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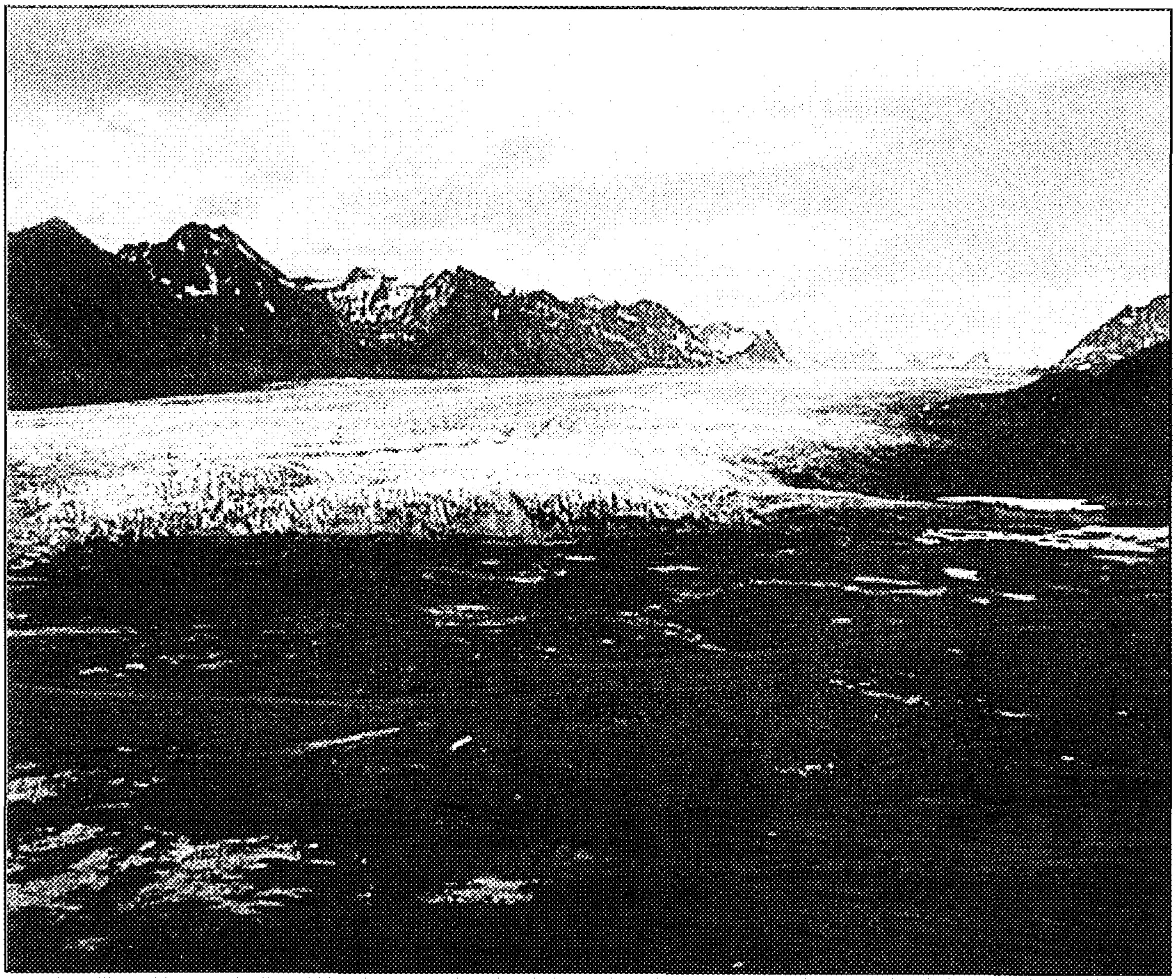
September 2002

Ducks Unlimited, Inc.

Tiekel
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 shows Tazlina Glacier. It depicts the remoteness of the area and the need to use helicopters for data collection.

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U. S. Department of the Interior
Bureau of Land Management
Alaska State Office
222 W. 7th Ave., #13
Anchorage, AK 99513

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

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Abstract

The Bureau of Land Management (BLM) – Alaska and Ducks Unlimited, Inc. (DU) have been cooperatively mapping wetlands and associated uplands in Alaska using remote sensing and GIS technologies since 1988. The goal of this project was to continue the mapping effort by mapping the Tiekel River Watershed. One Landsat TM satellite scene (Path 66, Row 17 acquired August 25, 1987) was used to classify the project area into 23 earth cover categories. An unsupervised clustering or seeding technique was used to determine the location of field sites and a custom field data collection card and digital database were used to record field information. A helicopter was utilized to gain access to field sites throughout the project area. Global positioning system (GPS) technology was used both to navigate to pre-selected sites and record locations of new sites selected in the field. Data were collected on 324 field sites during an 8-day field season from July 7, 1998 through July 14, 1998. Approximately 45% (144) of these field sites were set aside for accuracy assessment. A modified supervised/unsupervised classification technique was performed to classify the satellite imagery. The classification scheme for the earth cover inventory was based on Viereck *et al.* (1992) and revised through a series of meetings coordinated by the BLM – Alaska and DU. The overall accuracy of the major categories was 80%. The cooperators in this project were the Bureau of Land Management-Alaska, and Ducks Unlimited, Inc.

Introduction

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

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

The Tiekel Watershed Earth Cover Mapping project area contains highly diverse landscapes deemed important for wildlife and recreational values. The project area stretches from the Glenn Highway in the north, to the Thompson Pass area of the Chugach Mountains in the south, and from the Copper River in the east to Tazlina Glacier and Tazlina Lake in the west. The project area is relatively roaded and experiences high recreational use. The project area includes important wildlife habitat and supports an abundant tundra swan (*Cygnus columbianus*) population. The area has experienced a devastating infestation of spruce beetle over the past decade, killing the majority of mature white spruce (*Picea glauca*) in the area. The earth cover map will aid in the critical process of resource planning in this valuable and diverse area and will act as a base map for change detection studies. This is the third of three adjoining earth cover mapping projects performed within the BLM's Glennallen District. The Gulkana project is adjacent to this project to the north, and the Tanana Flats project adjoins the Gulkana project on its northern boundary. The combined area of these three projects totals over 19.2

million acres and stretches from Fairbanks in the northwest, to Delta Junction in the northeast, to Thompson Pass in the South.

Project Objective

The objective of this project was to develop a baseline earth cover inventory using Landsat TM imagery for the Tiekel River Watershed and associated areas. More specifically, this project purchased, classified, field verified, and produced high quality, high resolution digital and hard copy resource base maps. The result of this project was an integrated GIS database that can be used for improved natural resources planning.

Project Area

The Tiekel River Watershed mapping project area consisted of 2.4 million acres stretching from Glennallen south to Thompson Pass in the Chugach Mountain Range (Figure 1). The Glenn Highway bordered the project area in the north. The Richardson highway bisected the study area from north to south, with the Copper River marking the eastern boundary of the project area and Tazlina Lake near the western boundary. It included portions of the Gulkana and Valdez U.S.G.S. 1:250,000 scale quadrangles. Elevations ranged from 275 feet on the Copper River to 7,700 ft in the Chugach Mountains. The town of Glennallen fell just inside the northwestern boundary of the project.

The Tiekel project area encompasses a wide variety of environments, ranging from glaciated mountains to lowland black spruce (*Picea mariana*) muskeg. High elevations are home to Dall sheep (*Ovis dalli*), and moose (*Alces alces*) and bear (*Ursus* spp.) abound throughout most of the project area. A large percentage of the innumerable small lakes and ponds found here supported the pond lilies and other aquatic vegetation that make up an important summer food source for breeding tundra swans. The project area encompassed a variety of land ownership including Bureau of Land Management, State, Native Corporation, and Private.

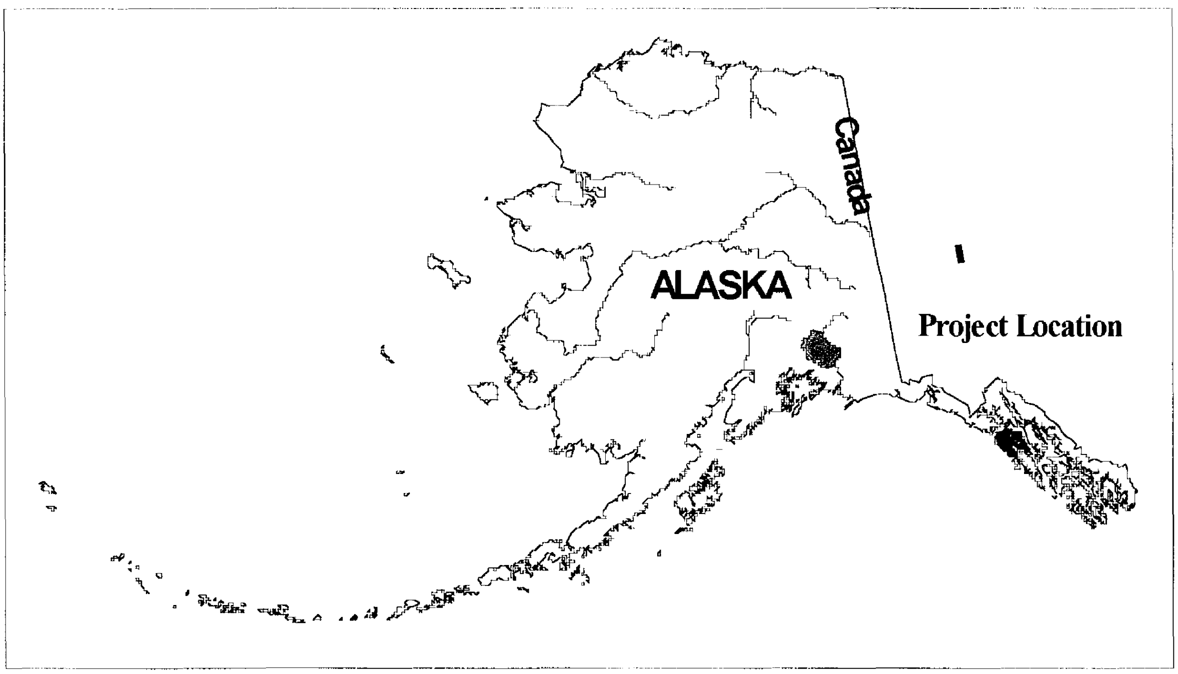


Figure 1. Tiekel watershed earth cover project area

Data Acquisition

One terrain corrected Landsat TM scene (Path 66, Row 17) was purchased to cover the project area (Figure 2). Due to the scarcity of cloud free summer images and the lack of a Landsat receiving station in Alaska since 1995, the most recent image of acceptable quality was acquired on August 25, 1987. The scene was purchased from the Earth Resource Observation Systems (EROS) Data Center in Universal Transverse Mercator (UTM) projection and was terrain corrected by EROS.

Field data were collected over an 8-day period from July 7, 1998 to July 14, 1998. Ancillary data used in this project included: 1:65,000 scale aerial photographs (color infrared transparencies from 1976, 1978, 1984, and 1985) on loan from BLM State Office and the United States Geological Survey's (USGS) 1:63,360 scale Digital Elevation Models (DEM).

