

**Ducks Unlimited, Inc.**

**U.S. Fish and Wildlife Service**

Kenai National Wildlife Refuge

**Kenai Peninsula**

**Earth Cover Classification**

**BLM-Alaska Technical Report 29**

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April 2002

U.S. Department of the Interior

Bureau of Land Management

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**Partners**

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

**Cover**

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

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Kenai Peninsula

Earth Cover Classification

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U.S. Department of the Interior

Bureau of Land Management

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# Abstract

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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 for the Kenai Peninsula. Two Landsat TM satellite scenes (Path 69, Row 17 and 18 acquired July 10, 1989) were used to classify the project area into 16 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 609 field sites during a 13 day field season from July 25, 1998 through August 6, 1998. Approximately 12% (73) 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 project cooperators (Alaska Department of Fish and Game, Alaska Department of Natural Resources, U.S. Forest Service, U.S. Fish and Wildlife Service, National Park Service, Kenai Borough, and Ducks Unlimited.

The following deliverable products resulted from this project:

Final land cover classification of the Kenai Peninsula study area;

1989 unclassified Landsat TM imagery;

Digital database of the field data;

ArcView project showcasing the products;

Final project report/User’s Guide.

The overall accuracy of the mapping categories was 81%. An overall accuracy of 89% and 94.5% were realized with a +/- 5% and 10% variation in interpretation of the accuracy assessment site data respectively.

# Introduction

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

During the past decade, tremendous change has occurred on the Kenai Peninsula. The immense population increase that has occurred since the 1980’s has resulted in previously unseen impacts on the natural resources of the peninsula. In addition, the relatively recent exploitation of the timber resource of the peninsula has prompted concerns over land use management, wildlife habitat preservation and restoration, and other resource management issues. Recently, a study of the environmental impacts of the cumulative effects of logging on the peninsula has been called for by several organizations. Meanwhile, the timber resource on the peninsula is itself in jeopardy as insect damage threatens the quality of some existing forest stands.

Each of these issues has heightened an already great awareness of the need for a comprehensive land use management planning strategy for the entire Kenai Peninsula. A key component of such a planning strategy is the availability of current spatial land cover/land use information. Unfortunately, no current, comprehensive, and detailed land information is available for the peninsula. Ducks Unlimited and Spatial Solutions, Inc. proposes to utilize digital spatial imagery to assist the various state, federal, local, and private entities on the Kenai Peninsula in developing a comprehensive land cover map for the peninsula. In addition, the project could include the incorporation of historic digital spatial imagery with more recent imagery for the purpose of examining the spatial trends in land use and land cover change during the past decade on the peninsula.

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

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

The Bureau of Land Management (BLM) – Alaska and Ducks Unlimited, Inc. (DU) have been cooperatively mapping wetlands and associated uplands in Alaska using remote sensing and GIS technologies since 1988. The initial mapping projects that were undertaken focused on mapping only certain wetland types such as deep marsh, shallow marsh, and aquatic classes (Ritter et al. 1989). It soon became apparent that mapping the entire landscape was more cost effective and useful to both managers and habitat studies. Over the years, many refinements have been made to both the techniques of collecting field information and classifying the imagery. The BLM is currently in the process of mapping all of their lands in Alaska using this methodology. Many other agencies in Alaska (i.e. National Park Service, 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 for mapping and wildlife habitat analysis.

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

## Project Objective

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

## Project Participants

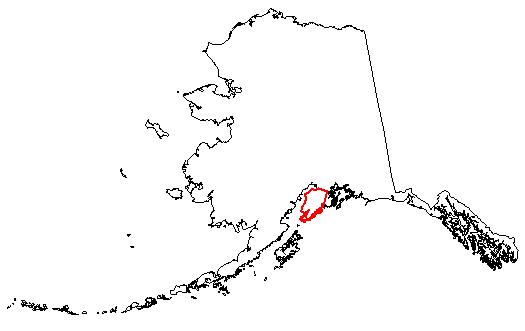
The project was administered by individuals from the Alaska Department of Fish and Game, Alaska Department of Natural Resources, USFS-Chugach NF, US Fish and Wildlife Service-Kenai National Wildlife Refuge, Kenai Borough, and the National Park Service-Kenai Fjords National Park, Robb Macleod (DU), and Jeff Campbell (Spatial Solutions, Inc.). The field work was accomplished by Jeff Campbell (SS), Tom Stephenson (ADF&G), Kelly Shea (USF&WS), Gino DelFrate (ADF&G), Dominique Collette, Grant Hildabrandt (ADF&G), and John Delapp (USFS). The pilot for the project Jonathan Laravee from QuickSilver Air, Fairbanks, AK. Jeff Campbell (SS) performed the image processing and accuracy assessment analysis.

## Project Area

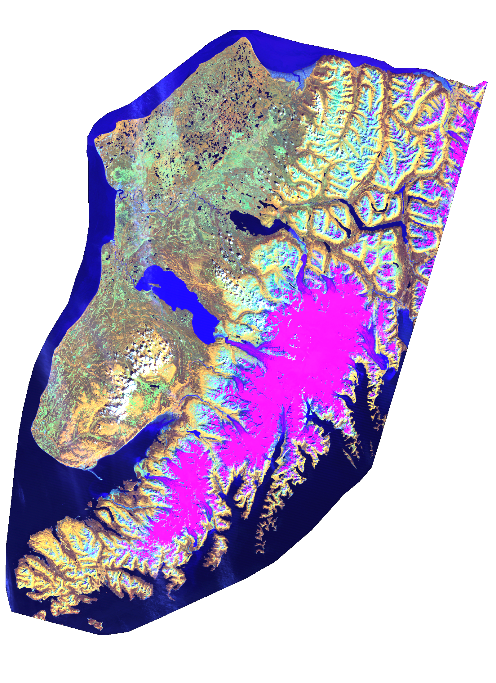
The project area (Figure 1) encompasses the entire Kenai Peninsula with the exception of the Sargent Icefield north and east of Seward and south and east of Whittier. The Turnagain Arm of Cook Inlet provided the northern boundary of the study area. All other portions of the Kenai Peninsula were mapped through this project including Kenai Fjords National Park, all of the western peninsula to Cook Inlet, and south to the Chugach Islands. Each of these land marks can be identified on the satellite imagery views presented in Figure 2. The study area is covered by the majority of 2 Landsat TM scenes, Paths 69, Row 17 and 18.

