DUCKS UNLIMITED CANADA
WESTERN BOREAL FOREST INITIATIVE

PASQUIA PROJECT

LANDCOVER INVENTORY AND MAPPING
WATERBIRD INVENTORY
WATER QUALITY SAMPLING
TRADITIONAL ECOLOGICAL KNOWLEDGE
FRAMEWORK FOR ECOSYSTEM MONITORING

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Executive Summary

The Western Boreal Forest located west of the Manitoba/Ontario border is second only to the Prairie Pothole Region in terms of continental waterfowl breeding effort and has been ranked number three in priority of the 26 most important waterfowl habitat areas in North America by Ducks Unlimited. Industrial activity including oil and gas, forestry, mining and hydro electricity generation as well as agriculture has greatly expanded in the Western Boreal Forest. The influence of these activities, and the potential consequences of climate change, on boreal wetland ecosystems remain largely unknown. In 1997 Ducks Unlimited Canada (DUC) established the Western Boreal Forest Initiative (WBFI) to help answer questions about boreal wetlands and the influence of associated land-use activities. DUC has identified the need to establish a project area in Manitoba and Saskatchewan to complement the work currently being conducted in Alberta, Northeastern BC, the NWT and the Yukon. The proposed Pasquia Project has been selected to represent the southeastern portion of the Boreal Plains Ecozone and straddles the Manitoba/Saskatchewan border. This report outlines initial components proposed including landcover inventory and mapping, waterbird and water quality inventory, and Traditional Ecological Knowledge. Projected costs and a discussion on a framework for ecosystem monitoring are also provided.

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I BACKGROUND

The Western Boreal Forest located west of the Manitoba/Ontario border is second only to the Prairie Pothole Region in terms of continental waterfowl breeding effort (Figure 1). This important area has been ranked number three in priority of the 26 most important waterfowl habitat areas at risk in North America (Ducks Unlimited, 1994). An extensive review of technical and scientific papers pertaining to wetlands, waterbirds and their habitats in the circumpolar boreal zone revealed a significant regional information gap exists (Foote, 1998). A large area of the Western Boreal Forest is surveyed annually by the US and Canadian Wildlife Services. These surveys have shown that, for reasons yet to be determined, populations of common boreal nesting species such as lesser scaup and scoters are declining. As a result, these species are currently the emphasis of research projects (Austin et al., 2000; Sea Duck Joint Venture, n.d.).

Figure 1. Western Boreal Forest, Ecozone Boundaries and Major Centres.

Industrial activity including petroleum exploration and development, forestry, mining and hydro electricity generation as well as agriculture expansion has greatly expanded in the Western Boreal Forest. The influence of these activities, and the potential consequences of climate change on boreal wetland ecosystems remain largely unknown. In 1997 Ducks Unlimited Canada (DUC) established its Western Boreal Forest Initiative (WBFI) to help answer questions about boreal wetlands and the influence of associated land-use activities. The Boreal and Taiga Plains Ecozones have been identified as the first priority area for study. Projects have been initiated at Norman Wells (NWT), Southern Lakes (NWT), Fort Nelson (BC) and Utikuma Lake, the Peace – Athabasca Delta and Fort McMurray (Alberta).

Partnerships have been established with industry, government, universities and aboriginal peoples who share Ducks Unlimited's goal of protecting and maintaining these important boreal wetland systems. DUC believes this is consistent with and complementary to Government and Industry's goal of sustainable and ecosystem based management.

One of the greatest information needs is an accurate inventory of wetlands, riparian areas and associated uplands. Since existing landcover inventory and mapping information is often unreliable, non-current or incomplete, a key component of the WBFI is landcover inventory and mapping. Other key objectives include waterbird and water quality inventories on associated wetlands and directed research on the ecology, hydrology and disturbance of boreal wetlands.

Manitoba and Saskatchewan are well recognized as contributing significantly to all flyways in North America, particularly their prairie and parkland regions. However, unlike these southern regions, boreal wetlands including those of the Saskatchewan River Delta provide more consistent water conditions and provide significant breeding, moulting and staging habitat for large numbers of waterbirds.

II PASQUIA PROJECT AREA

The Taiga Shield, Boreal Shield and Boreal Plain Ecozones represent the boreal forest in Manitoba and Saskatchewan. The proposed Pasquia Project (Figure 2) is located on the southeast edge of the Boreal Plains Ecozone and will cover approximately 7.4 million hectares (18 million acres). The Boreal Plains Ecozone extends as a wide band from the Peace River country of British Columbia to the southeastern corner of Manitoba. This ecozone is not bedrock controlled, has few bedrock outcrops and considerably fewer lakes than the Boreal Shield (Ecological Stratification Working Group, 1995).

The Pasquia Project was selected because it represents ecoregions not currently included in existing WBFI project areas. Pasquia includes portions of six ecoregions including the Mid-Boreal Uplands, Mid-Boreal Lowlands, Boreal Transition, Aspen Parkland, Lake Manitoba Plain, and the Interlake Plain. Notable features include the Saskatchewan River Delta (Mid-Boreal Lowlands), the Porcupine Mountains, the Pasquia Hills, the Duck Mountains (Mid-Boreal Uplands) and portions of Lake Winnipegosis (Interlake Plain).

The climate is typified by cold winters and moderately warm summers and is strongly influenced by continental climatic conditions. The mean annual temperature ranges between -2°C to 2°C. Mean summer temperatures range between 13°C to 15.5°C. Mean winter temperatures range from -17.5°C to -11°C. Mean annual precipitation is 625 mm (Ecological Stratification Working Group, 1995).

Figure 2. Proposed Pasquia Project Area, Western Boreal Forest Initiative.

Forest cover is predominantly coniferous with black spruce, jack pine, white spruce, and tamarack being principle species. Hardwoods, particularly trembling aspen, white birch, and balsam poplar are well represented and are often mixed with the conifers. Hardwood abundance increases in the southern portions of the ecozone and also within the Saskatchewan River Delta where willow species are locally abundant.

Landforms and soils in the Boreal Plain Ecozone are underlain by Cretaceous shales. The topography varies from nearly level gently rolling plain but also includes areas of hummocky to kettled glacial moraine and lacustrine deposits. The surface materials are usually deep and tend to mask the underlying topography. The soils of this ecozone are largely Luvisols. These grade southward into Black Chernozems and northward into Brunisols and Organics (Ecological Stratification Working Group, 1995).

Wetlands cover between 25–50% of the Boreal Plains Ecozone (Ecological Stratification Working Group, 1995). Within the Pasquia Project bogs and fens with deep organic soils are particularly well represented in the Mid-Boreal Lowlands Ecoregion. Other wetlands include emergent marshes, shallow lakes, and channel and shore wetlands. Additional features include the freshwater coastal wetlands along the shore of Lake Winnipegosis and the Saskatchewan River Delta, which is recognized as being one of the largest inland river deltas in North America.

