</u>
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 (*Equisitum 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. This class is only found in a small area southwest of the Yukon River outside the Steese-White Mountains project area.

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, marestail, or buckbean, 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, 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. Although the Yukon River is almost always turbid water, this and other water areas were classed together as water for the Steese-White Mountains project, since only a few accuracy assessment sites were taken only for both turbid and clear water.

5.1 (72) Snow

Composed of ≥50% snow.

5.2 (73) Ice

Composed of ≥50% ice.

5.3 and 5.4 (70 and 71) Water (Clear and Turbid)

Composed of ≥80% clear water. These two classes were combined because only a few accuracy assessment sites were digitized for both clear and turbid water. All of the turbid water sites were chosen in the Yukon River. The turbid water classes was a separate class in the Yukon Charley project map.

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. This was a difficult class to categorize because of it was difficult to maneuver the helicopter close enough to steep slopes to do an assessment of the site. In addition, the spectral characteristics were very close to both rock/gravel and dwarf shrub sites. Air photos were often used to make a determination between sparse vegetation and dwarf shrub. Sparse vegetation was only classified when significant rock exposure was present in air photos and showed similar characteristics to sparse vegetation training sites.

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. This class was fairly easy to classify except for some areas with northwest slopes that contained terrain shadows. The major confusion with this class may be along gravel bars within oxbows which may or may not contain enough vegetation to be classified as sparse vegetation.

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. No training site data (i.e. no sites mapped). These sites are most likely mapped as rock/gravel.

(90) Urban

At least 50% of the area is urban. This class was only found in the southwest portion of the project area near Fairbanks.

(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. These areas occur as black on the final classified imagery.

(95) Other
This class serves as a catch all for areas that have little or no data to determine a cover type or for areas in the imagery where sensor or atmospheric anomalies occur. For the northwest portion of the Steese-White Mountains project area, a fire was actually occurring during the time of image acquisition. In a small area within the Steese-White Mountains boundary an area can be found where smoke obscures the actual ground cover. Since this phenomenon only occurred in such a small portion of the scene and not enough ancillary data existed to make a confident assessment of the earth cover, the analyst decided to call this area other. There appears to be at least two cover types present. The best guess would be low shrub and deciduous, but the area could just as well be woodland needleleaf and tall shrub. The final classified map will have this area classified as 95 with a white color.

(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. Areas of interest (aoi's) were digitized around the major fires that were present in the imagery. Pixels that fell into these areas were classified as burned. Some pixels were originally classified as different cover types to older fires (mostly to the north of the imagery) to provide at least some information on the potential cover types to be found within these areas.

Appendix C - Earth Cover Classification Metadata

Metadata Information System (MIS): Steese-White Mountains

GENERAL DESCRIPTION

Coverage/Image Name:
FIN_EARTHCOV
Description: Merged data set of P68, R14 and P69, R14 of the classified images with the most detailed classes. Overall accuracy assessment for this data set is 78%.
Scale: 30 meter pixel resolution. Classes assumed accurate at a 5-acre minimum mapping unit or larger.
Date of Image: Classification derived from P68 R14, August 10, 1994 and P69, R14, June 22, 1991. Clouded areas on P69, R14 were filled in with P70, R14, June 29, 1991.
Date of Mapping: July, 1997 – March, 1999.

PROJECTION INFORMATION

Projection:	UTM
Zone:	6
Spheroid:	Clarke 1866
Units:	meters

GENERAL DESCRIPTION

Coverage/Image Name:
FIN_EARTHGRP
Description: Merged data set of P68, R14 and P69, R14 of the classified images with grouped classes. Overall accuracy assessment for this data set is 81%.
Scale: 30 meter pixel resolution. Classes assumed accurate at a 5-acre minimum mapping unit or larger.
Date of Image: Classification derived from P68, R14, August 10, 1994 and P69, R14, June 22, 1991. Clouded areas on P69, R14 were filled in with P70, R14, June 29, 1991.
Date of Mapping: July, 1997 – March, 1999.

PROJECTION INFORMATION

Projection:	UTM
Zone:	6
Spheroid:	Clarke 1866
Units:	meters

SOURCE INFORMATION

Landsat TM scenes purchased and terrain corrected by EROS Data Center, Sioux Falls, South Dakota.

Coverage/Image Name:
STEESE
Description: Political boundary for the Steese-White Mountains Project Area.