Elevations range from sea level to over 6000 feet in the mountains along the boundaries of the Harding Ice Field. Major vegetative communities include open and woodland Black Spruce *(Picea mariana)* and White Spruce *(Picea glauca)* forest, closed and open Sitka *Spruce (Picea sitchensis)* and Mountain Hemlock *(Tsuga mertensiana)* forest, open and closed alder stands, herbaceous and ericaceous shrub muskegs, tussock tundra, low shrub tundra, and dwarf shrub tundra. The climate is extreme, with winter temperatures reaching as low as –50 degrees F and occasionally exceeding 90 degrees F in the summer.

The project area includes the political boundaries of the Chugach National Forest, Kenai Fjords National Park, Kenai National Wildlife Refuge, and the Kenai Borough as well as lands administered by the Alaska Department of Natural Resources and Alaska Department of Fish and Game.



**Figure 1.** Study area for the kenai peninsula mapping project



**Figure 2.** Satellite imagery used for the Kenai Peninsula Earth Cover mapping project.

## Data Acquisition

Two Landsat TM scenes were purchased to cover the project area. The scenes were purchased from EROS Data Center in the

UTM projection, zone 5 and were terrain corrected. The scenes were: Path 68, Row 17 and Row 18 acquired on July 10, 1989 (Figure 2). Field data was collected over a 13 day period from July 25, 1998 to August 6, 1998. The ancillary data used in this project included: National Aeronautics and Space Administration (NASA) 1:60,000 aerial photographs (color infrared transparencies from 1980,1981,1982,1984, and 1986), United States Geological Survey’s (USGS) 1:63,360 and 1:250,000 scale Digital Elevation Models (DEM); USFS 1:24:000 scale aerial phtographs covering the Chugach National Forest (natural color prints from 1990, 1991, and 1993); enlarged aerial photographs covering the Kenai National Wildlife Refuge (color infrared prints from 1983 and 1987); and draft map comments received from project cooperators.

## Methods

The first step in any mapping project is the definition of a classification system that categorizes the features of the earth to be mapped. The system is derived by the anticipated uses of the map information and the features of the earth that can be discerned with the data (e.g., satellite imagery, aerial photography, or field information) being used to create the map. A classification system has two critical components: (1) a set of labels (e.g., forest, shrub, water); and (2) a set of rules, or a system of assigning labels. It is important that the set of rules of the system for assigning labels be both mutually exclusive and totally exhaustive (Congalton 1991). In other words, any area to be classified should fall into one and only one category or class and every area should be included in the classification. Until recently, the classification system for the BLM/DU earth cover projects was tailored to the needs of the area being studied. As the projects expanded in size and as other cooperators (i.e. U.S. Fish and Wildlife Service and National Park Service) began mapping and sharing data, the need to standardize the classification system arose so that data could be shared and utilized on a state wide basis. At the BLM Earth Cover Workshop in Anchorage from March 3-6, 1997, a classification system based on an existing vegetation classification (Viereck et al. 1992) was designed to address these needs. The goal of the classification system was to (1) develop an earth cover classification system for the state of Alaska that can be used in large regional mapping efforts, and (2) build consensus for the system among multiple agencies so a common integrated database can be built for the state of Alaska.

Due to budgetary constraints, the classification scheme utilized for this mapping effort was comprised of an aggregated subset of the original mapping classes. A classification decision tree (Appendix B) and written description was developed in order to eliminate any confusion in the classification. Each class was assigned a value or code that was used for the final classified file. The classification scheme utilized for the Kenai Peninsula mapping project is presented in Table 1.

**Table 1.** Classification scheme developed and utilized for the Kenai Peninsula Earth Cover Mapping Project.

1. **Forest**
2. Closed Needleleaf
3. Open Needleleaf

1.3 Woodland Needleleaf

1.4 Closed Deciduous

1.5 Open Deciduous

1.6 Closed Mixed Needleleaf/Deciduous

1.7 Open Mixed Needleleaf/Deciduous

1. **Shrub**

2.1 Riparian Alder/Willow

2.21 Alder

2.22 Willow

2.23 Other Shrub

1. **Herbaceous**
2. **Water**
3. Snow/Ice
4. Clear Water
5. Turbid Water
6. **Barren**
7. Barren/Sparsely Vegetated

7.0 **Urban**

8.0 **Agriculture**

1. **Cloud/Shadow**
2. Cloud
3. Shadow
4. **Other**

**Table 2.** Classes mapped and assigned value for the Kenai Peninsula project.

|  |  |
| --- | --- |
| Class Value | Class Name |
| 1 | Clear Water |
| 2 | Turbid Water |
| 3 | Snow / Ice |
| 4 | Barren / Sparsely Vegetated |
| 5 | Closed Conifer Forest |
| 6 | Open Conifer Forest |
| 7 | Woodland Conifer Forest |
| 8 | Closed Deciduous Forest |
| 9 | Open Deciduous Forest |
| 10 | Closed Mixed Forest |
| 11 | Open Mixed Forest |
| 12 | Alder |
| 13 | Riparian Alder / Willow |
| 14 | Willow |
| 15 | Other Shrub |
| 16 | Herbaceous |

## 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.

**1.0 Forest**

The predominant needleleaf species generally found are White Spruce and Black Spruce, Mountain Hemlock, and Sitka Spruce. White spruce tends to occur on warmer sites with better drainage, while black spruce dominates poorly drained sites. Mountain Hemlock and Sitka Spruce tend to occur primarily along slopes on the Chugach N.F., at the lower elevation slopes within Kenai Fjords N.P., as well as along slopes and drainages on the south side of Kachemak Bay and along the saltwater shoreline and interior drainages of the southern peninsula. The conifer classes include both White and Black Spruce, Mountain Hemlock, and Sitka Spruce.

The predominant deciduous tree species generally found are Paper Birch, Aspen and Cottonwood. Cottonwoods are found only in river valleys and on alluvial flats. Willow and Alder occasionally 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 as well as in the flats of the Swanson River area and the region southwest of Chickaloon Bay.

**1.1 (6) Closed Needleleaf Forest**

At least 60% of the cover is trees, and >75% of the trees are needleleaf trees. Since the earth cover mapping was completed to reflect 1989 coniditions, closed conifer sites are shown to be more abundant on the earth cover map than currently exist due to the more recent impact of beetle activity. The majority of the closed conifer class, however, is comprised of stands of Hemlock and Sitka Spruce; although substantial stands of closed White Spruce are present in the region south of Tustemena Lake.