Characteristic mammals include, moose, woodland caribou, white-tailed deer, wapiti (elk), coyote, wolf, fox, black bear, marten, mink, fisher, lynx, beaver and muskrat. Over 200 bird species are estimated to occur including permanent and seasonal residents and species that pass through during their migration (Repap Manitoba Inc, 1996). Representative species include spruce and ruffed grouse, bald eagle, merlin, great gray owl, and numerous warbler and woodpecker species. Waterbirds are common, including colonial nesting species such as Franklin's gull, black tern, double-crested cormorant, American white pelican and great–blue heron. Breeding populations of common loon, red-necked and eared grebe and several species of shorebirds including spotted sandpiper, lesser yellowlegs, and marbled godwit are also present. The endangered piping plover is also known to occur within the Manitoba portion of the proposed project area.

Specific to waterfowl, 18 species are known to nest including mallard, blue-winged teal, ring-necked duck, lesser scaup and white-winged scoter. In addition, millions of waterfowl and waterbirds utilize the Pasquia Project during migration. The Saskatchewan River Delta and the coastal marshes of Lake Winnipegosis are recognized important staging areas for migratory waterbirds.

Land use activities include forestry, agriculture, hydroelectric power generation, mineral exploration, aggregate extraction, hunting, trapping, fishing, tourism and traditional aboriginal activities. The primary industrial land use is forestry and Forest Management License Agreements have been established with Tolko Industries Ltd., Louisiana Pacific Canada and Saskfor MacMillan (Weyerhaeuser Canada). These companies conduct the majority of forest management in the area although a number of smaller independent quota holder operations are also ongoing. Hydroelectric power generation is significant both upstream and downstream of the Saskatchewan River Delta. Agriculture is most prominent in the southern portion of the project area along the forest fringe and immediately west of The Pas.

III LANDCOVER INVENTORY AND MAPPING

Overview

Ducks Unlimited Inc. has developed and utilizes a Geographic Information System (GIS)-based Thematic Mapper (TM) Satellite landcover inventory and mapping program that provides an accurate digital inventory of all landcover classes. Over the past 10 years, DU and partners have used this method to inventory and map over 48 million hectares (120 million acres) of boreal and tundra habitat in Alaska, providing an invaluable management tool to resource managers. This protocol uses extensive field verification with helicopters to increase accuracy assessment of final products and is now accepted as a statewide earth cover procedure (pers comm John Payne, Bureau of Land Management, Anchorage, AK).

A Landsat TM satellite scene covers 3.2 million hectares (8 million acres) and has a spatial resolution of 30m x 30m (pixel size). Up to six bands of information are combined to produce spectrally unique signatures that are classified via extensive field verification. For forested areas, late summer scenes are purchased to capture maximum biomass production. An unsupervised classification provides up to 30 cover classes from which up to 30 field verification sites per cover class are chosen for helicopter ground truthing. Two-thirds of the sites are used to process the image (classification), while the remaining 1/3 are used for independent cover-type accuracy assessment. The rigid and standardized protocols result in individual cover class accuracies of 80-95% (pers comm Dr. Fritz Reid, DU Sacramento). This process has been found to be very economical with costs per hectare ranging from $0.06-$0.08 (pers comm John Payne).

The classification is hierarchical in structure, starting at treetop and progressing downward through brush, shrub, grass etc. DU will meet with interested parties and potential partners to develop a landcover classification scheme for the proposed Pasquia Project. A detailed technical description of methods is included in Appendix I. This project will result in accurate, economical, digital map products available to all partners for various regional planning and management activities. In a GIS environment, other geo-referenced data sets can be readily imported and analyzed (i.e., wildlife population data; trapline information; parks and protected areas; fires; forest harvest; roads; etc.).

A standardized classification scheme for categorizing all landcover classes will be developed to meet the needs for a wide range of applications. Fieldwork is targeted for early August 2001. Helicopters will be used to collect vegetation data and to assess the accuracy of the final map classification. The final products will include GIS and raster data layers, field data, and hard copy maps of the land cover classification. A report will document the methods used and include a GIS demonstration of the digital products.

Data Acquisition

The most recently available Landsat TM (5 and 7) images of the project area will be acquired to produce the landcover map. Existing forest inventory data, Digital Elevation Models (DEM), aerial photography, orthophotography and other ancillary data will be identified and acquired to aid in the classification and accuracy assessment processes.

Image Pre-processing

Upon receipt, the Landsat TM imagery will be checked for quality and proper registration and then archived for permanent storage. DU will devise a set of classification definitions, decision rules and schemes that are compatible with current standards for use with satellite imagery, field data and other ancillary data. Field sites will be located using an unsupervised classification approach on the satellite data. Aerial photographs and other information including forest inventory data will be used to assist in the field site selection. Once these sites are selected, they will be plotted over the imagery and their geographic centers stored in a field Geographic Positioning System (GPS). A custom data entry form and digital database will be developed and placed on a laptop computer for inputting site information while in the field. The digital database program provides a user-friendly interface to maximize efficiency, access to digital photographs of each site, and the capability to generate statistics.

Field Verification

A five-person crew will perform field verification. The crew will consist of a pilot, biologist, recorder, navigator and an alternate. The navigator will run the GPS equipment and interpret the field maps. The biologist will possess extensive knowledge of the vegetation in the area. The recorder will verify the vegetation the biologist sees and record those types, percentages and other pertinent information about each field site. The alternate will also handle field logistics and data entry. A ground crew will perform initial sampling to verify and standardize the classification and sampling methods. After an initial on-the-ground training session, the remaining sites will be collected via helicopter to determine the percentage of each species and overall land cover class. Ground verification will be used as needed for sites where the vegetation is difficult to identify and/or species are uncertain.

Image Classification

After collecting the field data, the information will be quality checked for errors and entered into a digital database. The field site attributes will then be related to a GIS (Arc/Info) coverage of the field sites. A subset of the field data will be set aside from the classification for accuracy assessment. A combined supervised/unsupervised technique will be used to classify the imagery into land cover categories.

Accuracy Assessment

If needed, additional accuracy sites will be photo-interpreted to supplement field data. The accuracy assessment sites will then be compared with the classification to produce an error matrix. The matrix will be used to generate standard accuracy assessment statistics for each cover type.

