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Forestry Timber Typing Final Report  
Tanana Demonstration Project

Leslie A. Morrissey  
Vincent G. Ambrosia

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Tanana Demonstration Project

Leslie A. Morrissey  
Vincent G. Ambrosia  
Technicolor Government Services

Prepared for  
Ames Research Center  
under Contract NAS2-11101

**NASA**

National Aeronautics and  
Space Administration

**Ames Research Center**  
Moffett Field, California 94035

#  
N83-17926



FORESTRY TIMBER TYPING

TANANA DEMONSTRATION PROJECT

ALASKA ASVT

FINAL REPORT

Prepared in cooperation with:  
Department of Natural Resources

By:  
Leslie A. Morrissey (TGS)  
Vincent G. Ambrosia (TGS)  
NASA/Ames Research Center  
Moffett Field, California



## TABLE OF CONTENTS

	Page
Scope of the Final Report	1
I. INTRODUCTION	2
Objectives	2
Participating Agencies and Responsibilities	3
II. PROJECT CONSIDERATIONS	6
Technical Overview	6
Study Area	8
Classification Scheme	10
Output Products	14
Training	14
III. TECHNICAL ANALYSIS METHODOLOGY	16
Imagery Acquisition	16
Computer Systems	18
Field Data Collection	19
Preprocessing	20
Training Site Selection	25
Clustering and Classification	25
Evaluation of Classification	33
Integration of Digital Terrain Data	35
Post-Processing	36
Output Products	43
IV. FIRE HAZARD MODEL	52
V. CONCLUSIONS	56
Results and Recommendations	56
VI. REFERENCES	59
APPENDIX A. Project Participants	61
B. Characteristics of Landsat Satellite Data	62
C. Ground Data Forms	64
D. Detailed Ground Site Information	65



## CHAPTER I INTRODUCTION

As part of the Tanana Demonstration Project, NASA/Ames Research Center and the Alaska Department of Natural Resources (ADNR) embarked on a cooperative effort to test the feasibility of using Landsat digital data in conjunction with topographic data to map forest cover types in a study area northwest of Fairbanks. Based upon previous Landsat classification results in the Susitna River Basin and Tanana River Basin, it has become apparent that many forest types cannot be distinguished with spectral information alone. Previous investigations in the continental United States have come to this same conclusion (Hoffer and others, 1979; Woodcock and Logan, 1980; Logan and Strahler, 1980; Shasby and Burgan, 1981). Conditions of stand density and topographic position were found to cause similar spectral response from different forest cover types (species) as well as distinct differences in spectral response from a single cover type. It has also become clear that the occurrence of different forest cover types is significantly influenced by topographic position, that is, by elevation, slope and aspect. Therefore, to provide more reliable forest cover type maps with finer class distinctions, this project used a technique which combines topographic data with Landsat spectral data.

The State of Alaska is unique in that recent and impending legislative mandates require the transfer of millions of acres of federal, state, and local and native - selected lands. Land transfer requirements of these acts dictate statewide resource evaluation and use-classification. To address these critical data needs, the Alaska ASVT was designed to demonstrate and transfer methods for regional and detailed land cover mapping based on Landsat digital data and U-2 high altitude photography. The forestry timber type project evolved from the need for more detailed land cover assessments than were provided in the Intrisca and Tanana regional projects.

### Objectives

The Tanana Forestry project has been designed to facilitate user assessment and adoption of remote sensing technology by demonstrating Landsat capability as a land use and resource management tool. Completion of analysis has served to meet three overall goals: 1) to provide specific timber type information, 2) train agency personnel to understand the advantages and limitations of the technology, and 3) serve as a basis for evaluation of the technology for meeting agency needs.