PROJECTION INFORMATION

Projection:	UTM
Zone:	6
Spheroid:	Clarke 1866
Units:	meters

SOURCE INFORMATION

Derived from Bureau of Land Management-Alaska (Anchorage Field Office) land status map June, 1997.

Coverage/Image Name:
STEESEBUF
Description: 10 kilometers buffer of the political boundary for the Steese-White Mountains Project Area.

PROJECTION INFORMATION

Projection: UTM
Zone: 6
Spheroid: Clarke 1866
Units: meters

SOURCE INFORMATION

Derived from Bureau of Land Management-Alaska (Anchorage Field Office) land status map June, 1997.

Coverage/Image Name:
STEETRAIN
Description: Training site polygons for the Steese-White Mountains Project area. The polygons were delineated on Landsat TM data (P69, R14) which had a 30-class unsupervised classification run on it. Contains 185 polygons.

Attributes:

AREA_NAME	4 4 C
SITE_NUM	4 4 I
NAVIGATOR	2 2 C
VEG_CALL	2 2 C
RECORDER	2 2 C
DATE	8 10 D
CALC_CLASS	50 50 C
AA_FLAG	1 1 I

(0=TRAIN, 1=AA)

PROJECTION INFORMATION

Projection: UTM
Zone: 6
Spheroid: Clarke 1866
Units: meters

SOURCE INFORMATION

Derived from Bureau of Land Management-Alaska (Anchorage Field Office) land status map June, 1997.

Coverage/Image Name:
STEEAACFIN
Description: Accuracy assessment site polygons for the Steese-White Mountains Project Area. The polygons were delineated on Landsat TM data (P69, R14) which had a 30-class unsupervised classification run on it. Contains 164 polygons. Ten polygons were digitized from the imagery for the water class. Twenty-five polygons were digitized on the imagery based on field notes for the rock/gravel class. Site 194 was not used in the accuracy assessment since this area was classified as other.

Attributes:

AREA_NAME	4 4 C
SITE_NUM	4 4 I
NAVIGATOR	2 2 C
VEG_CALL	2 2 C
RECORDER	2 2 C
DATE	8 10 D
CALC_CLASS	50 50 C
AA_FLAG	1 1 I

(0=TRAIN, 1=AA)

PROJECTION INFORMATION

Projection: UTM
Zone: 6
Spheroid: Clarke 1866
Units: meters

SOURCE INFORMATION

Derived from Bureau of Land Management-Alaska (Anchorage Field Office) land status map June, 1997.

Coverage/Image Name:
STE2TRAIN
Description: Training site polygons for the Steese-White Mountains Project Area. The polygons were delineated on Landsat TM data (P68, R14) which had a 30-class

unsupervised classification run on it. Contains 56 polygons.

Attributes:

AREA_NAME	4 4 C
SITE_NUM	4 4 I
NAVIGATOR	2 2 C
VEG_CALL	2 2 C
RECORDER	2 2 C
DATE	8 10 D
CALC_CLASS	50 50 C
AA_FLAG	1 1 I

(0=TRAIN, 1=AA)

PROJECTION INFORMATION

Projection:	UTM
Zone:	6
Spheroid:	Clarke 1866
Units:	meters

SOURCE INFORMATION

Derived from Bureau of Land Management-Alaska (Anchorage Field Office) land status map June, 1997.

Coverage/Image Name:
STE2ACCFIN

Description: Accuracy assessment site polygons for the Steese-White Mountains Project Area. The polygons were delineated on Landsat TM data (P68, R14) which had a 30-class unsupervised classification run on it. Contains 50 polygons. Nine polygons were digitized from the raw imagery based on field notes for the water class.

Attributes:

AREA_NAME	4 4 C
SITE_NUM	4 4 I
NAVIGATOR	2 2 C
VEG_CALL	2 2 C
RECORDER	2 2 C
DATE	8 10 D
CALC_CLASS	50 50 C
AA_FLAG	1 1 I

(0=TRAIN, 1=AA)

PROJECTION INFORMATION

Projection:	UTM
Zone:	6
Spheroid:	Clarke 1866
Units:	meters

SOURCE INFORMATION

Derived from Bureau of Land Management-Alaska (Anchorage Field Office) land status map June, 1997.

Coverage/Image Name:
YBEXTRA

Description: Additional training site polygons for the Steese-White Mountains Project Area which were delineated for the Yukon Charley-Black River/40-Mile Project. Field work was conducted concurrent with the Steese-White Mountain Project. The polygons were delineated on Landsat TM data (P66 R14, shifted 40% south) which had a 30 class unsupervised classification run on it. Contains 79 polygons.