Change Detection

Historic Landsat TM pre-1990 images will be used to perform change detection analysis. A proven change detection technique, such as image differencing, will be used to extract areas of change from the imagery. The result will be a map of change areas indicated by a gain or loss of spectral reflectance. The areas of change will be identified using ancillary data such as aerial photography and existing base maps. Using both the historic Landsat TM image(s) and the recent Landsat TM image(s), fire scars will be identified and mapped. This historic fire scar information will be invaluable in modeling succession and fire patterns. Other significant changes that will be detected include forest harvest, agricultural expansion and natural succession.

Final Products

The final products will consist of a digital land cover dataset of the TM Landsat Scene(s), hard copy maps, all field site data, a detailed documentation of the analysis methods and products, metadata, an ArcView demonstration of the products developed and a Compact Disk of the final products. Fieldwork will be carried out during summer 2001 with final products prepared by the end of 2002. (*the length of time may need to be extended depending on the extent of the project). A detailed budget for the Landcover Inventory and Mapping is outlined in Table 1.

Table 1. Projected budget landcover and mapping

Components	Estimated Cost*
Project Work plan - design work plan, production schedule, coordination, supervision	$10,332
Image Pre-processing - data acquisition (TM image/ancillary data) - archive TM scenes, develop classification system - unsupervised classification, isolate unique spectral clusters - homogenous polygon selection, GPS centers delineation - custom data entry field work form - database program and decision tree development - develop map compositions, produce field maps - field meeting, supervision	$68,714
Field Verification - helicopter rental (20 days @ $6,500 per day) - helicopter fuel ($16,262 + $8500 for relocation) - airfare, logistics, room & board ($20,500) - staff time, field data collection/supervision ($47,000)	$231,483
Image Classification - compile field data, organize, digitize new sites, link attributes, accuracy assessment, site selection - seed training area, perform unsupervised and supervised classification, run cluster magic process for TM scene - remove clouds/cloud shadow/terrain shadow - interactive processing; isolate good classes; reprocess confused classes - image editing/aggregate classes - integrate with DEM/ancillary data - supervision	$137,742
Accuracy Assessment - summary of accuracy assessment sites against final classification - perform contingency table analysis to determine accuracy	$12,018
Mosaic With Two Classifications - mosaic with full scene with additional scene classification - edit seam between classification	$9,735
Subpixel Analysis - additional field days to collect data for subpixel analysis - subpixel analysis	$23,430
Change Detection - scene acquisition, image differencing, classify areas of change	$49,143
Final Production - create ArcView project for demos and data organization; document analysis methods and products - prepare map composition and final classification - generate Metadata, prepare final report, back-up data, meetings	$30,701
Equipment/Supplies - GPS Receivers, CD's, plotting materials, miscellaneous equipment	$3,798
TOTAL	**$577,096**

***DUC staff time = $41,200**

IV WATERBIRD INVENTORY

Wetland habitats distributed throughout the Pasquia Project area are important as production, molting and migratory staging areas. A waterbird inventory will be conducted to evaluate the use of selected wetland areas by waterfowl and other wetland-dependent waterbirds. This component of the proposed work plan will allow a broad scale analysis of the density and variability of waterbird use of wetland systems within the project area. Wetland habitats used by species of local or regional interest (e.g. cranes, loons, shorebirds) will also be specifically identified through this inventory. Collectively, these surveys will provide an assessment of wetlands capability within the area identified in the project area, and an indication of the importance of the various wetland types to breeding and post-breeding waterbirds. An understanding of the variability and range of waterbird use at a variety of sites is complementary to site and landscape scale interpretation of the potential influence of resource management activities.

Specific intervals of interest include the breeding, brood rearing, molting, and spring and fall pre-migration staging periods. Given the unique attributes contained in the Pasquia Project (both isolated basins and large wetland complexes), a combination of basin-specific (e.g. Arner et al., 1999) and wetland complex (e.g. Pollard et al., 2000) survey techniques will be required, as per established WBFI techniques (Ducks Unlimited Canada, n.d.). The protocols employed will be consistent with, and similar to, those employed for surveys carried out at the other WBFI sites. Survey protocols used are generally consistent with annual USFWS/CWS surveys (U.S. Fish and Wildlife Service/Canadian Wildlife Service, 1987; King, 2000).

Identification of the value of wetland type and specific sites will be accomplished using four helicopter aerial surveys during spring/summer (breeding and brood surveys), two fixed-wing aerial surveys in spring (spring staging), two fixed-wing aerial surveys in mid-summer (molting), and three fixed-wing aerial surveys in early fall (migration/molting/staging surveys). A detailed budget for the waterbird inventory is outlined in Table 2.

This inventory will be initiated in 2001 using the unsupervised classification of the TM Scene for site selection. Waterbird surveys will employ a subset of wetlands (approximately 242 basins) identified prior to the surveys using a proportional random sampling scheme, stratified by Ecodistrict. Historical inventory information and aerial photography will assist in site selection. In addition to wetlands selected for the basin-specific surveys, five to eight wetland complexes (e.g., Lake Winnipegosis, Cumberland, Redearth, Saskeram, Reader-Root, Helldiver, Tom Lamb, Cedar Lake) will be flown using a pre-established line transect survey scheme. Additional sites identified as warranting specific attention (e.g., Belanger, Pelican, Swan, Red Deer, Mawdesley, North and South Moose, Driftwood and Lamb lakes; (Leitch, n.d.) may also be included pending discussion with partners and availability of funds.

Species of interest, including all waterfowl, colonial waterbirds (e.g., gulls, terns) and other wetland-dependent avian species (e.g., loons) will be recorded as encountered. Other species of interest as determined by the project partners will also be recorded on surveys. Geo-referencing of waterbird survey data will be accomplished using flight following software (Fugawi® or ArcView Tracking Analyst®) and incorporated as point data.

This summarized digital data layer will then be compatible with the landcover mapping and inventory product previously identified. A detailed technical report summarizing this monitoring effort will be produced in spring 2002, following completion of the first year of the 3-year waterbird survey program.