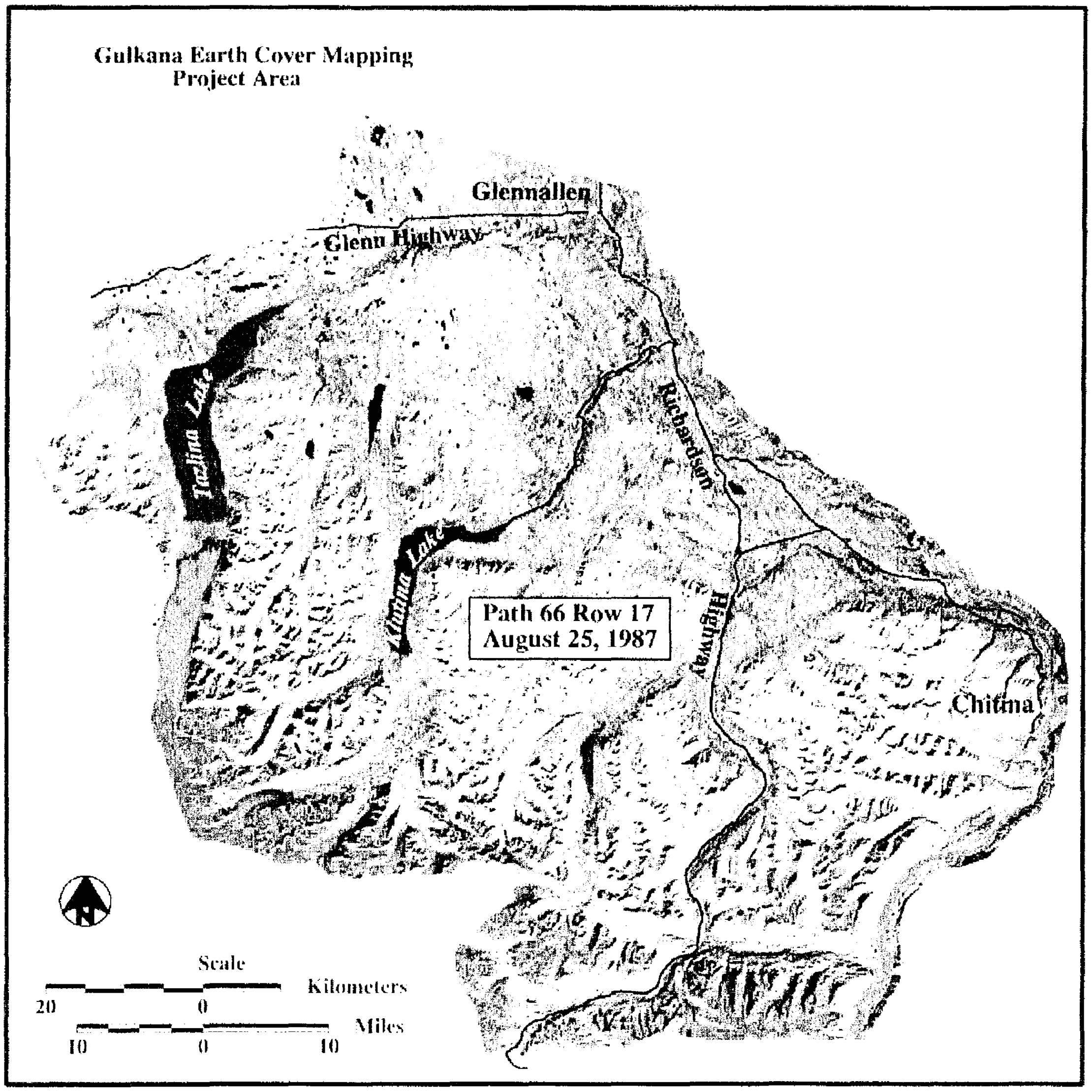


Figure 2. Satellite imagery used for the earth cover classification.

Methods

Classification Scheme

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

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

The classification scheme consisted of 10 major categories and 27 subcategories. A classification decision tree and written description (Appendices A and B) was developed in order to clarify the classification. Though based largely on Level III of the Viereck *et al.* (1992) classification, some classes have been modified, added or omitted for the Earth Cover Mapping projects: e.g., rock, water, ice, cloud and shadow classes were added. Other classes that could not reliably be discerned from satellite imagery had to be collapsed, such as open and closed low shrub classes, or dryas, ericaceous, willow, and dwarf shrub classes. Because of the importance of lichen for site characterization and wildlife, and because the presence of lichen can be detected by satellite imagery, shrub and forested classes with and without a component of lichen were distinguished. A few classes from Level IV of the Viereck *et al.* (1992) classification were also mapped because of their identifiable satellite signature and their importance for wildlife management. These Level IV classes included tussock tundra, low shrub tussock tundra and low shrub willow/alder.

Image Preprocessing

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

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

Table 1. Classification scheme developed at the BLM Earth Cover Workshop.

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

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

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

Field Verification

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

In order to obtain a reliable and consistent field sample, a custom field data collection form (Kempka *et al.* 1994) was developed and used to record field information (Figure 3). A five- person helicopter crew performed the field assessment. Each crew consisted of a pilot, biologist, recorder, navigator, and alternate. The navigator operated the GPS equipment and interpreted the satellite image derived field maps to guide the biologist to the pre-defined field site. It was valuable for the image processor to gain first-hand knowledge of the project area, therefore the image processor also fulfilled the role of the navigator. The biologist identified plant species, estimated the percent cover of each cover type, determined the overall earth cover class, and photographed the site. The recorder wrote species percentages and other data on the field form and generally assisted the biologist. The alternate was responsible for crew check-ins, data entry, and substitution in case of sickness. The majority of sites were observed without landing the helicopter. Ground verification was performed when identification of dominant vegetation was uncertain.

These DU/BLM procedures for collecting field data have evolved into a very efficient and effective means of data collection. The navigator used a GPS to locate the site and verified the location on the field map. As the helicopter approached the site at about 300 meters above ground level the navigator described the site and the biologist took a picture with a digital camera. The pilot then descended to approximately 5-10 meters above the vegetation and laterally moved across the site while the biologist called out the vegetation to the recorder. The biologist took another picture with the digital camera for a close-up view of the site. The pilot then ascended to approximately 100 meters so that the biologist could estimate the percentages of each species to the recorder. The navigator then directed the pilot to the next site. On average, it took approximately 6-10 minutes to collect all of the information for one site.

Field Data Analysis

The collected field information was entered into the Ducks Unlimited Field Form (DUFF) database, designed jointly by the BLM and DU and programmed by GeoNorth. The relational database was powered by SQL Anywhere while the user interface was programmed in Visual Basic. The user interface was organized similarly to the field form to facilitate data entry (Figure 4). The application utilized pull down menus to minimize keystrokes and checked for data integrity to minimize data entry errors. The database program also calculated an overall class name for each site based on the recorded species and its cover percentage. Digital images from each site were stored in the database and accessible from within the user interface. The number of field sites per earth cover class was tracked daily to ensure that adequate samples were being obtained within each class.

Classification

Every image was unique and presented special problems in the classification process. The approach used in this project (Figure 5) has been proven successful over many years. The image processor was actively involved in the field data collection and had first hand knowledge of every training site. The image processor's site-specific experience and knowledge in combination with high quality ancillary data overcame image problems to produce a high quality, useful product.

ERDAS Imagine (vers. 8.3) was used to perform the classification. Arc/Info (vers. 7.2.1) was utilized to manage the field site polygons. Various word processing and data analysis software were also used during the image classification including Microsoft Word, Excel, and Access.

Generation of New Bands

The Landsat TM imagery contained 7 bands of data: 3 visible bands, 1 near-infrared band, 2 mid-infrared bands, and 1 thermal band. One new band, the Normalized Difference Vegetation Index (NDVI), was generated for this project. The NDVI was highly correlated with the 4/3 ratio, a band ratio that typically reduces the effect of shadows in the image and enhances the differences between vegetation types (Kempka *et al.* 1995, Congalton *et al.* 1993). The NDVI had been correlated with various forest and crop canopy characteristics such as biomass and leaf area index. This NDVI band replaced thermal band (band 6) to retain a 7-band image for classification.

Removal of Clouds and Shadows

Clouds and cloud shadows were removed from the image before field sites were selected. This process eliminated any confusion between clouds, cloud shadows, and other vegetation types. They were removed using an unsupervised classification and manual on-screen editing. Clouds were separated from shadows and

Rev 7/15/97

Sample Field Form

1997-TIEK 1 - XXX Yr Project Crew Site Number	DF/JH/LF Observers	Obs. Date: 8 / 13 / 97 Mo Day Year	1 (2) 3 4 Obs. Level	Obs. Time: 16 : 27 Hr Min
Digital Photo 2 . 12, 13 Session # Photo #	LAT (GPS) ____ Decimal Degrees		LONG (GPS) ____ Decimal Degrees	

%Slope (Avg) 45 | Elev | Aspect: N NE E (SE) S SW W NW Flat

Average Distance Between Stems: 10-15' 15-20' 20-25' 25-30' 30-35' 35-40' (Open or Woodland Needleaf Only)

(Circle Lichen where present)

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

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

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

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

%Cov	HERBACEOUS cont'd	
	Forbs	
	Saxifrage	Saxifrage spp.
	Vetch	Astragalus spp.
	Horsetails	Equisetum spp.
	Fireweed	Epilobium spp.
	Coltsfoot	Petasites frigidus
	Cinquefoil	Potentilla spp.
	Bistort	Polygonum spp.
	Rubus	Rubus spp
	Bryoid	
5	Moss	
	Lichen	Color:

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

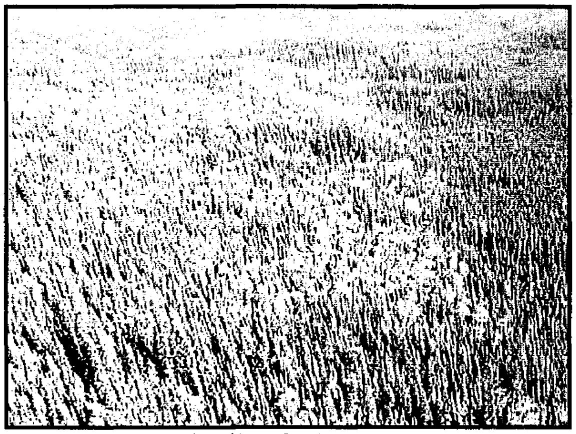
%Cov	NON-VEGETATED	
	Clear/Turbid Water	(circle one)
	Snow/Ice	(circle one)
	Mud/Silt/Sand	(circle one)
	Gravel/Rock	(circle one)
	Litter	
10	Bare Ground	
15	Subtotal % Cover	
100	GRAND TOTAL % COVER	

C#	COMMENTS

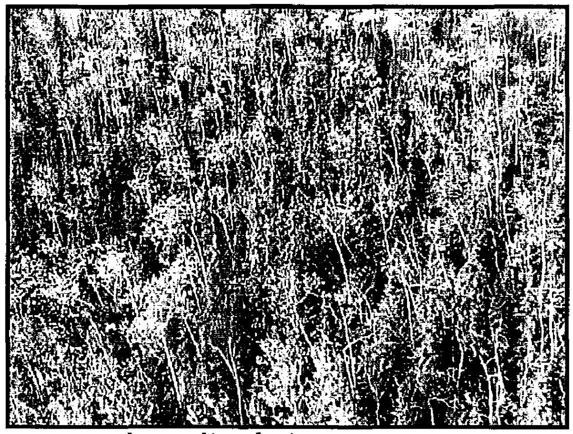
CALL Class. M NEED. NPS 8/14/?

Figure 3. Custom field data collection form.