**1.2 (7) Open Needleleaf Forest**

25-59% of the cover is trees, and >75% of the trees are needleleaf. This class is very common throughout the interior of the Kenai Peninsula. The Open Conifer class is comprised primarily of White and Black Spruce stands. A wide variety of understory plant groups are present, including low and tall shrubs, forbs, grasses, sedges, mosses, and lichens.

**1.3 (8) Woodland Needleleaf Forest**

From 10-24% of the cover is trees, of which >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.

**1.4 (9) Closed Deciduous Forest**

At least 60% of the cover is trees, of which >75% of the trees are deciduous. They occur 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 Aspen, Paper Birch, or Cottonwood.

**1.5 (10) Open Deciduous Forest**

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

**1.6 (11) Closed Mixed Forest**

At least 60% of the cover is trees, but neither needleleaf nor deciduous trees make up >75% of the tree cover. This class is uncommon and found mainly along major river channels.

**1.7 (12) Open Mixed Forest**

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 and in transition areas between stands of pure conifer and deciduous forest. Also, this class is more common in many of the older regenerating burn areas in the interior of the peninsula. Young stands of birch intermingled with regenerating spruce trees result in the Open Mixed Forest classification.

**2.0 Shrub**

The shrub classes are dominated by Alder *(Alnus spp.),* Willow species, Dwarf Birch (*Betula nana* and *Betula glandulosa*), *Ledum* species, and *Vaccinium* species.

This mapping classification scheme attempts only to differentiate pure or nearly pure stands of alder or willow. Mosaics of alder and willow as well as shrub communities comprised of shrub species other than alder or willow are captured in the Other Shrub class. This class includes ericaceous shrubs populating many muskeg regimes as well as dwarf shrub communities found in the alpine and sub-alpine regimes.

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 (13) Riparian Alder / Willow**

Shrubs make up 40-100% of the cover. Alder and/or Willow make up at least 60% of the total shrub cover. The site is in a riparian corridor.

**2.21 (12) Alder**

Shrubs make up 40-100% of the cover. Alder makes up at least 80% of the total shrub cover. These stands of pure or nearly pure alder occur throughout the peninsula on hillsides and non-forested flats. The Alder class is by far the most common shrub class within the study area.

**2.22 (14) Willow**

Shrubs make up 40-100% of the cover. Willow makes up at least 80% of the total shrub cover. These stands of pure or nearly pure willow occur most extensively in the Caribou Hills region south and west of Tustemena Lake. Other occurrences of pure stands of Willow are often present in stands too small to be effectively and consistently mapped using satellite imagery.

**2.23 (15) Other Shrub**

Shrubs make up 40-100% of the cover. Shrub species compositions do not meet the

requirements for the pure Alder or Willow classes described above. This class contains Dwarf Birch, Willow species, *Vaccinium* species, and *Ledum* species. This class also includes dwarf ericaceous shrubs and *Dryas* species, but often includes a variety of forbs and graminoids, and some rock. The Other Shrub class occupies a wide variety of regimes from wet muskeg sites to dry hillsides to dwarf shrub communities in alpine and sub-alpine regions.

**3.0 (16) Herbaceous**

The vegetation types 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.

Other typical sites are composed of >40% herbaceous species where >50% of the herbaceous cover is sedges, and between 5 and 25% water, occur where >50% of the herbaceous cover is sedges, or >20% of the site is Carex aquatilis. This class generally occurs in one of three general regimes: 1) low, barely sloping areas, and represents wet or seasonally flooded sites; 2) sloping hillsides intermingled and/or transitioning with/from stands of alder and other taller shrubs; or 3) sparsely vegetated alpine and sub-alpine regions that are composed primarily of lichen and small forbs.

**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.

**5.2 (3) Snow/Ice**

Composed of >50% snow and/or ice.

**5.3 (1) Clear Water**

Composed of >80% clear water.

**5.4 (2) Turbid Water**

Composed of >80% turbid water.

**6.0 Barren**

**6.1 (4) Barren / Sparsely Vegetated**

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.

At least 50% of the area is barren, but vegetation often can make up >20% of the cover. This class is often found on riparian gravel bars, on rocky or very steep slopes and in abandoned gravel pits. The plant species are generally herbs, graminoids and bryoids, and may include rare species. This class is also often made up of mountaintops or tallus slopes.

**7.0 Urban**

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

1. **Agriculture**

At least 50% of the area was agricultural. This class was not found in the study area.

**9.0 Cloud/Shadow**

At least 50% of the cover is made up of clouds/shadows.

**10.0 Other**

At least 50% of the cover is made up of other.

## Image preprocessing

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

Following archiving of the satellite imagery, preparations for field data collection must be completed. 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 are delineated using an unsupervised clustering and seeding technique to initially generate spectrally unique areas within the study area. These spectrally unique areas are 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 are grouped in clusters in order to reduce the amount of ferrying time between sites. A tally of estimated number of field sites per class is kept until all of the classes are adequately sampled throughout the project area. The coordinates of the center points (collected in degrees decimal minutes, UTM, NAD27) of the field sites are generated and uploaded into a Y-code Military GPS unit (PLGR) to be used while field sampling. 1:63,360 scale quadrangle color infrared plots of the Landsat TM data are also produced for the placement of additional field sample sites and for navigational purposes.

## Field Verification

The purpose of field data collection is to assess, measure, and document the on-the-ground vegetation variation within the project area. This variation will then be correlated with the spectral variation in the satellite imagery during the image classification process. Low-level helicopter surveys are a very effective method of field data collection since a much broader area can be covered with an orthogonal view from above, similar to a satellite sensor. 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 3). A five person helicopter crew is designated to perform the field assessment. Each crew consists of a pilot, biologist, recorder, navigator, and alternate. The navigator, who runs the GPS equipment and interprets the satellite image derived field maps, occupies the co-pilot seat. The biologist, the person most knowledgeable regarding the vegetation, and the recorder, who records species percentages and other data on the field form, occupy the remaining two seats in the back of the helicopter. The alternate is responsible for flight following, data entry of the previous day’s work, and substituting in case of sickness. On the first day of fieldwork, sampling is performed by landing the aircraft on the ground to verify and standardize the classification and sampling techniques. After the first day, the majority of the sites are observed without landing the helicopter to determine the percent cover for each species and an overall earth cover class. Ground verification is performed when identification of dominant vegetation and/or species is uncertain.

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 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 navigator will also take another picture with the digital camera for a close up view of the site. The pilot will then ascend to approximately 100 feet so that the biologist can call out the percentages of each species to the recorder. All observed species and taxa are identified to the extent possible from a helicopter. The ability to identify species is dependent on 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.