Table 2. Projected budget waterbird inventory

Inventory Component	Estimated Cost*
Survey Design / Pre-field Preparation - staff time (5,200)	**$6292**
Breeding Pairs (4 surveys) Helicopter (2 surveys) - helicopter rental (63,900) - fuel (9712) - staff time: (12,496) - travel, room, board (8094) Fixed Wing (2 surveys) - aircraft rental (12,650) - fuel (3036) - staff time (7920) - travel, room, board (3168)	**$120,976**
Brood Surveys (2 surveys) Helicopter - helicopter rental (69,870) - fuel (10,620) - staff time (14,000) - travel, room, board (10,275)	**$104,765**
Molting Surveys (2 surveys) Fixed Wing - aircraft rental (12,650) - fuel (3036) - staff time (7920) - travel, room, board (3168)	**$26,774**
Staging Surveys (3 surveys) Fixed Wing - aircraft rental (36,225) - fuel (8694) - staff time (12,144) - travel, room, board (10,692)	**$67,755**
Data Transcription / Data Entry - staff time (48,800)	**$48,800**
Project Supervision /GIS Analysis/Reports - staff time (20,000)	**$20,000**
Miscellaneous - software, misc. equipment (6292)	**$6292**
1 YEAR TOTAL	**$401,654**
3 YEAR TOTAL ($401,654 x 3 years)	**$1,204,962**

*** DUC Staff time = $128,480/year**

V Wetland Productivity Inventory

An initial wetland productivity inventory will be undertaken on a sub-sample of sites selected for the waterbird survey program. Analysis will include characterization of pH, conductivity, salinity, nutrients (NH_4, NO_2, NO_3, TP and SRP), primary productivity (Chlorophyll *a*), alkalinity, carbonate and bicarbonate, and dominant ions (e.g., Ca, Mg, K, Na, Cl and SO_4) in surface waters across the Pasquia Project area. This sampling regime will assist in defining the relative productivity of basins within the project plus help to develop the linkages between wetland type, productivity and waterbird use. It will also assist in determining the range of variability in basins located within the project area. Collection and analysis of isotope samples will further assist in determining the relative importance of groundwater versus surface water inputs to these systems. This in turn will allow development of hypotheses on the effects of various land-use practices on wetland water quality and productivity. Collectively, interpretation of these data will provide an indication of how surficial or landscape features (hydrology, relief, till deposits) are linked with regional geology, and how these features may affect wetland productivity. If these interactions are occurring, the work outlined above should provide evidence at which scale these interactions occur (local versus intermediate or regional versus Ecozone or Western Boreal Forest-wide).

Samples will be taken using a helicopter equipped with floats, and will generally occur coincidental (during the same week as) to the brood survey to minimize costs associated with travel, meals and lodging. In addition to the brood survey crews (who will collect water samples), one additional field staff will be required on site to assist with sample collection and to facilitate on-site sample preparation and analysis. Partial sample processing will be undertaken as samples are collected (pH, conductivity, salinity, sample filtration) with the bulk of the analysis occurring at facilities located at a cooperating agency with a suitable laboratory (e.g. University). Sample volume required will vary from one to two litres depending on specific analyses to be undertaken, and will be collected at one site per wetland. Individual wetlands to be sampled will be selected among the waterbird sites sampled during the pair and brood periods. Site selection will be completed in consultation with University cooperators, DUC staff, GIS specialists and project partners.

Preliminary work has been conducted at one site on the Boreal Plain (Utikuma Lake, AB) and a second on the Taiga Plain (Ft. Nelson, BC). Data from these recently completed surveys suggest a lack of consistency between water quality parameters for wetlands in boreal shield environments and Boreal and Taiga Plain sites underlain by glacial till. Evaluation of results from the Pasquia Project location will allow comparison with other areas exhibiting differing geological histories and landscape framework (inter- and intra-Ecoregion wetland comparisons). This data will also provide a benchmark for evaluating the value and potential of wetlands for waterbirds in the context of the specific Ecoregions of interest, and the Western Boreal ecosystem in general.

Final products generated and made available in digital format to cooperating agencies will include proofed data files identifying site location (latitude/longitude and UTM) and results of the water quality analysis. These products will be cross-referenced to individual basins (using unique basin identifiers) for ease in linking bird use statistics with water quality data. Additional work beyond the initial scoping study (e.g. evaluation of inter-annual variability, more precise estimation of within-wetland class variation) may be further developed pending data analysis and discussion of the results obtained with the project participants and DU. A detailed budget for the wetland productivity inventory is outlined in Table 3.

Table 3. Projected budget wetland productivity inventory

Inventory Component	Estimated Cost *
Field Expenses - helicopter (18,755) - fuel (2758) - staff time (2420) - contractor (3630) - travel, room, board (3872) - misc. equipment/shipping (1573)	**$33,008**
Project Supervision/Analysis/Report - staff time (6776) - analysis (9680)	**$16,456**
Total	**$49,464**

*** DUC Staff Time = $9196**

VI TRADITIONAL ECOLOGICAL KNOWLEDGE

The collection of information in the form of Traditional Ecological Knowledge (TEK) is proposed. TEK is the knowledge that Aboriginal people have accumulated over generations of intimate contact with all aspects of local ecosystems, including plants, animals and natural phenomena. It includes knowledge of animal behavior, seasons and cycles, and the interrelationships that exist among life-forms (Natural Resources Canada, 1997). This information will compliment the landcover inventory and mapping and waterbird and water quality inventories.

TEK can be all encompassing to include information such as medicinal plants, moose calving and fish spawning areas and spiritual sites. For the purpose of this project TEK will include non-aboriginal local knowledge and will focus on information related to wetlands, waterbirds and other wetland dependant wildlife. This will include documenting important seasonal waterbird areas, important areas for specific waterbird species (e.g. scoter, scaup or colonial nesting species) and key areas for other wetland dependant wildlife (e.g. moose, beaver, muskrat).

TEK information will be collected in cooperation with the First Nation and non-aboriginal communities located within the Pasquia Project area. Community elders will be selected for interviews to generate the information of interest. This information will be documented, mapped and integrated into GIS for future use. The manner that the information is collected, shared and available for future use will be discussed and determined with each community. A detailed budget for the TEK inventory is outlined in Table 4.

Table 4. Projected budget traditional ecological knowledge

TEK Components	Estimated Cost*
Planning - community contacts/liaison, meetings, selection of consultant (4840)	**$4840**
Field Work /Information Gathering - consulting fees (36,300) - supervision (1452)	**$37,752**
Final Report - GIS support/analysis, consultant/community liaison (7260)	**$7260**
Total	**$49,852**

***DUC staff time = $13,552**

VII FRAMEWORK FOR ECOSYSTEM MONITORING

DUC is establishing a number of WBFI project areas as long-term assessment sites. This provides the opportunity to monitor a variety of ecosystem components over time. The landcover classification and mapping, waterbird and water quality inventory are important ecosystem components that constitute the necessary first step to achieve this goal. In addition, change detection analysis on historical and future TM satellite images provides a means of documenting landscape changes over time.

The GIS-based TM satellite landcover classification and mapping scheme provides the ideal framework from which to build additional elements into an ecosystem-monitoring program. Although this scale of classification and mapping may not be suitable for more detailed monitoring projects, other digital inventory data can be easily nested within the TM Satellite landcover inventory since the data are stored in a geo-referenced environment. Examples include provincial forest inventory data, orthophotography, radarsat data etc. Other data can also be readily imported and analyzed over time including wildlife population data, forest harvest and other land-use activities.