Sample Field Site – Closed Mixed Needleleaf/Deciduous



High site photo



Low site photo

DUFF INTERFACE

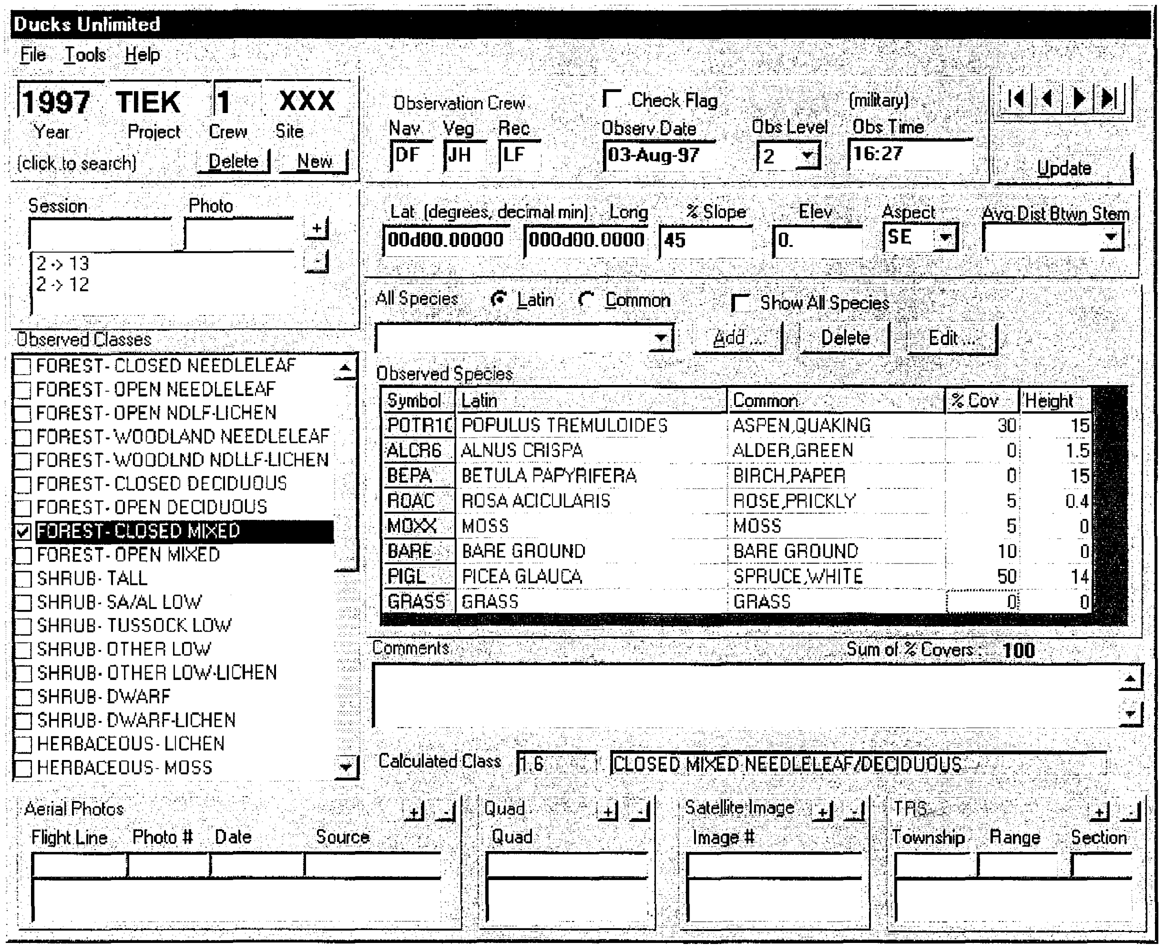


Figure 4. The customized database and user interface for field data entry (DUFF).

classes were recoded 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

Spectral signatures for the field sites to be used as training areas were extracted from the imagery using a "seeding" process in ERDAS Imagine. A pixel within each training area was chosen as a "seed" and adjoining pixels were evaluated for inclusion in each training site using a threshold value based on a spectral Euclidean distance. The standard deviations of the seeded areas were kept close to or below 3 and all seeded areas were required to be over 15 pixels (approximately 3.75 acres) in size. Along with the field training areas, additional "seeds" were generated for clear water, turbid water, and snow classes. These classes were easily recognizable on the imagery and aerial photography. The output of the seeding process in Imagine was a signature file that contained all of the statistics for the training areas. The signature file was then used in the modified supervised/unsupervised classification.

Generation of Unsupervised Signatures

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

Modified Supervised/Unsupervised Classification

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

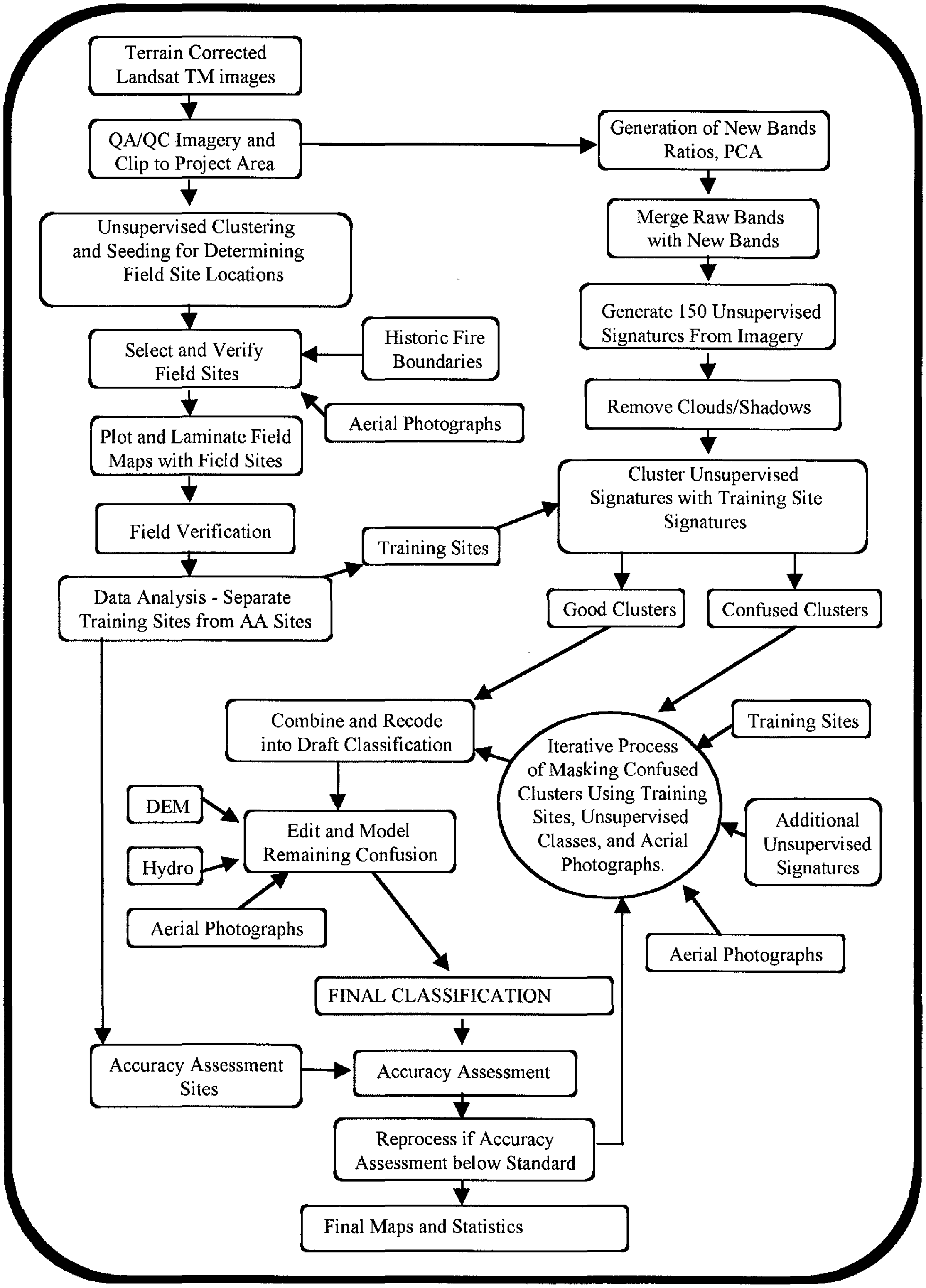


Figure 5. Image processing flow diagram.

sites were run through further iterations of the supervised/unsupervised classification and further refined. The iterative process of interim accuracy assessments and refining classifications was terminated when the accuracy assessments indicated no improvements between one iteration and the next.

Editing and Modeling

Models that incorporated ancillary data sets such as elevation, slope, aspect, shaded relief, or hydrography helped to separate confused classes. For instance, terrain shadow/water confusion was easily corrected by creating a model using a shaded relief layer derived from DEMs.

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

Accuracy Assessment

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

Alaska Perspective

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

In this project, the fieldwork for obtaining the training sites 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 (n=50) for the accuracy assessment. Some earth cover classes were naturally limited in size and distribution, so that a statistically valid accuracy assessment sample could not be obtained without additional field time. For classes with low sample sizes few, if any, field sites were withheld for the accuracy assessment. This does not indicate that the classification for these types is inaccurate but rather that no statistically valid conclusions can be made about the accuracy of these classes. However, withholding even a small percentage of sites for the accuracy assessment provided some confidence in the classification and guided the image processor and end user in identifying areas of confusion in the classification.

Selection of Accuracy Assessment Sites

Approximately 25-30% of the collected field sites were set aside for use in the assessment of map accuracy while the remainder were utilized in the classification process. Unfortunately, given time and budget constraints it was not always possible to obtain enough sites per class to perform both the classification and a statistically valid accuracy assessment. A minimum of 15 sites in an individual class (5 for accuracy assessment, 10 for image processing training sites) were required before any attempt was made to assess the accuracy of that class. Classes with less than 15 field sites were still classified. However, these classes were collapsed into the next, more general hierarchical class when accuracy assessment was performed. Accuracy assessment sites were selected randomly across the project area to reduce bias.

Error Matrix

The standard method for assessing the accuracy of a map was to build an error matrix, also known as a confusion matrix, or contingency table. The error matrix compares the reference data (field site or photo interpreted site) with the classification. The matrix was designed as a square array of numbers set out in rows and columns that expressed 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 represented the reference data while the rows indicated the classification (Lillesand and Kiefer, 1994). An error matrix was an effective way to represent accuracy in that the individual accuracy of each category was plainly described along with both the errors of inclusion (commission errors) and errors of exclusion (omission errors) present in the classification. A commission error occurred when an area was included in a category it did not belong. An omission error was excluding that area from the category in which it did belong. Every error was an omission from the correct category and a commission to a wrong category. Note that the error matrix and accuracy assessment was based on the assumption that the reference data was 100% correct. This assumption was not always true, especially when the reference data was derived from aerial photographs.

In addition to clearly showing errors of omission and commission, the error matrix was used to compute overall accuracy, producer's accuracy, and user's accuracy (Story and Congalton 1986). Overall accuracy was allocated as the sum of the major diagonal (i.e., the correctly classified samples) divided by the total number of samples in the error matrix. This value is the most commonly reported accuracy assessment statistic. Producer's and user's accuracies are ways of representing individual category accuracy instead of just the overall classification accuracy.