Attributes:

AREA_NAME	4 4 C
SITE_NUM	4 4 I
NAVIGATOR	2 2 C
VEG_CALL	2 2 C
RECORDER	2 2 C
DATE	8 10 D
CALC_CLASS	50 50 C
AA_FLAG	1 1 I

(0=TRAIN, 1=AA)

PROJECTION INFORMATION

Projection:	UTM
Zone:	6
Spheroid:	Clarke 1866
Units:	meters

SOURCE INFORMATION

Derived from Bureau of Land Management-Alaska (Anchorage Field Office) land status map June, 1997.

Field Data 1997

Field.db:

Field database for the Steese White Mountains, Yukon-Charley/Black River/Forty-Mile projects. In addition, two additional projects STE3 and STE4 contain data that was collected during August of 1998. The data base includes site-specific information as well as two digital oblique photos for each site.

Field.log:

Associated transaction file that contains update information to the DB file. This file must accompany the field.db file and contain the same date and time stamp for the DUFF program to work properly.

Field Photos

The field photos for both Steese-White and Yukon Charley are in the /final_products/ photos1997_1998 directory on the final CDRom. Photos from 1998 were taken by Jim Herriges at the BLM Northern Field Office during August 1998.

Appendix D - Error Matrices

D-1. Error Matrix for grouped earth cover classes for Steese-White Mountains Project Area

Reference Data (columns) / Classified Data (rows)

CLASS	CLOSE NEED.	OPEN NEED.	OPEN N. LICH	WOOD NEED.	CLOSE M. DEC	MIXED FOREST	TALL SHRUB	LOW SHRUB	DWARF SHRUB	TUSSOCK TUNDR	WATER	SPARS VEG.	ROCK/ GRAVE	FIRE	Total	User's	Low L	Upper L	Kappa	Variance
CLOSED NE	**7**														**7**	100.00	97.14	100.00	1.00	
OPEN NEED	2	**18**			1			2							**23**	78.26	60.53	95.99	0.76	
OPEN NEED. LICH.		1	**6**												**7**	85.71	56.93	100.00	0.85	
WOODLAND NEED.		2		**10**				1	1						**14**	71.43	46.34	96.52	0.70	
CL. MIX. DEC.				1	**13**	1									**15**	86.67	68.14	100.00	0.86	
MIXED FORE	1				3	**1**	1	1							**7**	14.29	0.00	43.07	0.13	
TALL SHRUB							**7**	4							**11**	63.64	33.39	93.89	0.62	
LOW SHRUB				1			2	**20**	3						**26**	76.92	59.95	93.89	0.73	
DWARF SHRUB								2	**31**	1		1	2		**37**	83.78	71.36	96.20	0.80	
TUSSOCK TUN.								2	1	**6**					**9**	66.67	33.65	99.69	0.66	
WATER											**19**				**19**	100.00	98.95	100.00	1.00	
SPASE VEG.												**1**	2		**3**	33.33	0.00	93.34	0.33	
ROCK/GRAVEL								1					**25**		**26**	96.15	87.99	100.00	0.96	
FIRE														**9**	**9**	100.00	97.78	100.00	1.00	
Total	**10**	**21**	**6**	**12**	**17**	**2**	**10**	**33**	**36**	**7**	**19**	**2**	**29**	**9**	**213**					
Producer's	70.00	85.71	100.00	83.33	76.47	50.00	70.00	60.61	86.11	85.71	100.00	50.00	86.21	100.00		**81.22**				
Low L	39.60	69.79	96.67	60.58	55.13	0.00	39.60	43.33	74.26	56.93	98.95	0.00	72.97	97.78			**75.74**			
Upper L	100.00	100.00	100.00	100.00	97.81	100.00	100.00	77.89	97.96	100.00	100.00	100.00	99.45	100.00				**86.70**		
Kappa	1.00	0.76	0.85	0.70	0.86	0.13	0.62	0.73	0.80	0.66	1.00	0.33	0.96	1.00					**0.79**	
Variance																				**0.0009**

D-2. Error Matrix for all earth cover classes for Steese-White Mountains Project Ar(