VIII BUDGET SUMMARY

Table 5 outlines the projected budget summary for the initial component of the proposed Pasquia Project. Note the landcover inventory component is projected over a two-year period. Waterbird surveys will occur over a three-year period. Projected DUC staff time costs are $134,800.

Table 5. Pasquia Project budget summary

Project Component	Estimated Cost*
Landcover Inventory and Mapping	$577,096 (over 2 years)
Waterbird Inventory	$401,654**
Wetland Productivity Inventory	$49,464 (year one only)
Traditional Ecological Knowledge	$49,852 (year one only)
Total	**$1,078,066**

***DUC staff time = $192,428 ($449,388 over 3 years)**
**** Annual cost. Surveys will be scheduled for 3 years**

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APPENDICES

APPENDIX I

AN ALASKAN EXAMPLE OF DUCKS UNLIMITED'S TM LAND CLASSIFICATION 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.

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.

The classification scheme consisted of 10 major categories and 27 subcategories (Table 1). A classification decision tree and written description was 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 2). 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).

Table 1. 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**

* indicates that these classes are not found in the final classification.

Table 2. The classes mapped and assigned value for the Steese-White Mountains project.

VALUE	CLASS NAME
1	Closed Needleleaf
2	Open Needleleaf
3	Open Needleleaf Lichen
4	Woodland Needleleaf
5	Woodland Needleleaf - Lichen
6	Woodland Needleleaf – Moss
11	Closed Birch
12	Closed Mixed Deciduous
13	Open Deciduous
16	Closed Mixed Needleleaf/Deciduous
17	Open Mixed Needleleaf/Deciduous
20	Tall Shrub
21	Low Shrub
22	Low Shrub – Lichen
23	Low Shrub – Tussock Tundra
24	Dwarf Shrub
25	Dwarf Shrub Lichen
32	Wet Graminoid
41	Mesic/Dry Sedge Meadow
43	Mesic/Dry Graminoid
50	Tussock Tundra
51	Tussock Tundra – Lichen
60	Aquatic Bed
70	Water
72	Snow
80	Sparsely Vegetated
81	Rock/Gravel
92	Cloud
93	Cloud Shadow
94	Terrain Shadow
95	Other
96	Fire (Burned)

DESCRIPTION OF CLASSES

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. A description of each class for the Steele-White Mountains Project follows:

1.0 Forest

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.

1.1 (1) Closed Needleleaf

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

1.2 (2) Open Needleleaf

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

1.21 (3) Open Needleleaf Lichen

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

1.3 (4) Woodland Needleleaf

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

1.31 (5) Woodland Needleleaf Lichen

From 10-24% of the cover is trees, ≥75% of the trees are needleleaf, and ≥ 20% of the understory is lichen. This class is more common than Open Needleleaf Lichen. The lichen often occurs in small round patches between trees.

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.

1.5 (13) Open Mixed Deciduous

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

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

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

2.0 Shrub

The tall and low shrub classes are dominated by willow species, dwarf birch (*Betula nana* and *Betula 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.

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.

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.

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.

2.31 (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.

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.

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.

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.

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.

4.0 Aquatic Vegetation

The aquatic vegetation is divided into Aquatic Bed and Emergent classes. The Aquatic Bed class is dominated by plants with leaves that float on the water surface, generally pond lilies (*Nuphar polysepalum*). The Emergent Vegetation class is composed of species that are partially submerged in the water, and may include freshwater herbs such as Horsetails (*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.

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.

5.1 (72) Snow

Composed of ≥50% snow.

5.2 (73) Ice

Composed of ≥50% ice.

5.3 (70) Clear Water

Composed of ≥80% clear water.

5.4 (71) Turbid Water

Composed of ≥80% turbid water.

6.0 Barren

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

6.1 (80) Sparse Vegetation
At least 50% of the area is barren, but vegetation makes up ≥20% of the cover. This class is often found on riparian gravel bars, on rocky or very steep slopes and in abandoned gravel pits. The plant species are generally herbs, graminoids and bryoids, and may include rare species.

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

6.3 (82) Non-vegetated Soil
At least 50% of the area is barren, ≥50% of the cover is composed of mud, silt or sand, and vegetation makes up less than 20% of the cover. This type is generally found along shorelines or rivers. 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 SW 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.

(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.

IMAGE PROCESSING

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

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

The field sites were delineated using an unsupervised clustering and seeding technique to initially generate spectrally unique areas within the study area. These spectrally unique areas were then refined and selected as sample sites for the fieldwork using aerial photography and a decision tree of the earth cover classification. Whenever possible, training sites were grouped in clusters in order to reduce the amount of ferrying time between sites. A tally of estimated number of field sites per class was kept until all of the classes were adequately sampled throughout the project area. The coordinates of the center points (collected in degrees decimal minutes, UTM, NAD27) of the field sites were generated and uploaded into a Y-code Military GPS unit (PLGR) to be used while field sampling. 1:63,360 scale quadrangle color infrared plots of the Landsat TM data were also produced for the placement of additional field sample sites and for navigational purposes.