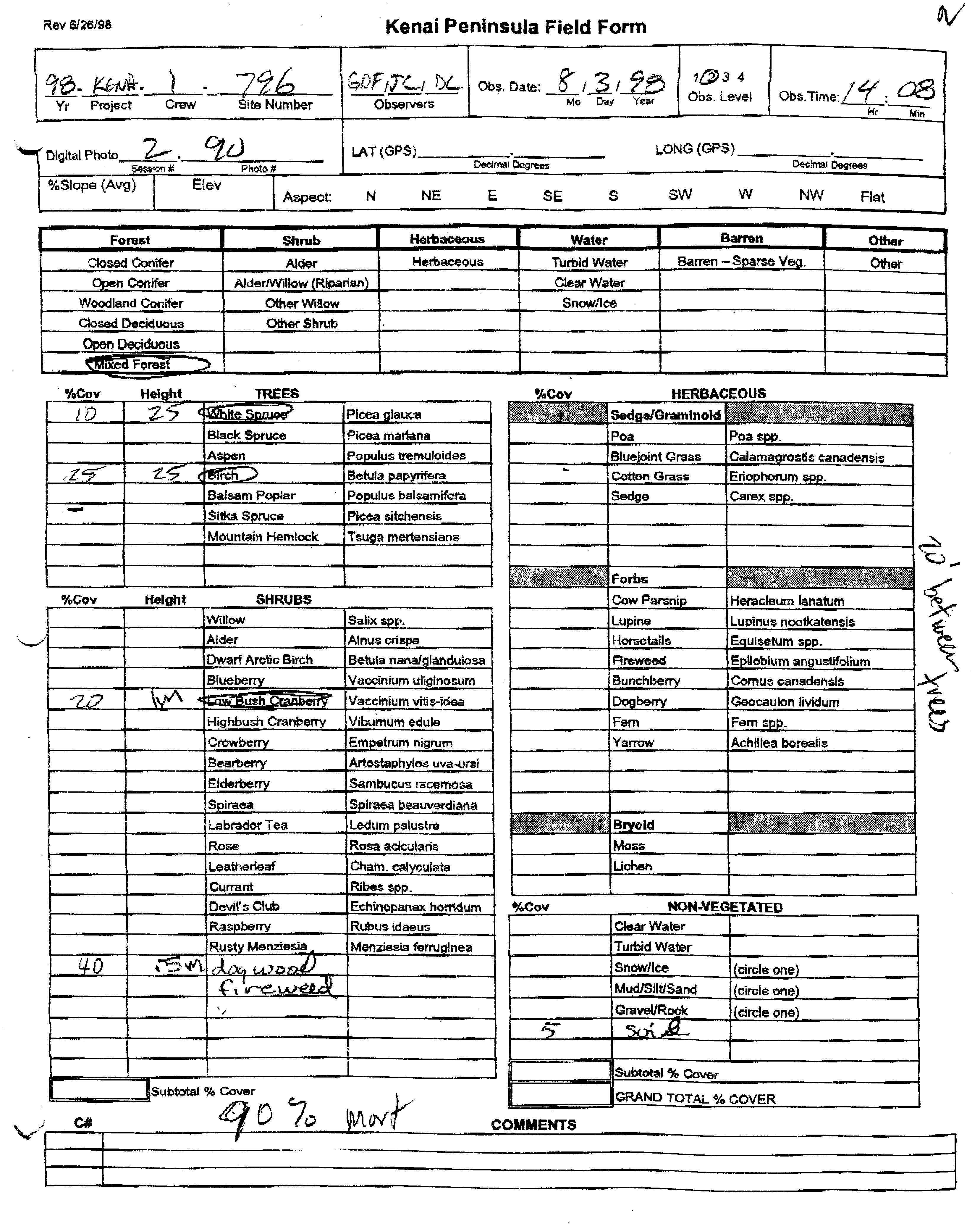
## Field Data Analysis

The field sites are entered into a customized database (DUFF) designed by the BLM and DU and developed 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. 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 to the field site is also compared to the class that the biologist assigned to the site as an additional check for data integrity; the calculated class was the class name assigned to the site. Table 3 shows a summary of the number of sites for each cover type visited.

## An ARC/INFO polygon coverage is 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

**High site photo. Low site photo.**

|  |  |
| --- | --- |
| 0803_090 | 0803_067 |

**Figure 3.** Hard copy field form and associated photos.

**Table 3.** Number of field training sites for each of the mapping classes.

|  |  |
| --- | --- |
| **Cover Type** | **No. of Sites** |
| Closed Conifer Forest | 99 |
| Open Conifer Forest | 59 |
| Woodland Conifer Forest | 33 |
| Closed Deciduous Forest | 30 |
| Open Deciduous Forest | 14 |
| Mixed Forest | 43 |
| Alder | 85 |
| Willow | 17 |
| Other Shrub | 53 |
| Herbaceous | 120 |
| Barren / Sparsely Vegetated | 26 |

image processor’s site-specific experience and knowledge in combination with high quality ancillary data can overcome many of these problems (e.g. clouds, terrain shadows, etc.) 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.

## Removal of Clouds and Shadows

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

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 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.

**Figure 4.** Image Processing Flow Diagram.

## 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 except that it contains the 150 unsupervised signatures. A maximum likelihood classification of the 150 unsupervised signatures is generated using the supervised classification program in Imagine.

## Modified Supervised/Unsupervised Classification

A modified supervised/unsupervised classification approach (Chuvieco and Congalton 1988) 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) it identifies areas of spectral reflectance present in the imagery that have not been represented by a training site.

## Editing and Modeling

Following the completion of the supervised/unsupervised classification process, several regions of misclassification and spectral confusion may still exist. Spatial modeling and manual editing techniques are employed to properly classify and map these areas of confusion that could not be satisfactorily resolved directly from the satellite image data. For instance, water may be classified where there are terrain shadow effects. This phenomenon can be easily corrected using DEM’s. Similarly, non-systematic classification errors may be present in the classification which can not be adequately remedied using either spectral separation or modeling techniques. In such cases, the image processor must use aerial photographs and field notes to employ on-screen digitizing to remedy the error(s).

## 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. 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 areal extent will have only a few samples that may severely impede future analysis. The other extreme is to force a given number of samples from each category. Depending on the extent of each category, this approach can significantly bias the results. Finally, a sampling scheme must be selected. A purely random approach has excellent statistical properties, but is practically difficult and expensive to apply. A purely systematic approach is easy to apply, but could result in sampling from only limited areas of the map. (See the Alaska Perspective section for the approach used in this project).