Kappa Analysis

A Kappa analysis was performed on the error matrix as a further measure of accuracy (Congalton 1991). Cohen's coefficient of agreement (Kappa) was calculated as a measure of overall agreement in the error matrix after chance agreement was removed from consideration. In other words, Kappa provided a better measure of agreement by adjusting the overall accuracy for chance agreement or that agreement that might be contributed solely by chance matching of the two maps. The result of the Kappa analysis was 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%) represented strong agreement; a value between 0.40 and 0.80 represented moderate agreement; and a value below 0.40 represented poor agreement.

In addition to calculating KHAT, confidence intervals were calculated using the approximate large sample variance. The large sample variance was used to test if the agreement between the classification and reference data was significantly different from zero or a random classification with the Z statistic. The Z statistic in the Kappa analysis was used to test if a classification was significantly different from another classification. A Z statistic of ≤ 1.98 indicated that the classification was not significantly different from a random classification at the 99% confidence level.

Accuracy Assessment Software

In order to automate the accuracy assessment process, a program was developed in Visual Basic to format the data, calculate the statistics for each individual accuracy assessment polygon, flag mixed sites, and generate the error matrix and statistics. The program generated a listing of accuracy assessment sites along with the assigned class value for both the reference data and classification. Additional information generated included a table of the percentage and number of pixels by class that fell within each accuracy assessment site. The table was used to analyze mixed classes and to clear up any confusion between the accuracy assessment site and the classification. The table also helped to identify any non-map errors in the accuracy assessment such as registration problems and labeling errors.

The accuracy assessment program also calculated an error matrix and Kappa statistics for the classification. The program generated the error matrix based on the reference value and the classification value that was created in the previous step. The error matrix was then used to compute the Kappa statistics. The error matrix and Kappa statistics were used to report the final accuracy of the classification.

Results

Spruce Beetle Damage

The Tiekel project area has experienced an outbreak of spruce bark beetle over the past decade resulting in large expanses where nearly all mature spruce have been killed. The majority of this "beetle kill" occurred after 1987, the acquisition date of the imagery. This posed a difficult situation for field data collection and image classification in these portions of the project area. Ideally, those portions of the image that had changed significantly between the date of image acquisition and the date of field data collection would be avoided so that field data would match what was present in the image. The beetle kill was too extensive to do this however, so sampling had to occur in beetle killed areas. The effect of this was that many sites that were open or woodland needleleaf sites at the image date (1987) had become woodland needleleaf or non-forested sites by 1998 because of the percentage of dead spruce. To account for this during classification process, class labels for all sites with standing dead trees were recalculated as if the standing dead trees were still alive. This resulted in each site having a calculated label for the field date (1998) as well as for the image date (1987). For example, if a site had 15% cover in live spruce and 15% cover in standing dead spruce, the site was labeled as woodland needleleaf in 1998 and open needleleaf in 1987. Seventy-one sites had some percentage of cover in standing dead trees. The calculated class for 34 of these sites changed between 1987 and 1998 (Table 2). The most common change was from open needleleaf in 1987 to woodland needleleaf in 1998. The calculated class labels for 1987, the date of the image, were used for labeling the training and accuracy assessment sites during image classification. All reference to calculated site labels throughout this report are to the 1987 calculated class unless otherwise stated.

Table 2. Changes in calculated class between 1987 and 1998 due to beetle kill.

Calculated Class - 1987	Calculated Class – 1998	Change
CLOSED NEEDLELEAF	OPEN NEEDLELEAF	2
OPEN NEEDLELEAF	WOODLAND NEEDLELEAF	18
OPEN NEEDLELEAF	OPEN MIXED NEEDLELEAF/DECID.	1
WOODLAND NEEDLELEAF	TALL SHRUB	1
WOODLAND NEEDLELEAF	LOW SHRUB – OTHER	2
CLOSED MIXED NEEDLELEAF/DECID.	CLOSED DECIDUOUS	3
CLOSED MIXED NEEDLELEAF/DECID.	OPEN DECIDUOUS	3
OPEN MIXED NEEDLELEAF/DECID.	OPEN DECIDUOUS	2
TOTAL		**34**

Field Verification

A Bell Jet Ranger helicopter was used to gain access to the field sites. Fieldwork was split evenly between two staging locations. The first 4 days were based out of a field camp located along the Richardson Highway near Pump Station 12, which provided access to the southern half of the project area. The remaining four days were used to sample the northern and western-most portions of the project area and were based out of the BLM's Glennallen Field Office. Fuel barrels were used at fuel cache at the Richardson Highway field camp, while commercial fuel was purchased from a local vendor for the fieldwork in Glennallen.

Field data were collected on a total of 324 field sites during the 8-day field season from 7-14 July 1998. On average, 40 sites were visited per day. Daily flight time did not exceed 6 hours. Approximately 45% (n=145) of the sites were reserved for accuracy assessment. At the request of the Ahtna Native Corporation, no field sites were taken within native conveyed lands that fell within the project area boundaries.

The proportions of sites per class (Table 3) largely reflected the proportion of corresponding earth cover types within the project area, though proportionally more sites were collected for classes that were difficult to map, e.g., wet graminoid meadows.

Helicopter surveys were the most efficient and economical sampling method for this type of fieldwork. In an effort to minimize travel time between sites and maximize sampling time, priority was given to sampling areas with an abundance of pre-selected field sites concentrated in areas of high cover class diversity. Sampling of other, more scattered, pre-selected sites was accomplished, usually when less common cover classes were encountered while en route between areas with higher concentrations of pre-selected sites. This sampling method produced a distribution of clustered sites that were scattered across the entire image (Figure 6).

Classification

The three most extensive vegetative classes were open needleleaf, low shrub, and woodland needleleaf (Figure 7, Table 4). These three classes covered 48% of the project area, with open spruce accounting for 25%, low shrub accounting for 15%, and woodland needleleaf accounting for 8%. Spruce muskeg dominated the flatter lowlands in the northern half of the study area while open and woodland spruce forests, with tall shrub and low shrub understories, were typical of the lower slopes of the Chugach Mountain Range. The closed needleleaf class made up only 1.5% of the total study area and was restricted to high quality sites along the flood plains of the Copper and Tazlina Rivers. Low shrub, consisting mostly of dwarf birch (*Betula glandulosa/nana*) and willow species (*Salix spp.*), was the dominant cover above approximately 3,250' elevation in the Chugach Mountains, and was found interspersed throughout open and woodland needleleaf muskegs in the lowlands.

Rock/gravel, sparse vegetation, and snow/ice, found at the highest elevations in the Chugach Mountain Range and its associated glaciers, accounted for 20% of the project area. Dwarf shrub cover types made up 7% of the area and typically occupped the transition area in the highlands of the Chugach range between the low shrub zone and the rock/gravel/sparse vegetation zone at the highest elevations.

Table 3. Field sites per mapped class.

Class Name	Total Field Sites per Class	Sites Withheld for Accuracy Assessment
CLOSED NEEDLELEAF	8	0
OPEN NEEDLELEAF	66	33
*OPEN NEEDLELEAF**	*(64)*	*(33)*
*OPEN NEEDLELEAF LICHEN**	*(2)*	*(0)*
WOODLAND NEEDLELEAF	37	18
CLOSED DECICUOUS	23	11
*CLOSED ASPEN**	*(8)*	*(4)*
*CLOSED MIXED DECIDUOUS**	*(15)*	*(7)*
OPEN DECIDUOUS	11	5
*OPEN ASPEN**	*(2)*	*(1)*
*OPEN POPLAR**	*(2)*	*(1)*
*OPEN MIXED DECIDUOUS**	*(7)*	*(3)*
CLOSED MIXED NEEDLELEAF/DECIDUOUS	12	6
OPEN MIXED NEEDLELEAF/DECIDUOUS	18	9
TALL SHRUB	21	10
LOW SHRUB	56	28
*LOW SHRUB – LICHEN**	*(10)*	*(5)*
*LOW SHRUB – WILLOW/ALDER**	*(6)*	*(3)*
*LOW SHRUB – OTHER**	*(41)*	*(20)*
DWARF SHRUB	35	17
*DWARF SHRUB – LICHEN**	*(6)*	*(3)*
*DWARF SHRUB – OTHER**	*(29)*	*(14)*
WET GRAMINOID	15	7
MESIC/DRY SEDGE MEADOW	1	0
AQUATIC BED	5	0
EMERGENT VEGETATION	1	0
SPARSE VEGETATION	5	0
ROCK/GRAVEL	8	0
OTHER	1	0
TOTAL	**324**	**144**

* Classes grouped into next highest hierarchical class for accuracy assessment.

The remaining 25% of the project area was dominated by deciduous, mixed needleleaf/deciduous, and tall shrub cover types. Closed and open deciduous stands comprised mostly of paper birch (*Betula papyrifera*) and aspen (*Populus tremuloides*) were typically found in two general areas: on well-drained, sandy flood plains and bluffs along the major rivers, and also on well drained slopes in the lower elevations of the Chugach Mountains. Tall shrub was found in similar areas to the deciduous classes but extended to higher elevations. It was also highly associated with riparian areas at all elevations, and was found extensively on wet, steep mountain slopes along the Copper River and its major tributaries.

Herbaceous classes were uncommon. The wet graminoid class was found along the edges of the numerous lakes and ponds and primarily in drained ponds, lakebeds, and oxbows in early stages of succession. Dominant graminoids were typically *Carex aquatilis* and *Eriophorum spp*. Only one dry herbaceous site, a mesic/dry sedge meadow, was found during field sampling.

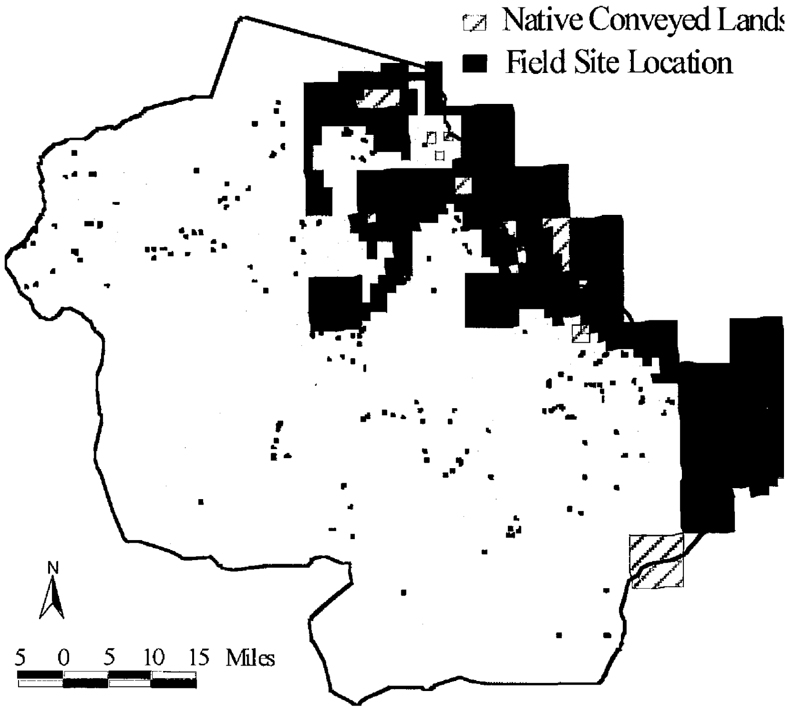


Figure 6. Field site distribution.