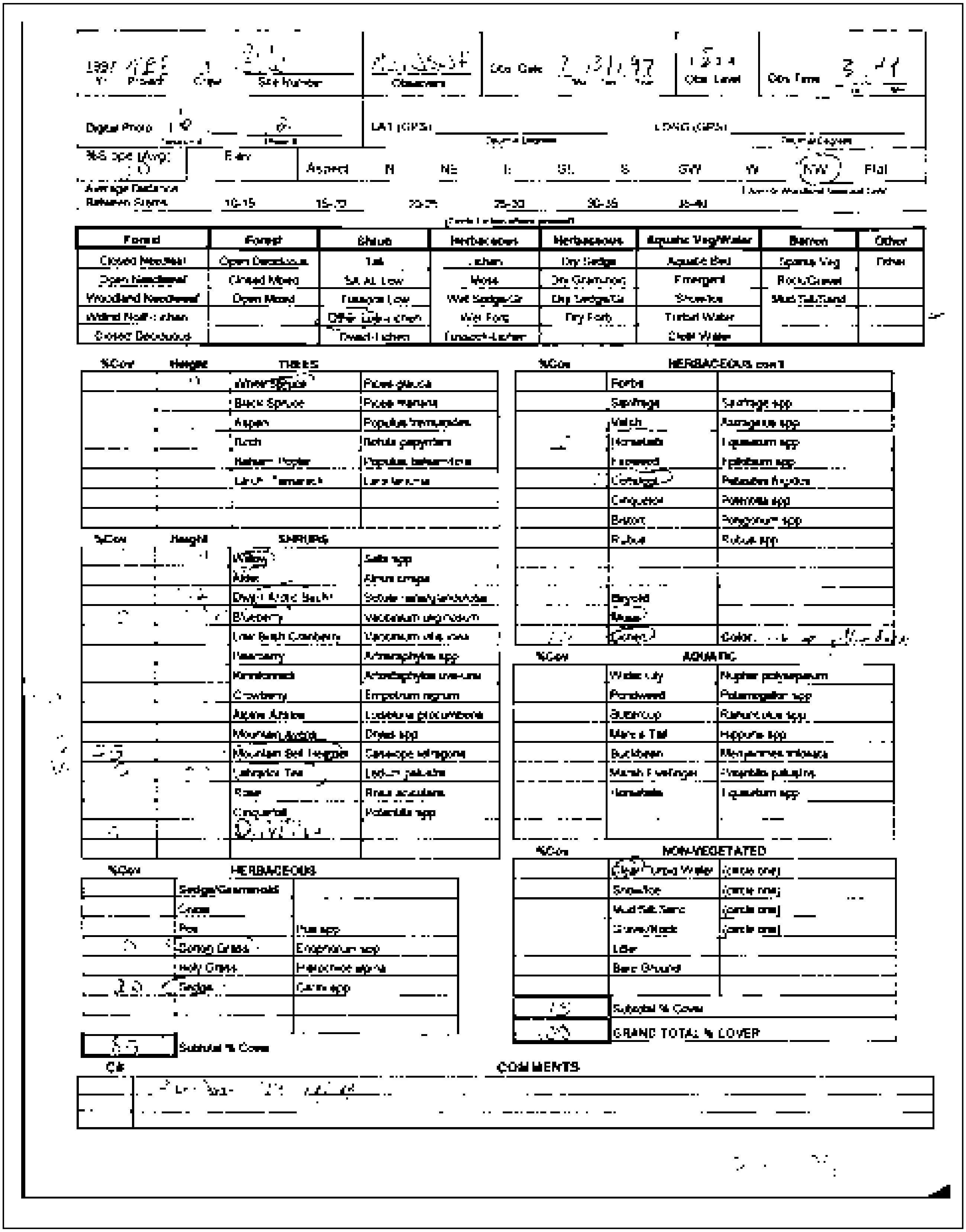
FIELD VERIFICATION

The purpose of field data collection is to assess, measure, and document the on-the-ground vegetation variation within the project area. This variation will then be correlated with the spectral variation in the satellite imagery during the image classification process. Low-level helicopter surveys are a very effective method of field data collection since a much broader area can be covered with an orthogonal view from above, similar to a satellite sensor. Helicopter surveys are sometimes the only alternative in Alaska due to 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 1). A five-person helicopter crew was designated to perform the field assessment. Each crew consisted of a pilot, biologist, recorder, navigator, and alternate. The navigator, who runs the GPS equipment and interprets the satellite image derived field maps, occupies the co-pilot seat. The biologist, the person most knowledgeable regarding the vegetation, and the recorder, who records species percentages and other data on the field form, occupy the remaining two seats in the back of the helicopter. The alternate is responsible for flight following, data entry of the previous day's work, and substituting in case of sickness. On the first day of fieldwork, sampling was performed by landing the aircraft on the ground to verify and standardize the classification and sampling techniques. After the first day, the majority of the sites were observed without landing the helicopter to determine the percent cover for each species and an overall earth cover class. Ground verification was performed when identification of dominant vegetation and/or species was uncertain.

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.

Figure 1. Field data collection form.


Yr Project Crew Site Number Observers Obs. Date Obs. Level Obs. Time

Digital Photo LAT (GPS) LONG (GPS)

% Slope (Avg) 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

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	
		Other Low-Lichen	Wet Forb	Dry Forb	Turbid Water		
Closed Deciduous		Dwarf-Lichen	Tussock-Lichen		Clear Water		

TREES: White Spruce (Picea glauca); Black Spruce (Picea mariana); Aspen (Populus tremuloides); Birch (Betula papyrifera); Balsam Poplar (Populus balsamifera); Larch Tamarack (Larix laricina)

SHRUBS: Willow (Salix spp); Alder (Alnus crispa); Dwarf Arctic Birch (Betula nana/glandulosa); Blueberry (Vaccinium uliginosum); Low Bush Cranberry (Vaccinium vitis-idaea); Bearberry (Arctostaphylos spp); Kinnikinnick (Arctostaphylos uva-ursi); Crowberry (Empetrum nigrum); Alpine Azalea (Loiseleuria procumbens); Mountain Avens (Dryas spp); Mountain Bell Heather (Cassiope tetragona); Labrador Tea (Ledum palustre); Rose (Rosa acicularis); Cinquefoil (Potentilla spp)

HERBACEOUS: Sedge/Graminoid; Grass; Poa (Poa spp); Cotton Grass (Eriophorum spp); Holy Grass (Hierochloe alpina); Sedge (Carex spp); Subtotal % Cover

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

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)

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

COMMENTS

All observed species and taxa were identified to the extent possible from a helicopter. The ability to identify species was dependent on attitude 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 were entered into a customized database (DUFF) designed by the BLM and DU and programmed by GeoNorth. The relational database is powered by SQL Anywhere 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 2). 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 is also compared to the class that the biologist assigned the site as an additional check for data integrity; the calculated class was the class name assigned to the site. Figure 3 provides a summary of the number of sites from both Path 68 and 69 respectively. An ARC/INFO polygon coverage was generated for each site collected in the field. The pertinent attributes from the database were then related to the ARC/INFO coverage. A new attribute (AAflag) was added to the coverage indicating if the site was to be used as a training area or for accuracy assessment. Two separate coverages were created using the 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 were stored in separate files. Only the coverage with the training sites was used in the classification process.

CLASSIFICATION

Every image is unique and presents it's own special problems in the classification process. The approach that was used in this project has been used and proven to be successful over many years (Figure 4). The image processor's site-specific experience and knowledge in combination with high quality ancillary data can overcome image uniqueness to produce a high quality and extremely useful product. Therefore, the image processor should be actively involved in the field data collection and hopefully have first hand knowledge of every training site.