The primary objective of this demonstration was to test and evaluate a technique using Landsat spectral data in conjunction with topographic data to provide forest resource information in a cost effective and timely manner. In fulfilling this objective, ADNR wanted to test the feasibility of using satellite derived information to delineate potential commercial forest stands. Specifically, ADNR wished to generate information on major forest types based upon stand size and crown closure as follows:

#### Stand Size

Seedling (less than 1.0 inch DBH)

Sapling (1.0 - 4.9 inches DBH)

Poietimber (5.0 -8.9 inches spruce, 5.0 - 10.9 inches hardwoods)

Sawtimber (9.0 inches and greater - spruce, 11.0 inches hardwoods)

#### Crown Closure (Stocking Level)

Code 1 (25 - 39%)

Code 2 (40 - 69%)

Code 3 (70 - 100%)

Stand size and crown closure for coniferous and hardwood forests were based on the dominant species in that stand. Due to the limitations of the satellite, only open and closed forests were considered; woodlands (less than 25% crown cover) fall into other land cover categories based on the predominant vegetation type. A secondary objective was to differentiate forest species - an activity which historically requires large scale, aerial photography, according to ADNR foresters.

To further demonstrate the utility of remotely sensed data in a fire protection planning framework, the timber type data were subsequently integrated with terrain information to generate a fire hazard map of the study area. This hazard map will provide valuable assistance in initial attack planning, determining accessibility for equipment and fire growth modeling.

#### Participating Agencies and Responsibilities

The Division of Forestry (ADNR) assumed the lead role in providing technical support and on-going evaluation of the data.

A number of other divisions within ADNR, and other state agencies also participated in various phases of the project. A list of agency participants is shown in Appendix A. Those agencies participating in the demonstration include:

Department of Natural Resources  
Division of Forestry  
Division of Research and Development  
Division of Technical Services  
Department of Environmental Conservation  
U.S. Department of Agriculture,  
Soil Conservation Service

One of the major factors determining the success of a technology transfer project is the level of commitment and contribution of agency participants. A firm commitment from both NASA and the agencies was necessary to ensure project success. In meeting this commitment, all parties assumed specific responsibilities which are summarized below:

NASA/Ames

Information and Training

Image Analysis Processing

Imagery Acquisition

Technical Assistance

State Agencies

Ground Data Collection

Commitment of Personnel

Classification Evaluation

Verification of Results

The cooperative nature of this demonstration project required the active participation of state agency personnel. Following completion of the digital analysis, the final assessment of the data will reside with the state agencies.

## CHAPTER II PROJECT CONSIDERATIONS

### Technical Overview

Major forest types can be mapped reliably with Landsat spectral data. However, to obtain more reliable forest stand information at a greater level of detail, topographic data must be incorporated and used in conjunction with the spectral data. This combination of spectral information and topographic data provided the basis for the Landsat derived timber type mapping reported herein.

A supervised classification approach (which utilizes ground data to develop spectral statistics representative of information classes) provided the basis for an initial classification of cover types which was used to generate a timber type map. Landsat scenes from August and September 1979 were registered to provide improved discrimination of forest types. Spectral information for 134 sites was collected and clustered to yield spectral statistics. These supervised statistics were supplemented with a number of unsupervised cluster statistics which represented cover types not ground sampled. The combined statistics file was then used to assign each picture element to the cluster it most nearly resembled using a maximum likelihood classifier. To evaluate the classification a workshop was held in Anchorage to identify classification errors, that is, spectral classes which represented more than one cover type. Strategies for refining the classification with digital terrain data were also developed.

Concurrently, the ground sites were used to determine significant relationships between the occurrence of specific timber types and their topographic position. Stratification to eliminate known classification problems was handled using the digital terrain data based on the characterization of forest types by slope, aspect and elevation. The final classification was smoothed to simulate a ten acre minimum mapping, unit and output products (prints and acreage summaries) were generated. The major analysis steps were completed in the following sequence:

1. The Landsat digital data, CIR photography and terrain data (DMA tapes) were acquired.
2. Two bands (one visible, one IR) from each of the August and September Landsat scenes were registered to create a multi-date image.

3. The terrain data (DMA) was registered to the Landsat data. Elevation, slope and aspect files were generated.
4. The ground data (training sites) were delineated on the Landsat data, and the MSS data retrieved for clustering.
5. This training site information was then clustered to develop spectral signatures for each cover type.
6. An unsupervised clustering of the study region provided cluster statistics for those land cover categories which were not represented in the training sites.
7. The combined cluster statistics (supervised and unsupervised) were used to classify the MSS data.
8. The topographic data was then correlated with the training site information to define the distribution of forest stand types by topographic position.
9. An evaluation workshop was held with ADNR to evaluate the classification.
10. Strategies were devised for incorporating the topographic data to improve mapping accuracy.
11. The topographic data were used to stratify the Landsat classification, thereby eliminating known classification errors.
12. The final classification was smoothed to simulate a ten acre minimum mapping unit.
13. Final products were generated including color coded maps and acreage summaries for the Livengood A-3 quad and the full data set (1:250,000 scale).