Classified Data

CLASS	CLOSE NEED.	OPEN NEED.	OPEN N. LICH	WOOD NEED.	CLOSE BIRCH	CLOSE M. DEC	OPEN DEC.	CLOSE N./DEC	OPEN N./DEC	TALL SHRUB	LOW SHRUB	LOW SH. LIC	LOW SH. TU	DWARF SHRUB	DWARF SH. LIC	TUSSOCK TUNDRA	WATER	SPARS VEG.	ROCK/ GRAVE	FIRE	Total	User's	Low L	Upper L	Kappa	Variance
CLOSED NE	7																				7	100.00	97.14	100.00	1.00	
OPEN NEED	2	18				1					1		1								23	78.26	60.53	95.99	0.76	
OPEN NEED. LICH.		1	6																		7	85.71	56.93	100.00	0.85	
WOODLAND NEED.		2		10							1			1							14	71.43	46.34	96.52	0.70	
CLOSED BIRCH				1	6	3															10	60.00	27.64	92.36	0.58	
CLOSED M. DEC.					1	2															3	66.67	6.66	100.00	0.66	
OPEN DECIDUOUS					1			1													2	0.00	0.00	10.00	0.00	
CL. NEED./D	1				1			1		1											4	25.00	0.00	72.44	0.24	
OP. NEED./DEC.					1	1					1										3	0.00	0.00	6.67	0.00	
TALL SHRUB										7	2	1	1								11	63.64	33.39	93.89	0.62	
LOW SHRUB				1						1	14		1	1	1						19	73.68	52.83	94.53	0.71	
LOW SH. LICH.												4									4	100.00	95.00	100.00	1.00	
LOW SH. TUSS.										1			1	1							3	33.33	0.00	93.34	0.32	
DWARF SHRUB											1	1		26	1	1		1	2		33	78.79	64.24	93.34	0.75	
DWARF SH. LICH.															5						5	100.00	96.00	100.00	1.00	
TUSSOCK TUN.												1	1			6					8	75.00	42.49	100.00	0.74	
WATER																	19				19	100.00	98.95	100.00	1.00	
SPARSE VEG.																		1	2		3	33.33	0.00	93.34	0.33	
ROCK/GRAVEL											1								25		26	96.15	87.99	100.00	0.96	
FIRE																				9	9	100.00	97.78	100.00	1.00	
Total	10	21	6	12	10	7	0	2	0	10	21	7	5	29	7	7	19	2	29	9	213					
Producer's	70.00	85.71	100.00	83.33	60.00	28.57	-----	50.00	-----	70.00	66.67	57.14	20.00	89.66	71.43	85.71	100.00	50.00	86.21	100.00		78.40				
Low L	39.60	69.79	96.67	60.58	27.64	0.00	-----	0.00	-----	39.60	45.56	17.62	0.00	77.89	35.11	56.93	98.95	0.00	72.97	97.78			72.64			
Upper L	100.00	100.00	100.00	100.00	92.36	64.89	-----	100.00	-----	100.00	87.78	96.66	59.06	100.00	100.00	100.00	100.00	100.00	99.45	100.00				84.16		
Kappa	1.00	0.76	0.85	0.70	0.58	0.66	0.00	0.24	0.00	0.62	0.71	1.00	0.32	0.75	1.00	0.74	1.00	0.33	0.96	1.00					0.76	
Variance																										9E-04

D-3. Error Matrix for earth cover classification for Path 68 Row 14 image

Reference Data

Classified Data

CLASS	CLOSE NEED.	OPEN NEED.	WOOD NEED.	CLOSE BIRCH	CLOSE M. DEC	OPEN DEC.	CLOSE N./DEC.	OPEN N./DEC	TALL SHRUB	LOW SHRUB	DWARF SHRUB	WATER	SPARS VEG.	ROCK/ GRAVEL	Total	User's	Low L	Upper L	Kappa	Variance
CLOSED NE	3														3	100.00	93.33	100.00	1.00	
OPEN NEED.		4													4	100.00	95.00	100.00	1.00	
OPEN NEED. LICH.			3							1	1				5	60.00	13.06	100.00	0.57	
CLOSED BIRCH				1	2										3	33.33	0.00	93.34	0.28	
CLOSED M. DEC.															0	-----	-----	-----	-----	
OPEN DECIDUOUS				1			1								2	0.00	0.00	10.00	0.00	
CL. NEED./D	1			1			1		1						4	25.00	0.00	72.44	0.22	
OP. NEED./DEC.				1	1										2	0.00	0.00	10.00	0.00	
TALL SHRUB									1						1	100.00	80.00	100.00	1.00	
LOW SHRUB										2	1				3	66.67	6.66	100.00	0.65	
DWARF SHRUB											10				10	100.00	98.00	100.00	1.00	
WATER												9			9	100.00	97.78	100.00	1.00	
SPARSE VEG.														2	2	0.00	0.00	10.00	0.00	
ROCK/GRAVEL														2	2	100.00	90.00	100.00	1.00	
Total	4	4	3	4	3	0	2	0	2	3	12	9	0	4	50					
Producer's	75.00	100.00	100.00	25.00	0.00	-----	50.00	-----	50.00	66.67	83.33	100.00	-----	50.00		72.00				
Low L	27.56	95.00	93.33	0.00	0.00	-----	0.00	-----	0.00	6.66	60.58	97.78	-----	0.00			58.55			
Upper L	100.00	100.00	100.00	72.44	6.67	-----	100.00	-----	100.00	100.00	100.00	100.00	-----	100.00				85.45		
Kappa	1.00	1.00	0.57	0.28	-----	0.00	0.22	0.00	1.00	0.65	1.00	1.00	0.00	1.00					0.68	
Variance																				0.005