Generation of New Bands

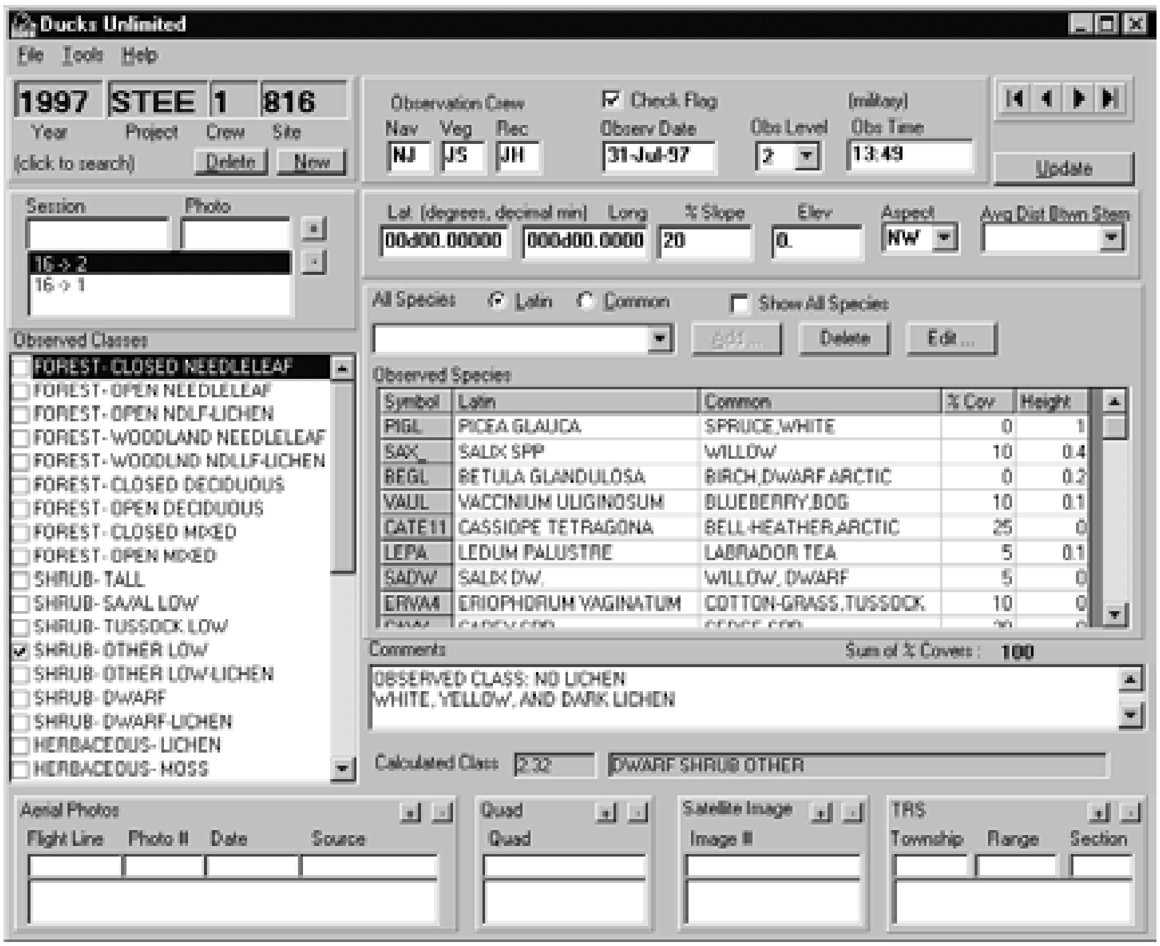
New bands can be derived from the raw data by simple operations like dividing one band by another or complex statistical computations like principle components transformations. The idea behind generating new bands is that unique information will be derived from the process and will enhance the classification. The possibilities of generating new bands from the raw imagery are infinite.

Figure 2. The customized database and user interface for field data entry (DUFF).

Field Site STEE816 – Dwarf Shrub Other

High site photo.

Low site photo.



DUFF screen capture.

Figure 3. Example of DUFF Program Showing Number of Sites by Cover Class.

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

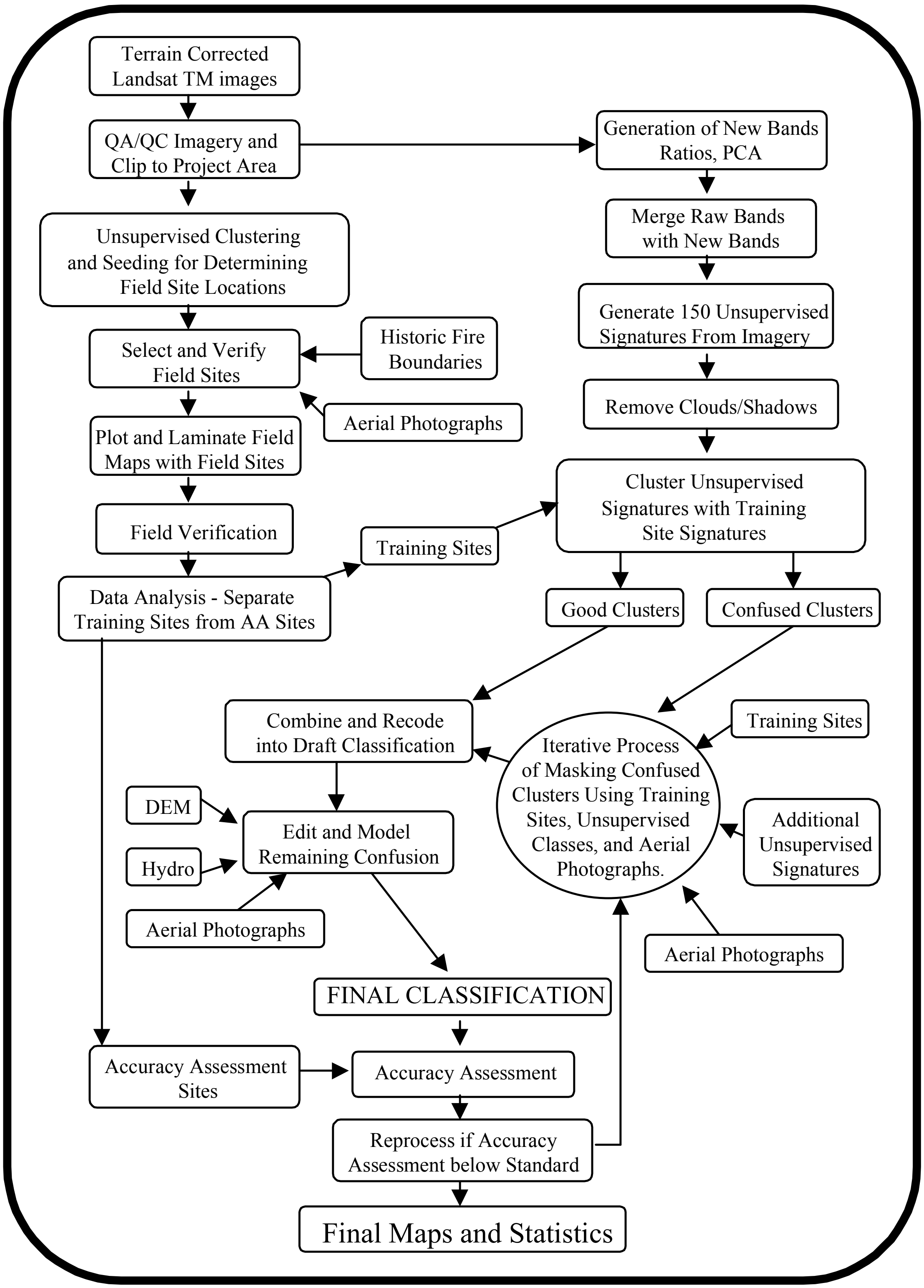
View Statistics

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 4. Image Processing Flow Diagram.