## Error Matrix

The standard method for assessing the accuracy of a map is to build an error matrix (also known as a confusion matrix or contingency table). The error matrix compares the reference data (field site or photo interpreted site) with the classification data (Appendix D). The shows the number of sites assigned to a particular category in the reference data relative to the number of sites assigned to a particular category in the classification. The columns usually represent the reference data while the rows indicate the classification (Lillesand and Kiefer, 1994). An error matrix is an effective way to represent accuracy in that the individual accuracy of each category are 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 to which 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).

## Alaska Perspective

Obtaining adequate reference data for performing an accuracy assessment can be extremely expensive in remote areas. Aircraft is the only means of transportation throughout most of Alaska. Aerial

photographs are available for much of Alaska, but most are at a scale that make it difficult if not impossible to distinguish some vegetation classes. Ideally, fieldwork should be performed during one summer, the classification should be performed during the subsequent winter, and the reference data should be collected during the next summer. This procedure would allow a stratified random sample of the classification and ensure adequate sampling of all the classes. Unfortunately, this methodology is not typically feasible due to the cost of obtaining the field data.

For this project, the fieldwork for obtaining the training sites for classifying the imagery and the reference data for the accuracy assessment was accomplished at the same time. Special care was taken during the preprocessing stage and in the field to make sure adequate samples were obtained. However, funding limitations did not allow for the number of samples suggested for each class (15-25) for the accuracy assessment. The first priority for the field collected data was given to making the best map possible. Therefore, in certain cases few, if any, field sites were withheld for the accuracy assessment. This means that there is little measure of confidence for those classes in the accuracy assessment. However, withholding a percentage of sites for the accuracy assessment provides a certain reasonable degree of confidence in the classification and guides the image processor to certain areas of confusion in the classification. An effort is underway to enhance the accuracy assessment sample size for this mapping effort. The increased sample size will provide a more robust measure of per-class accuracy for each of the mapping classes. The results of this enhanced accuracy assessment analysis were not available at the time of development of this report.

## Some Considerations

While the accuracy assessment performed in this project is by no means a robust test of the classification, it does give the user some confidence in using the classification. It also provides enough detail for the end user to determine where discrepancies in the classification may cause a problem while using the data. It is also important to note the variations in the dates of the imagery, aerial photographs, and field data. For this project, the imagery was from July 10, 1989; the aerial photographs spanned a seven year period from 1980 through 1987, the field data was collected in July/August 1998. Differences due to environmental changes from the different sources may have had a major impact on the accuracy assessment.

In addition, several major ecological changes have occurred on the Kenai Peninsula during the past 9+ years since the acquisition date of the satellite imagery. Primarily, tremendous land cover change has occurred throughout the peninsula as a result of beetle and fire activity. This on-going phenomenon has had a remarkable impact on the density and composition of forest and other vegetative species within the study area. The objective of this mapping project was to classify and map earth cover conditions as the existed in 1989. Therefore, biologists collecting field data, as well as the analyst conducting daily photo-interpretation in support of image processing tasks, had to “visualize” vegetative compositions as they would have appeared during the summer of 1989 prior to the significant beetle activity present in 1998. Obviously, this results in the *potential* introduction of error and/or variation in human interpretation of land cover composition that may impact the reliability and consistency of the reference accuracy assessment data.

A major assumption of quantitative accuracy assessments is that the label from the reference information represents the “true” label of the site and that all differences between the remotely sensed map classification and the reference data are due to classification and/or delineation error (Congalton and Green 1993). Unfortunately, error matrices can be inadequate indicators of map error because they are often confused by non-map error differences. Some of the non-map errors that can cause confusion are: registration differences between the reference data and the remotely sensed map classification, digitizing errors, data entry errors, changes in land cover between the date of the remotely sensed data and the date of the reference data, mistakes in interpretation of reference data, and variation in classification and delineation of the reference data due to inconsistencies in human interpretation of vegetation. As a result, the stated accuracies in the error matrix are most likely overestimated.

In an effort to account for some of the variation in human interpretation in the accuracy assessment process, overall classification accuracies were also generated assuming a +/- 5% and +/- 10% variation in estimation of vegetation compositions for each of the accuracy assessment sites. In other words, if a variation in interpretation of +/- 5% or 10% would have resulted in the generation of a different reference site label, this new label was also considered an acceptable mapping label for the reference site.

# 

# Results

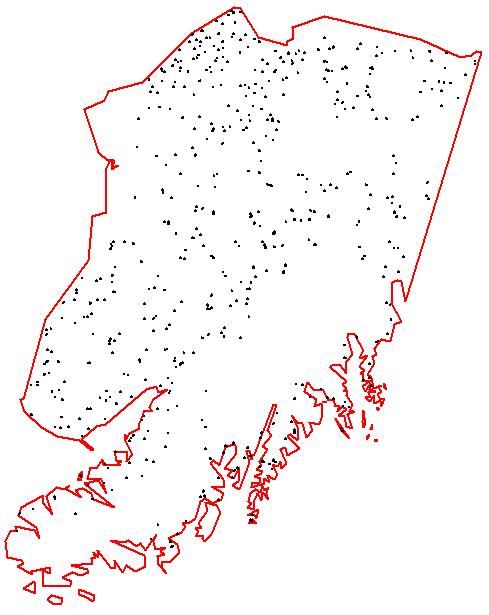
# \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

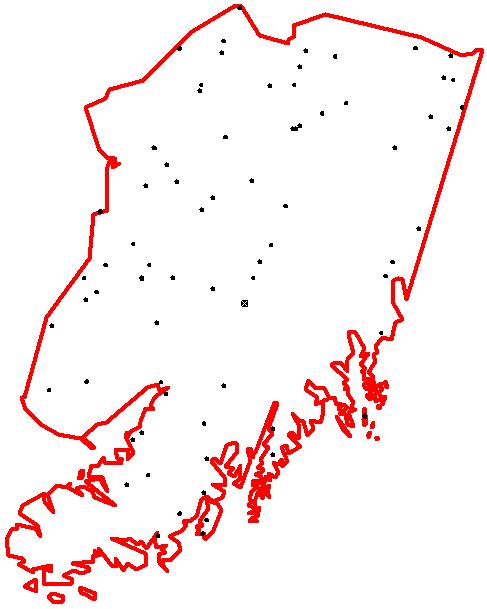
## Field Verification

Field data were collected on a total of 609 field sites during the 13 day field season from July 25, 1998 through August 6, 1998. Figures 5a and 5b show the spatial distribution of the training and accuracy assessment sites. Approximately 12% (73) of these sites were reserved for accuracy assessment. None of these accuracy assessment sites contained captured the classes of Water or Snow/Ice. These classes will be captured in the enhanced accuracy assessment process. A Robinson R-44 helicopter was used to gain access to the field sites. No remote field camps were required for the field data collection effort. All field activities were conducted from the USF&WS helispot in Soldotna. Remote helicopter refueling was accomplished through rendezvous with a pick-up truck carrying barrels of aviation gas. Remote refueling was conducted from the Swanson