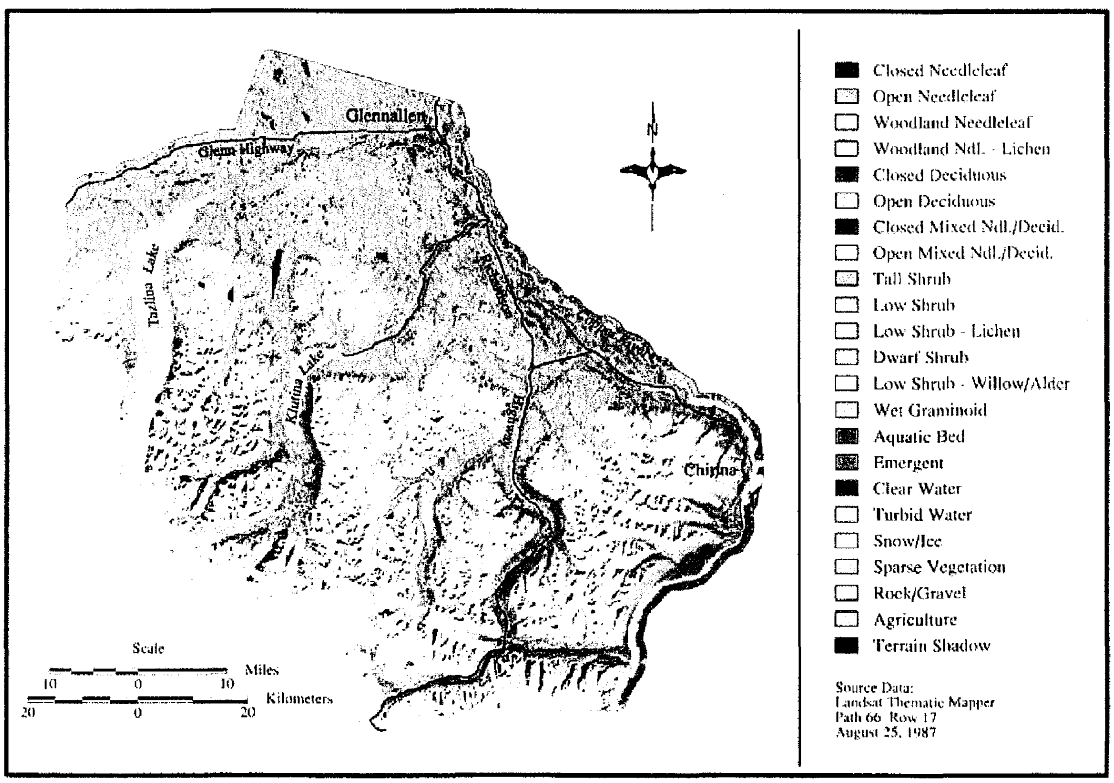


Figure 7. Tiekel River watershed final classified map.

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

CLASS NUMBER	CLASS NAME	MAPPED ACRES	MAPPED PERCENT
1	Closed Needleleaf	28,910	1.19%
2	Open Needleleaf	597,953	24.58%
4	Woodland Needleleaf	201,278	8.27%
5	Woodland Ndl. – Lichen	1048	0.04%
10	Closed Deciduous	103,413	4.25%
13	Open Deciduous	29584	1.22%
16	Closed Mixed Ndl./Decid.	59,287	2.44%
17	Open Mixed Ndl./Decid.	102,566	4.22%
20	Tall Shrub	100,653	4.14%
21	Low Shrub	369,539	15.19%
22	Low Shrub - Lichen	7,897	0.32%
24	Dwarf Shrub	168,866	6.94%
26	Low Shrub - Willow/Alder	11,088	0.46%
32	Wet Graminoid	1788	0.07%
60	Aquatic Bed	1310	0.05%
61	Emergent	31	0.00%
70	Clear Water	18,456	0.76%
71	Turbid Water	82,576	3.39%
72	Snow/Ice	162,469	6.68%
80	Sparse Vegetation	72,515	2.98%
81	Rock/Gravel	249,963	10.27%
91	Agriculture	1399	0.06%
94	Terrain Shadow	60,475	2.49%
Total		**2,433,064**	**100%**

Dry herbaceous areas that were observed in the field were typically too small in extent to identify on the Landsat TM image. Larger areas that may have been dominated by herbaceous species typically had a minimum of 25% cover in shrub species and therefore always fell into the low or dwarf shrub classes. No attempt was made to classify a dry herbaceous cover type because of the lack of samples.

Modeling

Modeling was performed using a shaded relief image and an elevation zone image derived from USGS DEMs at 1:63,360 scale. The shaded relief image was created in ERDAS Imagine using the solar azimuth and solar elevation listed in the header file for the TM image. The elevation zone image was classed into 250-foot elevation zones. Modeling was primarily used to identify misclassed areas. Since water, wet graminoid, closed canopy needleleaf forest and shadow have similar spectral signatures, these classes were often confused. Terrain shadows were identified using the shaded relief image. Shaded areas on the shaded relief image that coincided with areas being classed by signatures that confused shadow, water, and forest were relabeled to the Terrain Shadow class. Water obviously did not occur on a slope, but terrain shadows do occur in steep areas, so a slope based model was used to identify shadowed areas that had been misclassed as water or wet graminoid. Needleleaf classes are generally found only at lower elevations within the project area, so modeling was also used to check for cloud or terrain shadowed areas at high elevations that had been misclassed as forest. Closed needleleaf pixels above 2,500' elevation, open needleleaf pixels above 3,750' elevation, and woodland needleleaf pixels above 4,000' elevation were flagged and then either edited to the correct class or scanned out of the image using a majority filter. These elevation limits were determined through review of field site data, field notes, and photo interpretation.

Elevation based models did not always affect the entire study area at once. Models were often run to affect only the pixels classified by an individual unsupervised class. For example, for several unsupervised classes, closed deciduous areas were being confused with low shrub and tall shrub areas. Upon further examination of these unsupervised classes it was determined that nearly all the areas below 3,250' elevation being classed by those signatures were closed deciduous areas, while those above 3,250' were low and tall shrub. A model was written to label all the areas classed by these signatures below 3,250' to closed deciduous. This did not eliminate all low and tall shrub below 3,250' in the entire study area, it only affected those areas classed by the specified unsupervised signatures.

Editing

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

Another kind of editing was needed to classify areas that fell in the middle of the gradient between one class and another, for example, between woodland and shrub. A woodland area of 10-15% trees could easily be confused with a shrub area of 5-10% trees. Similarly, low shrub areas at a height of 1 meter could be confused with tall shrub areas of only 1.5 meters in height. These transitional areas and signatures had to be examined and a classification decision made based on the available data.

In some cases, a single pixel fell across two cover types, e.g., when a pixel occurs at the edge between a lake and the forested land surrounding it. These half-water half-land signatures were often confused with wet sedge and open needleleaf signatures. Editing was done to separate legitimate wet sedge, open needleleaf or mixed forest pixels based on aerial photography, field notes and topography. The remaining mixed pixels were blended into surrounding areas with a limited majority scan algorithm.

The wet graminoid, emergent vegetation and aquatic bed classes were also heavily edited based on aerial photography and field notes. These cover types commonly require extra editing because they are generally both limited in extent and highly variable. Aquatic beds often occur in narrow strips around the edges of lakes, often only a few pixels wide, making it very difficult to obtain reliable ground samples. Wet graminoid sites were more extensive and common, but were highly variable with respect to spectral reflectance. Small differences in soil moisture content, density of vegetation, and the proportion of senescent plants drastically affected the reflectance values. Standing water created a very dark signature, while senescent plants created a very bright signature. Dense, lush graminoid vegetation that completely obscured the presence of water created a third signature, often confused with other leafy cover types, like tall shrub. The emergent vegetation class was entirely the result of editing and only accounted for about 30 acres throughout the entire project area. These areas were edited based on field notes. Emergent vegetation also produced a highly variable signature and was often found in long narrow strips that were too small to be accurately mapped with Landsat TM data. Larger areas of emergent vegetation that could be detected with Landsat TM data, but not classified due to a lack of emergent vegetation training sites, were most likely classified into the wet graminoid class.

The agriculture class was entirely the result of editing. It was added into the classification to account for several agricultural fields (mostly hay fields) along the Edgerton Highway. Spectrally these fields were most similar to and confused with the low shrub classes. This may indicate that fields had been left unharvested and were reverting back to natural conditions, but this is purely conjecture since the private land surrounding these fields was avoided during field data collection.

Accuracy Assessment

Some earth cover classes were inadequately represented in the field data available for training and accuracy assessment, either because of their scarcity within the project area, e.g., dry herbaceous and closed needleleaf classes, or because they were difficult to reach, e.g., the high elevation sparsely vegetated class. Classes with an inadequate sample size were grouped up into the next hierarchical cover type for accuracy assessment of the classification. This grouping resulted in 11 accuracy assessment classes. Low shrub lichen, low shrub willow/alder and low shrub other were grouped into a general low shrub class. Species specific closed and open deciduous subclasses were grouped into general closed and open mixed deciduous classes. No accuracy assessment was attempted for mesic/dry sedge meadow, aquatic bed, emergent vegetation, sparse vegetation, and rock/gravel due to limited sample size. The overall accuracy of the grouped classes was 80%. A complete error matrix presenting the overall accuracy, as well as the Kappa statistic and a user's and producer's accuracy for each class is given in Appendix D.

Producer's and user's accuracy of the open needleleaf class was high (94% and 89%, respectively), as would be expected since it was the most extensive cover type. The woodland needleleaf class also had a relatively high user's accuracy (81%), but a slightly lower producer's accuracy (72%). The high user's accuracy indicated that an area classified as woodland needleleaf on the map had a high likelihood of being woodland needleleaf on the ground. The lower producer's accuracy indicated that some woodland needleleaf areas on the ground were classed as something other than woodland needleleaf on the map. This resulted partly because of the nature of the woodland class; it was a difficult class to map due to its high diversity of possible components. For example, a woodland site could include 40% graminoid cover and just 10% trees, or it could contain 20% trees and

50% shrubs. In some cases, cover types other than trees dominated the signature of woodland sites, in other cases spruce trees dominated.

The most difficult portion of the classification was attempting to distinguish the deciduous, mixed needleleaf/deciduous, and shrub classes. This was reflected in the relatively low user's and producer's accuracies, ranging from 50% to 78% for the various deciduous and mixed needleleaf/deciduous classes. This was partly a result of the limited number of samples that were available for classifying these classes and mostly because of the spectral similarities exhibited by these classes. Also, the species composition of these classes were sometimes similar, and small differences in the percentage of a species or height of a species changed the site label from one class to another without largely affecting the spectral signature. For example, a site with 10% spruce and 35% willow over 4 meters tall was labeled Open Mixed. If the percentage of willow were 5% greater (40%), the site was labeled Open Deciduous. However, if the willow was less than 4 meters tall in either of those situations it was considered a shrub and the site was labeled woodland needleleaf. These changes in class label with minor changes in species composition or height were a direct result of forcing discrete cover type boundaries onto an ecological gradient. Compounding this problem was the fact that even sites that were near the boundary between two classes were often spectrally inseparable.

Accuracies of the low shrub and dwarf shrub classes were very high, ranging from 81% to 90%. As with the open and woodland needleleaf classes, this was not surprising since such a large portion of the project area consisted of these two classes and there was a relatively large number of representative field sites collected. The tall shrub user's and producer's accuracies, (75% and 60%, respectively), were significantly lower than the other shrub classes. The confusion occurred primarily with the deciduous and mixed needleleaf/deciduous forest classes. This was not surprising since the major components of all these classes were willow, birch, and alder, and there was very little spectral difference between these species.