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 subset with the six raw bands to produce a seven band file to be used in the classification. The thermal band was not used in the classification.

Removal of Cloud and Shadows

The clouds and cloud shadows are removed from the image before the classification is started. This process eliminates the confusion that is caused between the clouds and cloud shadows and other vegetation types. They are removed using an unsupervised classification and manual on-screen editing. The clouds are separated from the shadows and the two classes are recoded to their respective class number. The cloud/shadow layer is then combined with the rest of the classified image during the last step in the classification process.

Seeding process

The field sites that were designated as training areas were “seeded” (generate statistics from the imagery) in ERDAS Imagine using spectral bounds as the limit for seed growth. The standard deviations of the seeded areas were kept to approximately 3 and all seeded areas were required to be over 15 pixels (approximately 3.75 acres) in size. Along with the field training areas, additional “seeds” were generated for the water. These classes were easily recognized on the imagery and aerial photography. The output of the seeding process in Imagine is a signature file that contains all of the statistics for the training areas. The signature file is then used in the modified supervised/unsupervised classification.

Generation of Unsupervised Signatures

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

Modified Supervised/Unsupervised Classification

A modified supervised/unsupervised classification approach (Chuvieco and Congalton 1988) was used for the classification. This approach uses a statistical program to group the spectrally unique signatures from the unsupervised classification with the signatures of the supervised training areas. In this way, the spectrally unique areas were labeled according to the supervised training areas. This approach is an iterative process because all of the supervised signatures are not going to cluster perfectly with the unsupervised signatures the first time. The unsupervised signatures that match well with the supervised signatures were inspected and removed from the classification process. The remaining confused clusters were grouped into general categories (forest, shrub, non-vegetation, etc.) and re-run through the process. This process was repeated until all of the spectral classes were adequately matched and labeled. This classification approach provides three major benefits: (1) it aids in the labeling of the unsupervised classes by grouping them with known supervised training sites; (2) it helps identify classes that possess no spectral uniqueness, (i.e. training sites that are spectrally inseparable); and (3) identifies areas of spectral reflectance present in the imagery that have not been represented by a training site.

Editing and Modeling

The final step of the classification process was to model the remaining confusion and make final edits. There may be a few problem areas in the classification that the spectral data can not separate, but a simple model can take care of the problem. For instance, water may be classified where there are terrain shadow effects, which can be easily modeled out of the classification using DEM's. In the end, there may be a few problems in the classification which cannot be addressed with either spectral separation or modeling. When this happens, the image processor must use aerial photographs and on screen digitizing to remedy the situation

ACCURACY ASSESSMENT

The purpose of quantitative accuracy assessments is the identification and measurement of map errors. There are two primary motivations for accuracy assessment: to understand the errors in the map (so they can be corrected), and to provide an overall assessment of the reliability of the map (Gopal and Woodcock, 1992). There are many factors to consider when designing an accuracy assessment. These include how to determine the sample size, how to allocate this sample, and which sampling scheme to employ. Congalton (1991) suggests that 50 samples be selected for each map category as a rule of thumb. This value has been empirically derived over many projects. A second method of determining sample size is using the multinomial distribution and specifying a given confidence in the estimate (Tortora 1978). The results of this calculation tend to favorably agree with Congalton's rule of thumb. Once the sample size is determined, it then must be allocated among the categories in the map. A strictly proportional allocation is possible. However, the smaller categories in a real 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. (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. The matrix is a square array of numbers set out in rows and columns that express the number of sites assigned to a particular category in the reference data relative to the number of sites assigned to a particular category in the classification. The columns usually represent the reference data while the rows indicate the classification (Lillesand and Kiefer, 1994). An error matrix is an effective way to represent accuracy in that the individual accuracy of each category are plainly described along with both the errors of inclusion (commission errors) and errors of exclusion (omission errors) present in the classification. A commission error occurs when an area is included in a category it does not belong. An omission error is excluding that area from the category in which it does belong. Every error is an omission from the correct category and a commission to a wrong category. It is important to note that the error matrix and accuracy assessment is based on the assumption that the reference data is 100% correct. This assumption is not always true, especially when the reference data is derived from aerial photographs.

In addition to clearly showing errors of omission and commission, the error matrix can be used to compute overall accuracy, producer's accuracy, and user's accuracy (Story and Congalton 1986). Overall accuracy is simply the sum to the major diagonal (i.e., the correctly classified samples) divided by the total number of samples in the error matrix. This value is the most commonly reported accuracy assessment statistic. Producer's and user's accuracies are ways of representing individual category accuracy instead of just the overall classification accuracy. 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 that agreement that might be contributed solely by chance matching of the two maps. The result of the KAPPA analysis is the KHAT statistic. Landis and Koch (1977) characterized the possible ranges for KHAT into three groupings: a value greater then 0.80 (i.e., 80%) represents strong agreement; a value between 0.40 and 0.80 (i.e., 40 - 80%) represents moderate agreement; and a value below 0.40 (i.e., 40%) represents poor agreement.

In addition to calculating KHAT, confidence intervals can be calculated using the approximate large sample variance. The large sample variance can then be used to test if the agreement between the classification and reference data is significantly different from zero or a random classification with the Z statistic. The Z statistic in the Kappa analysis can also be used to test if a classification is significantly different from another classification. A Z statistics of 1.98 or less means that the classification is not significantly different from a random classification at the 99% confidence level. 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 of 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 an associated label (class name). This file is used in the class listing to compare reference and classified values. The third input is a list of class names, total number of sites, and total number of classes used in the classification and defines the error matrix.

After the three files are input, the program generates a listing of accuracy assessment sites along with the assigned class value for both the reference data and classification. The class value that is assigned for the classification is based on the majority rule (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 helps to identify any non-map errors in the accuracy assessment such as registration problems and labeling errors.

The next step in the program calculates the error matrix and KAPPA statistics for the classification. The program generates an error matrix based on the reference value and the classification value (majority class) that was generated in the previous step. The error matrix was then used to compute the KAPPA statistics. The error matrix and KAPPA statistics were used to report the final accuracy of the classification and are produced for the final report.

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