River Road, Hope Airport, Seward Airport, Quartz Creek Airstrip, Ninilchik Airstrip, and Homer Airport. The participants in the field data collection were: Jeff Campbell (SS), Kelly Shea (USF&WS), Dominique Collette (ADF&G volunteer), Tom Stephenson (ADF&G), Gino DelFrate (ADF&G), Grant Hildebrant (ADF&G), John DeLapp (USFS), and Carlos Paez (NPS). The helicopter was piloted by Jonathan Laravee from Quick Silver Air, Fairbanks, AK. It should be noted that the tremendous success, efficiency, and productivity in the collection of the field data for this mapping effort was due in part to the skillful piloting and performance of the R-44 aircraft. The agility, efficiency, and overall performance of this helicopter coupled with the control of a pilot that thoroughly *understood* the data collection process resulted in one of the most successful field data collection efforts ever for this type of mapping in Alaska.

**Figure 5a.** Spatial Distribution of field training sites for the Kenai Peninsula project.





**Figure 5b.** Spatial Distribution of field accuracy assessment sites for the Kenai Peninsula project.

|  |  |  |
| --- | --- | --- |
| **Class Name** | **Acres** | **Percent Cover** |
| Clear Water | 1,343,389 | 21.22% |
| Turbid Water | 184,164 | 2.91% |
| Snow / Ice | 805,715 | 12.73% |
| Barren / Sparsely Vegetated | 564,843 | 8.92% |
| Closed Conifer Forest | 421,819 | 6.66% |
| Open Conifer Forest | 607,708 | 9.60% |
| Woodland Conifer Forest | 301,488 | 4.76% |
| Closed Deciduous Forest | 94,608 | 1.49% |
| Open Deciduous Forest | 16,452 | 0.26% |
| Closed Mixed Forest | 43,693 | 0.69% |
| Open Mixed Forest | 234,612 | 3.71% |
| Alder | 612,172 | 9.67% |
| Alder / Willow Riparian | 25,647 | 0.41% |
| Willow | 39,863 | 0.63% |
| Other Shrub | 345,168 | 5.45% |
| Herbaceous / Graminoid | 594,478 | 9.39 |
| Clouds | 57,202 | 0.90% |
| Cloud Shadow | 37,674 | 0.60% |

**Table 4.** The area and percent area of the 16 classified earth cover classes.

## Classification

The result of the Landsat TM classification is shown in Figure 6. Classification of 16 earth cover classes was accomplished. The area and percent area was calculated for each of the 16 earth cover classes (Table 4). A metadata file was also created for use with distributing the classified data (Appendix C).

## Modeling / Editing

GIS modeling and manual editing were performed to some extent on all classes depending on how well the iterative classification process worked for each. Extensive modeling was not employed for two primary reasons. First, generating and applying “global” GIS models have the potential to impact and change specified classes throughout the entire study area in one application. While correcting potential classification errors in this manner is often very efficient, this process is also capable of generating mapping errors in areas where they did not previously exist. This is often the case since most GIS modeling relies on ancillary data such as DEMs, hydrography, etc. to determine appropriate classification results instead of using base image data that directly indicates the type(s) of land cover present. The second reason for limiting the extent of GIS modeling in this project relates to the level of detail of the mapping classes that were identified. For this project, a medium-to-coarse level of vegetation classification detail was discriminated. Therefore, developing ecologically based modeling rules that could be accurately applied across the landscape is less reliable. For instance, since the Herbaceous class exists throughout the study area at elevations from sea level to over 5,000 ft, devising a model that would potentially limit the range

of this class or discriminate it from another class using ancillary data becomes an difficult task. Since an extremely high priority was placed on the spatial and thematic accuracy of this classification, other methods of classification refinement and quality control were utilized. It was the goal of the analyst for this project to ensure that any modifications made to the map be conducted on a site-by-site basis using personal experience, interpretation, and evaluation given to each map classification decision. When GIS modeling routines were utilized, they were generally in the form of a re-processing of the satellite image data of a given local geographic region. These areas were subsequently followed-up with some personal visual review, evaluation, and subsequent manual editing to insure the accuracy and consistency of the map correction process.

The primary method for correcting known map classification errors was conducted through manual editing. Essentially, manual editing consists of digitizing an area of interest (AOI) around the pixels in question, then using a recoding tool to change the class value of the questionable pixels to a new class value. These areas were changed based primarily on air photo interpretation, field notes, and the analyst’s experience in the field. The following summarizes the primary areas of classification confusion that were addressed and remedied via image reprocessing and manual editing techniques.

*OPEN / CLOSED CONIFER:* Confusion between Open and Closed Conifer occurred in two primary situations. First, the often significant loss of live tree cover between the date of the satellite imagery (1989) and when the field data was collected (1998) had a direct impact on the ability to consistently and accurately distinguish the 60% forest canopy cover break. Many of the expansive White Spruce stands that have been impacted by the beetle activity presented a canopy cover of 50 – 70% prior to the mortality that is currently evident. Consistent interpretation of the 1989 canopy cover of these stands in 1998 was difficult. Manual editing and image re-processing applied to correct many of the classification confusion between Open and Closed Conifer stands relied heavily on photo-interpretation of mid- and late-1980’s aerial photography.

A second condition influencing the confusion between Open and Closed Conifer was caused by slope and aspect. Especially on the steep forested slopes within Kenai Fjords National Park, aspect differences occasionally resulted in closed stands being classified as “open” on south-facing slopes. Open stands presented a similar problem on north-facing slopes as they were often classified as “closed”. Again these phenomena were addressed using extensive photo-interpretation coupled with image re-processing and manual editing.