Wet graminoid accuracy was higher in the user's category (80%) than the producer's (57%), indicating that areas classed as wet graminoid had a high likelihood of actually containing wet graminoid. The difference between user's and producer's accuracies for wet graminoid reflects the extensive editing done for this class. A large percentage of the wet graminoid class was edited into the map, so it is likely to be accurate in these areas. However, there were wet graminoid areas that were undoubtedly overlooked or too difficult to distinguish on aerial photos. These areas reduced the producer's accuracy for this class.

Discussion

While the accuracy assessment performed in this project was by no means a robust test of the classification, it gives the user some confidence when using the classification. It also provided 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 25 August 1987. The aerial photographs spanned a nine-year period from 1976 through 1985, and the field data was collected in July 1998. Differences due to environmental changes from the different sources may have had a major impact on the accuracy assessment.

A major assumption of quantitative accuracy assessments is that the label from the reference information represented the "true" label of the site and that all differences between the remotely sensed map classification and the reference data were 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.

Final Products

Final products included a digital classification, physical maps and a database of 23 earth cover classes within the Tiekel River Watershed project area. The digital map was delivered in ArcGrid and ERDAS Imagine format. The unclassified Landsat TM images used to create the cover type map were also delivered to project cooperators. The field site database, a species list and earth cover acreage tables were stored as digital tables in Microsoft Excel and Access format. Digital photos of the field sites were stored as JPEG's. Plots of the entire project area at 1:250,000 scale, and selected 1:63,360 scale quadrangles were also produced. All of the delivered datasets were loaded into ArcView projects for display purposes.

Summary

The Bureau of Land Management – Alaska and Ducks Unlimited, Inc. have been cooperatively mapping wetlands and associated uplands in Alaska using remote sensing and GIS technologies since 1988. This project continued this mapping effort for the Tiekel River Watershed project using Landsat TM data for Path 66 Row 17, acquired 25 August 1987. The project area was classified into 23 earth cover categories with an overall accuracy of 80%. The digital database and map of the classification were the primary products of this project along with hard copy maps of the classification, a complete field database, and an ArcView project.

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Appendices

Appendix A. Alaska Earth Cover Classification Class Descriptions.

1.0 <u>Forest</u>

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

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

1.1 Closed Needleleaf

At least 60% of the cover was trees, and ≥75% of the trees were needleleaf trees. Closed needleleaf sites were rare because even where stem densities were high, the crown closure remained low. Generally, closed needleleaf sites were found only along major rivers.

1.2 Open Needleleaf

From 25-59% of the cover was trees, and ≥75% of the trees were needleleaf. This class was very common throughout the interior of Alaska. A wide variety of understory plant groups were present, including low and tall shrubs, forbs, grasses, sedges, horsetails, mosses and lichens.

1.21 Open Needleleaf Lichen

From 25-59% of the cover was trees, ≥75% of the trees were needleleaf, and ≥ 20% of the understory was lichen.

1.3 Woodland Needleleaf

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

1.31 Woodland Needleleaf Lichen

From 10-24% of the cover was trees, ≥75% of the trees were needleleaf, and ≥ 20% of the understory was lichen. The lichen often occurred in small round patches between trees. Within the study area, this class was generally found along ridgetops or on riparian benches.

1.4 Closed Deciduous (Mixed Deciduous Species 1.45)

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

1.41 Closed Birch

At least 60% of the cover was trees, ≥75% of the trees were deciduous, and ≥75% of the deciduous trees were paper birch (*Betula Papyrifera)*. This class was very rare.

1.42 Closed Aspen

At least 60% of the cover was trees, ≥75% of the trees were deciduous, and ≥75% of the deciduous trees were aspen. Stands of pure aspen occurred, but were generally no larger than a few acres. They were found on steep slopes, with particular soil conditions, and on river floodplains.

1.43 Closed Poplar

At least 60% of the cover was trees, ≥75% of the trees were deciduous, and ≥75% of the deciduous trees were cottonwood. Stands of pure cottonwood were occasionally found on riparian gravel bars.

1.5 Open Deciduous (Mixed Deciduous Species 1.54)

From 25-59% of the cover was trees, and ≥75% of the trees were deciduous. There was generally a needleleaf component to this class though it was less than 25%. This was a relatively uncommon class.

1.51 Open Birch

From 25-59% of the cover was trees, ≥75% of the trees were deciduous, and ≥75% of the deciduous trees were paper birch. This class was very rare. No examples of this class were found in the study area.

1.52 Open Aspen

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

1.53 Open Cottonwood

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

1.6 Closed Mixed Needleleaf/Deciduous

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

1.7 Open Mixed Needleleaf/Deciduous

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

2.0 <u>Shrub</u>

The tall and low shrub classes were dominated by willow species, dwarf birch (*Betula nana* and *B. glandulosa*) and *Vaccinium* species, with alder being somewhat less common. However, the proportions of willow to birch and the relative heights of the shrub species varied widely, which created difficulties in determining whether a site was made up of tall or low shrub. As a result, the height of the shrub species making up the largest proportion of the site dictated whether the site was called a low or tall shrub. The shrub heights were averaged within a genus, as in the case of a site with both tall and low willow shrubs. Dwarf shrub was usually composed of dwarf ericaceous shrubs and *Dryas* species, but often included a variety of forbs and graminoids. The species composition of this class varied widely from site to site and included rare plant species. It is nearly always found on hill tops or mountain plateaus, and may have included some rock.

2.1 Tall Shrub

Shrubs made up 40-100% of the cover and shrub height was ≥1.3 meters. This class generally had a major willow component that was mixed with dwarf birch and/or alder, but could also have been dominated by nearly pure stands of alder. It was found most often in wet drainages, at the head of streams, or on slopes.

2.21 Willow/Alder Low Shrub
Shrubs made up 40-100% of the cover, shrub height was .25-1.3 meters, and ≥75% of the shrub cover was willow and/or alder.

2.22 Other Low Shrub/Tussock Tundra
Shrubs made up 40-100% of the cover, shrub height was .25-1.3 meters, and ≥35% of the cover was made up of tussock forming cotton grass *(Eriophorum vaginatum*). This class was found in extensive patches in flat, poorly drained areas. It was generally made up of cotton grass, ericaceous shrubs, willow and/or alder shrubs, other graminoids, and an occasional black spruce.

2.23 Other Low Shrub/Lichen
Shrubs made up 40-100% of the cover, shrub height was .25-1.3 meters, and ≥20% of the cover was made up of lichen. This class was found at mid-high elevations. The shrub species in this class were nearly always dwarf birch.

2.24 Other Low Shrub
Shrubs made up 40-100% of the cover, shrub height was .25-1.3 meters. This was the most common low shrub class. It was generally composed of dwarf birch, willow species, *Vaccinium* species, and ledum species.

2.31 Dwarf Shrub/Lichen
Shrubs made up 40-100% of the cover, shrub height was ≤.25 meters, and ≥20% of the cover was made up of lichen. This class was generally made up of dwarf ericaceous shrubs and *Dryas* species, but often included a variety of forbs and graminoids. It was nearly always found at higher elevations on hilltops, mountain slopes and plateaus. This class may be more open than the Other Dwarf Shrub class.

2.31 Other Dwarf Shrub
Shrubs made up 40-100% of the cover, the shrub height is ≤.25 meters. This class was generally made up of dwarf ericaceous shrubs and *Dryas* species, but often included a variety of forbs and graminoids, and some rock. It was nearly always found at higher elevations on hilltops, mountain slopes, and plateaus.

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

3.11 Lichen
Composed of ≥40% herbaceous species, ≤25% water, and ≥ 60% lichen species.

3.12 Moss
Composed of ≥40% herbaceous species, ≤25% water, and ≥60% moss species.

3.21 Wet Graminoid
Composed of ≥40% herbaceous species, ≤25% water, and where ≥60% of the herbaceous cover was graminoid, and ≥20% of the graminoid cover was made up of *Carex aquatilis*. This class represented wet or seasonally flooded sites. It was often present in stands too small to be mapped at the current scale.

3.31 Tussock Tundra
Composed of ≥40% herbaceous species, ≤25% water, where ≥50% of the herbaceous cover was graminoid, and ≥35% of the

graminoid cover was made up of tussock forming cotton grass. Tussock tundra often included ericaceous shrubs, willow and/or alder shrubs, forbs, bryoids, and other graminoids, and was usually found at lower elevations in flat, poorly drained areas.

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

3.34 Mesic/Dry Graminoid
Composed of ≥40% herbaceous species, ≤5% water, with ≥50% graminoids excluding tussock forming cotton grass and *Carex aquatilis*. This class was not common and was found generally only at high elevations.

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

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

4.1 Aquatic Bed
Aquatic vegetation made up ≥20% of the cover, and ≥20% of the vegetation was composed of plants with floating leaves. This class was generally dominated by pond lilies.

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

5.1 Clear Water
Composed of ≥80% clear water.

5.2 Turbid Water
Composed of ≥80% turbid water.

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

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

6.2 Rock/Gravel
At least 50% of the area was barren, ≥50% of the cover was composed of rock and/or gravel, and vegetation made up less than

20% of the cover. This class was most often made up of mountaintops or glaciers.

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

7.0 Urban
At least 50% of the area was urban. This class was not found in the study area.

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

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

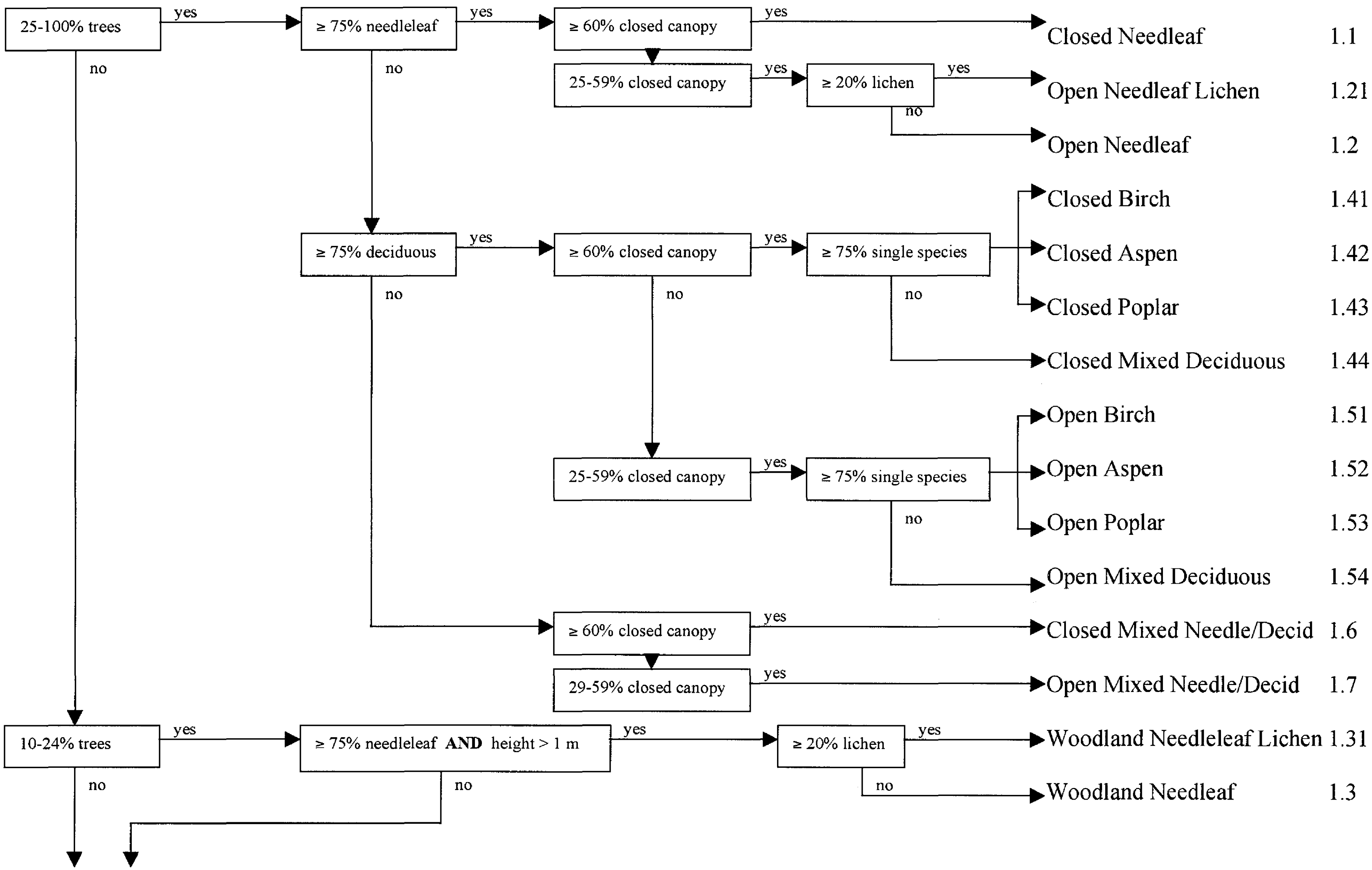
9.2 Cloud
At least 50% of the cover was made up of clouds.