D-4. Error Matrix for earth cover classification for Path 69 Row 14 image

Classified Data

CLASS	CLOSE NEED.	OPEN NEED.	OPEN N. LICH	WOOD NEED.	CLOSE BIRCH	CLOSE M. DEC	CLOSE N./DEC	TALL SHRUB	LOW SHRUB	LOW SH. LIC	LOW SH. TU	DWARF SHRUB	DWARF SH. LIC	TUSSOCK TUNDR	WATER	SPARS VEG.	ROCK/ GRAVE	FIRE	Total	User's	Low L	Upper L	Kappa	Variance
CLOSED NE	4																		4	100.00	95.00	100.00	1.00	
OPEN NEED	2	14				1			1		1								19	73.68	52.83	94.53	0.71	
OPEN NEED. LICH.		1	6																7	85.71	56.93	100.00	0.85	
WOODLAND NEED.		2		7															9	77.78	48.40	100.00	0.76	
CLOSED BIRCH				1	5	1													7	71.43	35.11	100.00	0.70	
CLOSED M. DEC.					1	2													3	66.67	6.66	100.00	0.66	
CL. NEED./DEC.									1										1	0.00	0.00	20.00	0.00	
TALL SHRUB								6	2	1	1								10	60.00	27.64	92.36	0.58	
LOW SHRUB				1				1	12		1		1						16	75.00	52.53	97.47	0.72	
LOW SH. LICH.										4									4	100.00	95.00	100.00	1.00	
LOW SH. TUSS.								1			1	1							3	33.33	0.00	93.34	0.31	
DWARF SHRUB									1	1		16	1	1		1	2		23	69.57	49.90	89.24	0.66	
DWARF SH. LICH.													5						5	100.00	96.00	100.00	1.00	
TUSSOCK TUN.										1	1			6					8	75.00	42.49	100.00	0.74	
WATER															10				10	100.00	98.00	100.00	1.00	
SPARSE VEG.																1			1	100.00	80.00	100.00	1.00	
ROCK/GRAVEL									1								23		24	95.83	87.00	100.00	0.95	
FIRE																		9	9	100.00	97.78	100.00	1.00	
Total	6	17	6	9	6	4	0	8	18	7	5	17	7	7	10	2	25	9	163					
Producer's	66.67	82.35	100.00	77.78	83.33	50.00	-----	75.00	66.67	57.14	20.00	94.12	71.43	85.71	100.00	50.00	92.00	100.00		80.37				
Low L	25.62	63.05	96.67	48.40	50.17	0.00	-----	42.49	43.78	17.62	0.00	81.76	35.11	56.93	98.00	0.00	80.57	97.78			73.97			
Upper L	100.00	100.00	100.00	100.00	100.00	100.00	-----	100.00	89.56	96.66	59.06	100.00	100.00	100.00	100.00	100.00	100.00	100.00				86.77		
Kappa	1.00	0.71	0.85	0.76	0.70	0.66	0.00	0.58	0.72	1.00	0.31	0.66	1.00	0.74	1.00	1.00	0.95	1.00					0.79	
Variance																								0.001

Appendix E – Contact Information

The following additional data is available:

ARC/INFO coverages
Final map classification in ERDAS Imagine format
Final map compositions in Imagine 8.2 format
Raw Landsat TM and DEM imagery
Field database files and FoxPro data entry program
ARC/INFO coverage of aerial photograph flight lines

For more information please contact:

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