*MUSKEG VEGETATION DISCRIMINATION:* The identification and mapping of “muskegs” throughout the study area was effectively accomplished utilizing the satellite imagery. The unique spectral characteristics of these regimes were readily visible and discernable from the imagery. However, it proved to be more challenging to discriminate between the often complex mosaic of vegetation that makes up these areas. The transition from a mature Black Spruce stand surrounding the muskeg to the center of the muskeg, for instance, may present a change in cover type from Open Conifer to Woodland Conifer to Other Shrub (ericaceous shrubs) to Herbaceous (generally wet sedges / grasses) mapping classes; with mosaics of each throughout. Discrimination of forested (woodland) muskeg areas from non-forested (herbaceous and other shrub) areas was accomplished primarily via photo-interpretation and manual editing. Discrimination between ericaceous shrubs and herbaceous vegetation was achieved by utilizing ground moisture information derived from the satellite imagery as well as from specific draft map comments. It should be noted that the spectral reflectance characteristics of the muskegs provided the great majority of the information necessary to discriminate most of the vegetation composition within the muskeg communities. The techniques outlined here were used specifically to improve the cover type classification for those areas demonstrating some amount of confusion.

*ALDER / OTHER SHRUB / HERBACEOUS:* Particularly on south-facing slopes where spectral reflectance of vegetation is most pronounced, consistently distinguishing the mosaic of Alder, Herbaceous (primarily *Calamagrastis)*, and Other Shrub cover types was difficult. Iterative unsupervised classifications supported by extensive photo-interpretation acted to effectively refine this portion of the classification.

*ALDER / WILLOW RIPARIAN:* The Alder/Willow Riparian class was derived solely from manual editing based on interpretation of aerial photography and satellite imagery. The Alder, Willow, and Other Shrub classes were mapped from the satellite imagery using techniques described earlier in this report. From this classification, stands of Alder and/or Willow that fell within an active riparian zone were manually delineated and labeled as “Alder/Willow Riparian”. Using this technique, it is expected that errors of *commission* within this class should be greatly minimized. However, areas of riparian alder and/or willow may exist that were not delineated on the final land cover map as such. This may occur especially in areas presenting a relatively narrow and/or inconsistent riparian corridor.

*OPEN MIXED FOREST / OPEN CONIFER:* The Open Mixed Forest class is one of the more abundant Forest classes within the land cover classification map. This class occurs in two primary regimes. First, it provides the transition cover type between the Open Conifer (generally White or Black Spruce) class and the pure Deciduous classes. In this case, there is often confusion between the Open Conifer and Open Mixed Forest classes. This has to do with the significance of the deciduous component within the stand. Due to the highly variable spectral response of deciduous vegetation in multi-spectral satellite imagery, consistent discrimination of the breakpoint of deciduous vegetation present within a stand is difficult. The classification problems associated with this phenomenon were most effectively corrected through manual editing supported by thorough interpretation of aerial photography.

The other ecological regime most noted for its Open Mixed Forest classification is the regenerating burn areas. These areas typically contain a mix of relatively young Black and White Spruce and young Birch trees. The significance of the conifer species establishing in the site generally dictated the discrimination between the site qualifying as an Open Mixed Forest site or an Open (or Woodland) Conifer site. Unfortunately, most of the aerial photography available in these areas was of insufficient scale to consistently, accurately interpret the presence/absence of such young forest vegetation. Manual editing in these areas was supported primarily by field notes, draft map comments, and field photos.

*SHADOWS:* When earth cover classification using satellite imagery are applied in regions of high relief, terrain shadows present a specific challenge. For this project, the regions presenting the most significant terrain shadows were located within Kenai Fjords National Park. Numerous steep north-facing slopes resulted in terrain shadows on the satellite imagery that masked nearly every cover type in their path. However, greater reflectance information relating to earth cover feature composition was obtained from the satellite imagery than was available from the 1:60,000 CIR aerial photography for the park.

The terrain shadowing present on the photography was generally more extensive and provided nearly no spectral or textual information regarding land cover within the shadows when compared to terrain shadowing present on the satellite imagery. A combination of image stratification and re-processing, field notes, and draft map comments were used to derive an accurate and consistent classification of severely shadowed terrain.

## Accuracy Assessment

The overall classification accuracy was 80.8% (Appendix D). The error matrices present values for user’s accuracy, producer’s accuracy, and the overall accuracy for +/- 5% and +/- 10% reference data variation in interpretation levels.

**Table 5.** Accuracy assessment results for the Kenai Peninsula Earth Cover Mapping Project.

|  |  |
| --- | --- |
| Overall Accuracy | 80.8% |
| +/- 5% Variation | 89.0% |
| +/- 10% Variation | 94.5% |

The accuracy assessment that was performed included information from the entire study area. Examination of the error

matrices in Appendix D provides valuable

information regarding the vegetation classification data. In the error matrix, numbers along the main diagonal of the matrix indicate an exact match between the

reference data site and the map. If two numbers occupy a cell, the left number indicates an acceptable match between the reference data site and the map assuming a +/- 5% or +/- 10% variation in reference data interpretation. The number on the right indicates the number of sites that are not acceptable matches.

Two primary sources of confusion in the classified map data are revealed in the error matrix. The first is between the Closed Conifer Forest and Open Conifer Forest classes. Twelve Closed Conifer and seven Open Conifer reference data sites exist. While fourteen of these sites are direct matches with the map data (ten Closed and four Open), each of the remaining sites are found to be classified as either Open or Closed Conifer. At the +/- 10% variation in interpretation level, all but one of these non-direct matches is found to be an acceptable match with the map data. This would indicate that the reference sites that are not a direct match with the map data are within +/- 10% tree crown cover of the breakpoint between Closed and Open Conifer (i.e. 60% crown cover). Confusion with no other class was found between the Closed and Open Conifer reference sites. A similar phenomenon is evident between the Woodland Conifer and Open Conifer sites.

The other point of confusion indicated by the error matrix relates to the Herbaceous map class. While thirteen of the fourteen Herbaceous reference sites match directly, a total of four reference sites from other cover type classes are found to be classified in the map as Herbaceous. This would indicate a

propensity for errors of *commission* in the Herbaceous class. In each of these four instances, however, the sites are found to be an acceptable match with the map data at the +/- 10% variation level. Again, this indicates that the reference sites that do not result in a direct match with the map data are comprised of a vegetation composition that is very near the breakpoint of one or more classes. In each of the circumstances described above, the general indication is that the map provides a good representation of actual vegetation cover based on the preliminary accuracy assessment reference sites. Reference sites that are firmly established in one individual mapping class are generally found to be mapped accordingly while the highly variable reference sites (i.e. sites that may characterize two or more cover type classes) are found to be consistently mapped into one or more of the *acceptable* mapping classes, assuming some level of variation in human interpretation of the reference data. While the enhanced accuracy assessment process will lend more specific credibility to an examination of per-class accuracy, this preliminary accuracy assessment error matrix does provide valuable insight into the major trends found with the satellite image-based earth cover classification.