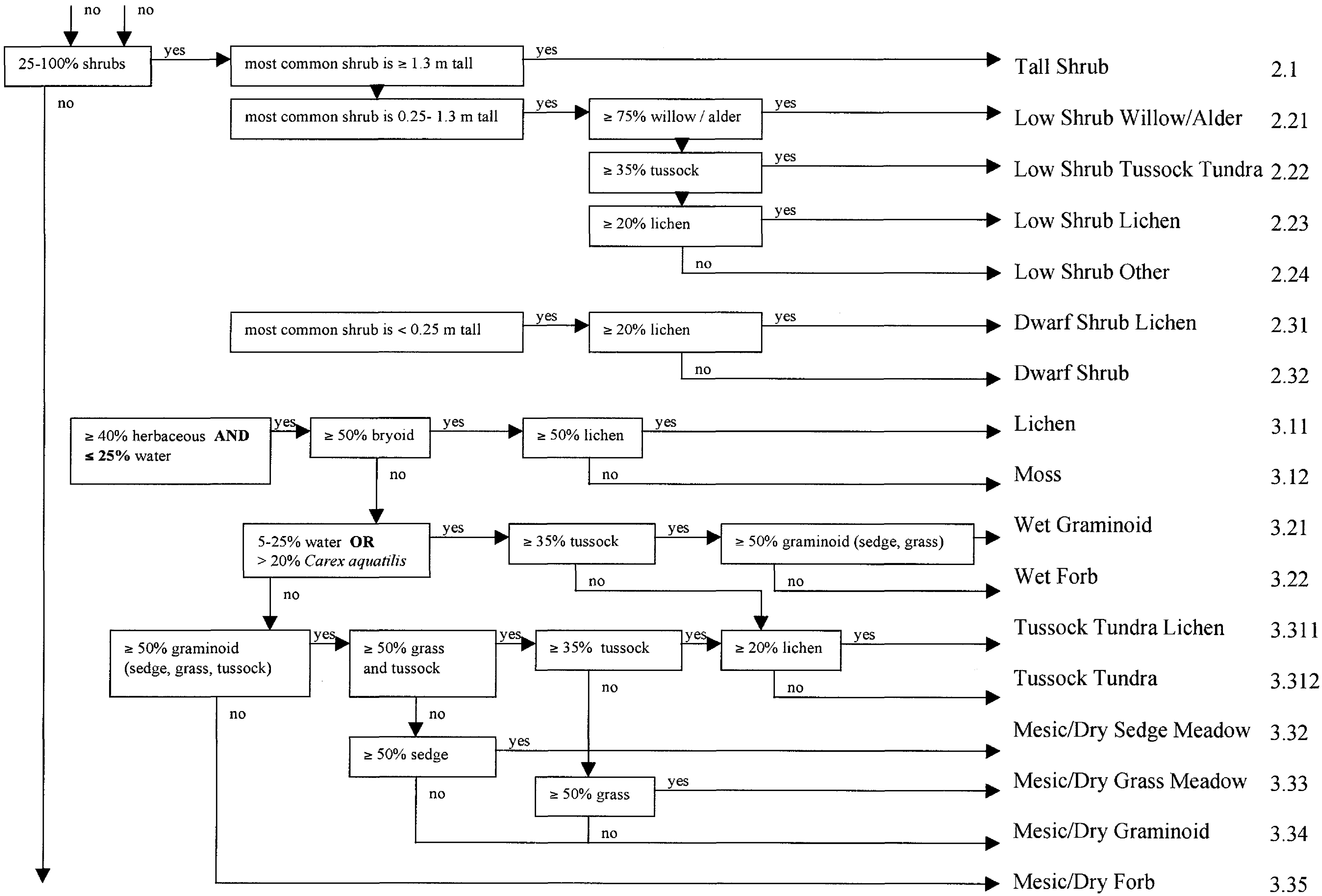
9.3 Cloud Shadow
At least 50% of the cover was made up of cloud shadows.

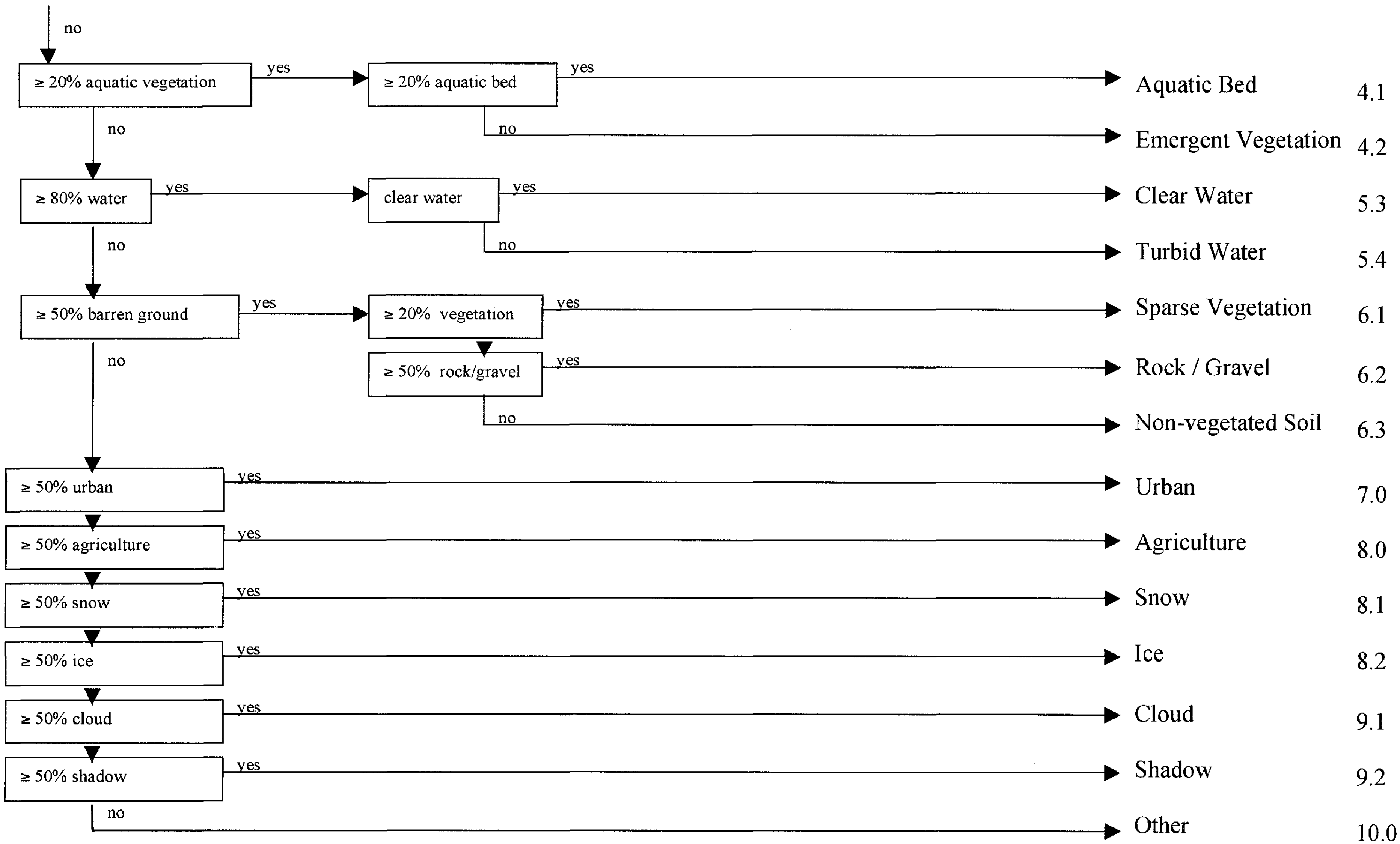
9.4 Terrain Shadow
At least 50% of the cover was made up of terrain shadows.

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

Appendix B. Earth cover classification decision tree.




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


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

Appendix C. Plant Species Occurrence and Percent Cover.