## Final Products

The primary product of this project is a digital database of the 16 earth cover classes for the Kenai Peninsula project. A hard copy map of the full project area was also produced from the final earth cover classification. In addition, the field database with the digital images of the sites was delivered. An ArcView project was also created that showcases the classification, raw imagery, and field data in a user friendly system.

## Conclusions

The Bureau of Land Management (BLM) – Alaska and Ducks Unlimited, Inc. (DU) have been cooperatively mapping wetlands and associated uplands in Alaska using remote sensing and GIS technologies since 1988. This project continued with the mapping effort for the Kenai Peninsula projectusing Landsat TM satellite scenes,

Path 69 Rows 17-18, July 10, 1989. The project area was classified into 16 earth cover categories with an accuracy of 81%. The digital database of the classification was the primary product of this project along with hard copy maps of the classification, a complete field database and program, and an ArcView project.

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## 

# Appendix A. Metadata for TM imagery

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

# 

# Appendix B. Decision Tree for Classification Scheme.

9.2

Clear Water

Turbid Water

5.3

Clear Water

> 80% Water \*

6.1

Barren/Sparse Vegetation

5.4

Vegetation < 10% \*

5.1

9.1

Cloud

Cloud > 50% \*

5.2

Ice

Ice > 50% \*

Shadow

Shadow > 50% \*

Snow

Snow > 50% \*

3.0

Riparian

> 60% cc

> 75% deciduous

25-59% cc

25-59% cc

> 60% cc

2.1

Woodland Needleleaf

Mixed Needleleaf/Deciduous

> 80% Willow

> 60% shrub Willow

AND/OR Alder

Shrubs 40-100% \*

Riparian Alder/Willow

> 75% needleleaf AND ht. > 1m

Trees 10-24% \*

Alder

> 80% Alder.

No

> 75% needleleaf

No

Trees 25-100% \*

Other Willow

Open Deciduous

Open Needleleaf

Closed Needleleaf

Yes

Yes

> 40% Herbaceous AND/OR Graminoid \*

Herbaceous/Graminoid

10.0

Other

Other

Closed Deciduous

1.4

2.23

Other Shrub

2.22

2.21

1.3

1.6

1.5

1.2

1.1

# Appendix C. Earth Cover Classification Metadata

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

#### **Metadata Information System (MIS): Kenai Peninsula**

##### GENERAL DESCRIPTION

**Coverage/Image Name: KENAI\_EARTHCOV.IMG**

**Description:** Data set of P68 R17 and R18 of the classified Landsat TM images. Overall accuracy assessment for this data set is 81%.

**Scale:** 28.5 meter pixel resolution. Classes assumed accurate at a 5 acre minimum mapping unit or larger.

**Date of Image:** Classification derived from P68 R17 and R18, July 10, 1989.

**Date of Mapping:** June, 1998 – May, 1999.

PROJECTION INFORMATION

**Projection:** UTM

**Zone:** 5

**Spheroid:** Clarke 1866

**Units:** meters

**SOURCE INFORMATION**

Landsat Thematic Mapper scenes purchased and terrain corrected by EROS Data Center, Sioux Falls, SD.

**Coverage/Image Name: KENAI\_7-89.IMG**

**Description:** Original unclassified Landsat Thematic Mapper satellite imagery clipped to Kenai Peninsula project area boundary (P68 R17-18).

**Scale:** 28.5 meter pixel resolution.

**Date of Image:** Satellite imagery acquired on July 10, 1989.

PROJECTION INFORMATION

**Projection:** UTM

**Zone:** 5

**Spheroid:** Clarke 1866

**Units:** meters

**SOURCE INFORMATION**

Landsat Thematic Mapper scenes purchased and terrain corrected by EROS Data Center, Sioux Falls, SD.

**Coverage/Image Name: KEN\_TSITES.E00**

**Description:** Training site polygons for the Kenai Peninsula Project area, excluding Kenai Fjords National Park. The polygons were delineated on Landsat TM data (P66 R17-18) which had a 30 class unsupervised classification run on it. Contains 471 polygons.

**Attributes:**

**CLASS NAME** 18 18 S

**SITE#** 8 8 I

PROJECTION INFORMATION

**Projection:** UTM

**Zone:** 5

**Spheroid:** Clarke 1866

**Units:** meters

**SOURCE INFORMATION**

Training site polygons digitized over geo-referenced Landsat TM imagery and 30-class unsupervised classification.

**Coverage/Image Name: KFNP\_TSITES.E00**

**Description:** Training site polygons for Kenai Fjords National Park. The polygons were delineated on Landsat TM data (P66 R17-18) which had a 30 class unsupervised classification run on it. Contains 66 polygons.

**Attributes:**

**CLASS NAME** 18 18 S

**SITE#** 8 8 I

PROJECTION INFORMATION

**Projection:** UTM

**Zone:** 5

**Spheroid:** Clarke 1866

**Units:** meters

**SOURCE INFORMATION**

Training site polygons digitized over geo-referenced Landsat TM imagery and 30-class unsupervised classification.

**Coverage/Image Name: KENAI\_AA.E00**

**Description:** Accuracy assessment site polygons for the entire Kenai Peninsula study area. The polygons were randomly extracted from a separate coverage containing all 609 field sites. Contains 73 polygons.

**Attributes:**

**CLASS NAME** 18 18 S

**SITE#** 8 8 I

PROJECTION INFORMATION

**Projection:** UTM

**Zone:** 5

**Spheroid:** Clarke 1866

**Units:** meters

**SOURCE INFORMATION**

Accuracy assessment site polygons originally digitized over geo-referenced Landsat TM imagery and 30-class unsupervised classification.

**Field Data 1997**

Field.db Field database for the Kenai Peninsula project. The data base includes site specific information as well as two digital oblique photos for each site. Field data was captured July/August, 1998.

Field.log Associated transaction file that contains update information to the DB file. This

file must accompany the field.db file and contain the same date and time stamp for the DUFF program to work properly.

**CONTACT INFORMATION**

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National Park Service

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Bureau of Land Management-Alaska

Alaska State Office

222 W. 7th Ave. #13

Anchorage, AK 99513-7599

# Appendix D. Error Matrices