Symbol	Family	Species	Common	% Cover
BEGL	FABACEAE	BETULA GLANDULOSA	BIRCH,RESIN	10.12%
SAX_	SALICACEAE	SALIX SPP	WILLOW	9.49%
PIGL	PINACEAE	PICEA GLAUCA	SPRUCE,WHITE	8.78%
MOXX	MOSS	MOSS	MOSS	5.76%
LITT	LITTER	LITTER	LITTER	4.61%
EMNI	EMPETRACEAE	EMPETRUM NIGRUM	CROWBERRY,BLACK	4.26%
CAAQ	CYPERACEAE	CAREX AQUATILIS	SEDGE,WATER	4.24%
GRASS	GRASS	GRASS	GRASS	3.90%
ROCK	ROCK	ROCK	ROCK	3.73%
LEPA	ERICACEAE	LEDUM PALUSTRE	LABRADOR TEA	3.58%
SATRE	SALICACEAE	SALIX TREE	WILLOW TREE	3.55%
POTR10	SALICACEAE	POPULUS TREMULOIDES	ASPEN,QUAKING	3.13%
LIXX	LICHEN	LICHEN	LICHEN	2.99%
ALTE2	BETULACEAE	ALNUS TENUIFOLIA	ALDER,THIN-LEAF	2.62%
LITT2	LITTER STANDING	LITTER STANDING	STANDING DEAD	2.38%
GRAV	GRAVEL	GRAVEL	GRAVEL	2.36%
PIMA	PINACEAE	PICEA MARIANA	SPRUCE,BLACK	2.13%
CLWA	CLEAR WATER	CLEAR WATER	CLEAR WATER	2.04%
DRXX	ROSACEAE	DRYAS SPP	MOUNTAIN-AVENS	2.01%
ALTRE	BETULACEAE	ALNUS SPP TREE	ALDER, TREE	1.98%
CAXX	CYPERACEAE	CAREX SPP	SEDGE SPP	1.98%
CATE11	ERICACEAE	CASSIOPE TETRAGONA	BELL-HEATHER,ARCTIC	1.90%
VAUL	ERICACEAE	VACCINIUM ULIGINOSUM	BLUEBERRY,BOG	1.16%
ARRU	ERICACEAE	ARCTOSTAPHYLOS RUBRA	RED BEARBERRY	1.12%
POBA2	SALICACEAE	POPULUS BALSAMIFERA	POPLAR,BALSAM	0.99%
SADW	SALICACEAE	SALIX DW.	WILLOW, DWARF	0.85%
ARUV	ERICACEAE	ARCTOSTAPHYLOS UVA-URSI	KINNEKINNICK	0.83%
ALCR6	BETULACEAE	ALNUS CRISPA	ALDER,GREEN	0.56%
EQXX	EQUISETACEAE	EQUISETUM SPP	HORSETAILS SPP	0.56%
MYGA	MYRICACEAE	MYRICA GALE	SWEETGALE	0.54%
SHCA	ELAEAGNACEAE	SHEPHERDIA CANADENSIS	SOAPBERRY	0.51%
COCA13	CORNACEAE	CORNUS CANADENSIS	BUNCHBERRY,CANADA	0.43%
SAXX	SAXIFRAGACEAE	SAXIFRAGA SPP	SAXIFRAGE SPP	0.43%
NUPO	NYMPHAEACEAE	NUPHAR POLYSEPALUM	WATER LILY	0.40%
SAND	SAND	SAND	SAND	0.40%
GELI2	SANTALACEA	GEOCAULON LIVIDUM	TOADFLAX,NORTHERN	0.33%
BARE	BARE GROUND	BARE GROUND	BAR GROUND	0.32%
BEPA	BETULACEAE	BETULA PAPYRIFERA	BIRCH,PAPER	0.32%
CACA4	POACEAE	CALAMAGROSTIS CANADENSIS	REEDGRASS,BLUE-JOINT	0.28%
MUDX	MUD	MUD	MUD	0.28%
LUPS	FABACEAE	LUPINUS SPP.	LUPINE	0.25%
ERXX	CYPERACEAE	ERIOPHORUM SPP	COTTON-GRASS	0.22%
METR3	MENYANTHACEAE	MENYANTHES TRIFOLIATA	BUCKBEAN	0.17%
POFR4	ROSACEAE	POTENTILLA FRUTICOSA	CINQUEFOIL,SHRUBBY	0.16%
ROAC	ROSACEAE	ROSA ACICULARIS	ROSE,PRICKLY	0.16%
CHCA2	ERICACEAE	CHAMAEDAPHNE CALYCULATA	LEATHERLEAF	0.15%
POTR7	BETULACEAE	POPULUS TRICHOCARPA	BLACK COTTONWOOD	0.14%
DRDI2	ASPLENIACEAE	DRYOPTERIS DILATATA	WOODFERN,MOUNTAIN	0.11%

Symbol	Family	Species	Common	% Cover
PEFR5	ASTERACEAE	PETASITES FRIGIDUS	COLTSFOOT,ARCTIC SWEET	0.10%
EPAN2	ONAGRACEAE	EPILOBIUM ANGUSTIFOLIUM	FIREWEED	0.08%
POPA14	ROSACEAE	POTENTILLA PALUSTRIS	CINQUEFOIL,MARSH	0.08%
VEVI	LILIACEAE	VERATRUM VIRIDE	FALSE-HELLEBORE	0.08%
ECHO	ARALIACEAE	ECHINOPANAX HORRIDUM	DEVIL'S CLUB	0.05%
POTS	ROSACEAE	POTENTILLA SPP.	CINQUEFOIL	0.05%
SOSI2	ROSACEAE	SORBUS SITCHENSIS	MOUNTAIN ASH	0.05%
TUWA	TURBID WATER	TURBID WATER	TURBID WATER	0.05%
VIED	CAPRIFOLIACEAE	VIBURNUM EDULE	CRANBERRY,HIGHBUSH	0.05%
ASXX	FABACEAE	ASTRAGALUS SPP	VETCH	0.03%
GEPR4	GERANIACEAE	GERANIUM PRATENSE	CRANE'S-BILL,MEADOW	0.03%
POSP	POTAMOGETONACEAE	POTAMOGETON SPP.	PONDWEED	0.03%
HELA4	APIACEAE	HERACLEUM LANATUM	COW-PARSNIP	0.02%
EPXX	ONAGRACEAE	EPILOBIUM SPP	FIREWEED SPP	0.02%
EQSP	ONAGRACEAE	EPILIOBIUM SPP	FIREWEED	0.02%
MYAL	BORAGINACEAE	MYOSOTIS ALPESTRIS	FORGET-ME-NOT,ALPINE	0.02%
RISP	SAXIFRAGACEAE	RIBES SPP.	CURRANT, SPP.	0.02%
SAPL2	SALICACEAE	SALIX PLANIFOLIA	WILLOW,DIAMOND-LEAF	0.02%
SIAL2	BRASSICACEAE	SISYMBRIUM ALTISSIMUM	MUSTARD,TALL TUMBLE	0.02%
SPBE	ROSACEAE	SPIRAEA BEAUVERDIANA	SPIRAEA,BEAUVERED	0.02%
VAVI	ERICACEAE	VACCINIUM VITIS-IDAEA	CRANBERRY,LOWBUSH	0.00%
ACMI2	ASTERACEAE	ACHILLEA MILLEFOLIUM	YARROW,COMMON	0.00%
ANPO	ERICACEAE	ANDROMEDA POLIFOLIA	ROSEMARY,BOG	0.00%
ARAL3	ASTERACEAE	ARTEMISIA ALASKANA	SAGEBRUSH, ALASKA	0.00%
ARNS	ASTERACEAE	ARNICA SPP.	ARNICA	0.00%
ARSP	ERICACEAE	ARCTOSTAPHYLOS SPP.	BEARBERRY	0.00%
ASUM	FABACEAE	ASTRAGALUS UMBELLATUS	VETCH, HAIRY ARCTIC MILK	0.00%
CACA20	SCROPHULARIACEAE	CASTILLEJA CAUDATA	INDIAN-PAINTBRUSH,SPP	0.00%
CALA7	CAMPANULACEAE	CAMPANULA LASIOCARPA	BELLFLOWER,COMMON	0.00%
CASP	SCROPHULARIACEAE	CASTILLEJA	INDIAN-PAINTBRUSH	0.00%
CEAR4	CARYOPHYLLACEAE	CERASTIUM ARVENSE	CHICKWEED,MOUSE-EAR	0.00%
HEAL	FABACEAE	HEDYSARUM ALPINUM	SWEETVETCH,ALPINE	0.00%
HESPP	FABACEAE	HEDYSARUM SPP.	SWEETVETCH, SPECIES	0.00%
LIBO3	CAPRIFOLIACEAE	LINNAEA BOREALIS	TWINFLOWER	0.00%
LUAR	FABACEAE	LUPINUS ARCTICUS	ARCTIC LUPINE	0.00%
LYCO3	LYCOPODIACEAE	LYCOPODIUM COMPLANATUM	CLUBMOSS,TRAILING	0.00%
LYSP	LYCOPODIACEAE	LYCOPODIUM SPP.	CLUBMOSS	0.00%
MEPA	BORAGINACEAE	MERTENSIA PANICULATA	BLUEBELLS,TALL	0.00%
PECA2	SCROPHULARIACEAE	PEDICULARIS CAPITATA	LOUSEWORT,CAPITATE	0.00%
PELA	SCROPHULARIACEAE	PEDICULARIS LABRADORICA	LOUSEWORT,LABRADOR	0.00%
POBI5	POLYGONACEAE	POLYGONUM BISTORTA	BISTORT,MEADOW	0.00%
PODI2	ROSACEAE	POTENTILLA DIVERSIFOLIA	CINQUEFOIL,VARILEAF	0.00%
PTAQ	DENNSTAEDTIACEAE	PTERIDIUM AQUILINUM	FERN,BRACKEN	0.00%
RUAR	ROSACEAE	RUBUS ARCTICUS	RASPBERRY,ARCTIC	0.00%
RUCH	ROSACEAE	RUBUS CHAMAEMORUS	CLOUDBERRY	0.00%
SAAR4	SALICACEAE	SALIX ARCTICA	WILLOW,ARCTIC	0.00%
SAPH	SALICACEAE	SALIX PHLEBOPHYLLA	WILLOW,SKELETON-LEAF	0.00%
SESP	ASTERACEAE	SENECIO SPP	UNKNOWN	0.00%
SIAC	CARYOPHYLLACEAE	SILENE ACAULIS	CAMPION,MOSS	0.00%
SNOW	SNOW	SNOW	SNOW	0.00%

Symbol	Family	Species	Common	% Cover
SOSC2	ROSACEAE	SORBUS SCOPULINA	MOUNTAIN-ASH,GREENE'S	0.00%
SPHY	SPARGANIACEAE	SPARGANIUM HYPERBOREUM	BURREED,NORTHERN	0.00%
VASI	VALERIANACEAE	VALERIANA SITCHENSIS	VALERIAN,SITKA	0.00%
ZIEL2	LILIACEAE	ZIGADENUS ELEGANS	DEATHCAMAS,MOUNTAIN	0.00%

Appendix D. Tiekel River Watershed Accuracy Assessment Error Matrix

Reference Class

Map Class

	Open Ndlf.	Wdlnd. Ndlf.	Closed Decid.	Open Decid.	Closed Mixed	Open Mixed	Tall Shrub	Low Shrub	Dwarf Shrub	Wet Gram.	Aq. Bed	Sp. Veg.	Total	User's	Low Limit	Upper Limit	Kappa	Variance
Cl. Ndlf.	1												1	**0**	-------	-------	-------	
Opn Ndlf	**31**	2	1			1							35	**88.57**	77.46	99.68	0.8517	
Wdld Ndlf		**13**	1				1			1			16	**81.25**	60.87	100	0.7857	
Cld Decid			**7**		1		1						9	**77.78**	48.4	100	0.7594	
Op. Decid.				**3**									3	**100**	93.33	100	1	
Cld Mix		1	1		**4**	1	1						8	**50**	12.85	87.15	0.4783	
Op. Mix	1	1			1	**7**							10	**70**	39.6	100	0.68	
Tall Shrb			1				**6**	1					8	**75**	42.49	100	0.7313	
Low Shrb		1		1			1	**25**	2	1			31	**80.65**	66.1	95.2	0.7597	
Dwf Shrb								1	**15**				16	**93.75**	80.64	100	0.9291	
Wet Grmd								1		**4**			5	**80**	40.94	100	0.7898	
Aq. Bed										1			1	**0**	-------	-------	-------	
Sp. Veg.				1									1	**0**	-------	-------	-------	
Total	33	18	11	5	6	9	10	28	17	7	0	0	144					
Producer's	**93.94**	**72.22**	**63.64**	**60**	**66.67**	**77.78**	**60**	**89.29**	**88.24**	**57.14**	-------	-------		**79.86**				
Low L	85.19	50.42	33.39	13.06	25.62	48.4	27.64	77.12	71.75	17.62	-------	-------			72.96			
Upper L	100	94.02	93.89	100	100	100	92.36	100	100	96.66	-------	-------				86.76		
Kappa	.8517	0.7857	0.7594	1.00	0.4783	0.6800	0.7313	0.7597	0.9291	0.7898	-------	-------					.7652	
Variance																		0.0015

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:

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

Ducks Unlimited, Inc.
3074 Gold Canal Drive
Rancho Cordova, CA 95670-6116
916-852-2000