A detailed discussion of the above digital analysis steps can be found in Chapter III.

## List of Figures

Figure	Page
1. Location Map of Study Area	9
2. Major Analysis Steps	17
3. Typical Vegetation Communities	21-23
4. Histogram of a Birch Forest	27
5. Statistic Plot of Forest Types	29
6a. Composite Statistic Plot For The August Date	31
6b. Composite Statistic Plot For The September Date	32
7. Aspect and Slope Ranges of Black and White Spruce	34
8. Elevation Data For The Livengood A-3 Quad	37
9. Aspect Data For The Livengood A-3 Quad	38
10. Slope Data For The Livengood A-3 Quad	39
11. Determination of Dem Stratification Rules	42
12a. Color Legend For The Forestry Classification	45
12b. Classification of Full Data Set	46
13. Classification of The Livengood A-3 1:63,360 Quad	47
14. Fire Hazard Model For The Full Data Set	54
15. Fire Hazard Model For The Livengood A-3 Quad	55
16. Data Bases For The Tanana Forestry Project	58

## List of Tables

Table	Page
1. Classification Scheme	11
2. Ground Information Summary	24
3. Stratification Decisions	40
4. Grouping of the Spectral Classes Into Cover Categories	44
5. Acreage Summaries By Cover Type For The Full Data Set and The Livengood A-3, 1:63,360 Quad	49
6. Acreage Summaries For Aggregated Land Cover Categories	50
7. Ecological Attributes of The Tanana Forestry Project Cover Classes	51



## Study Area

The study area, located within the Tanana River basin, extends north to Livengood, west to Minto, east to Chena Hot Springs and south to the Blair Lakes (see Figure 1). Geographically, the study area lies within 65 30' north latitude and 150 west longitude and 64 30' North 147 West. This area represents a diversity of landscapes, and a corresponding diversity of vegetation types. The White Mountains include gently rolling hills to rugged peaks upwards of 5000 feet in elevation, generally supporting hardwood and coniferous forests on the slopes, alpine tundra above the treeline and bog species in the basins and valleys. Minto Flats include extensive wetlands interspersed with hundreds of lakes and ponds. The lowlands south of Fairbanks are characterized by black spruce bogs with hardwood species occurring along the Tanana River and smaller tributaries.

Permafrost, found throughout the study area, plays an important role in providing a substrate for plant growth. Continuous and discontinuous permafrost is found at varying depths throughout the region and greatly influences vegetative types and growth patterns by limiting the depth to which plant roots may grow. Although the annual precipitation is rather low (7-30 inches annually), permafrost holds moisture near the surface while vegetative ground cover retards runoff and provides insulation, thereby maintaining a saturated substrate for plant growth. Permafrost (often found on north facing slopes) commonly supports black spruce vegetation, while south facing slopes with less insulating ground cover and warmer soils, support mainly birch and aspen forests. White spruce is found along many of the floodplains in well drained soils and as the successional species in many hardwood forests. These commonly occurring vegetation patterns are disrupted by fire which can destroy the insulating moss ground cover, thereby allowing underlying permafrost to thaw and retreat, providing a substrate for a greater diversity of species. One of the most recent and extensive fires within the study area (northeast corner) occurred near Wickersham Dome, which now supports mainly bare ground, tall shrubs, and hardwood seedlings.

The test site is traversed by major highways, the Alaskan railroad, and the Alaska pipeline. Fairbanks is the largest city with numerous other smaller settlements and a number of military installations. Land ownership patterns have undergone radical change due to numerous state and federal legislative mandates regarding land selection, disposal and classification. As a result, a need for cooperative land management exists. In addition, the checker - board ownership patterns have compounded accessibility problems. The principal political subdivision within the basin is the Fairbanks North Star Borough. However,

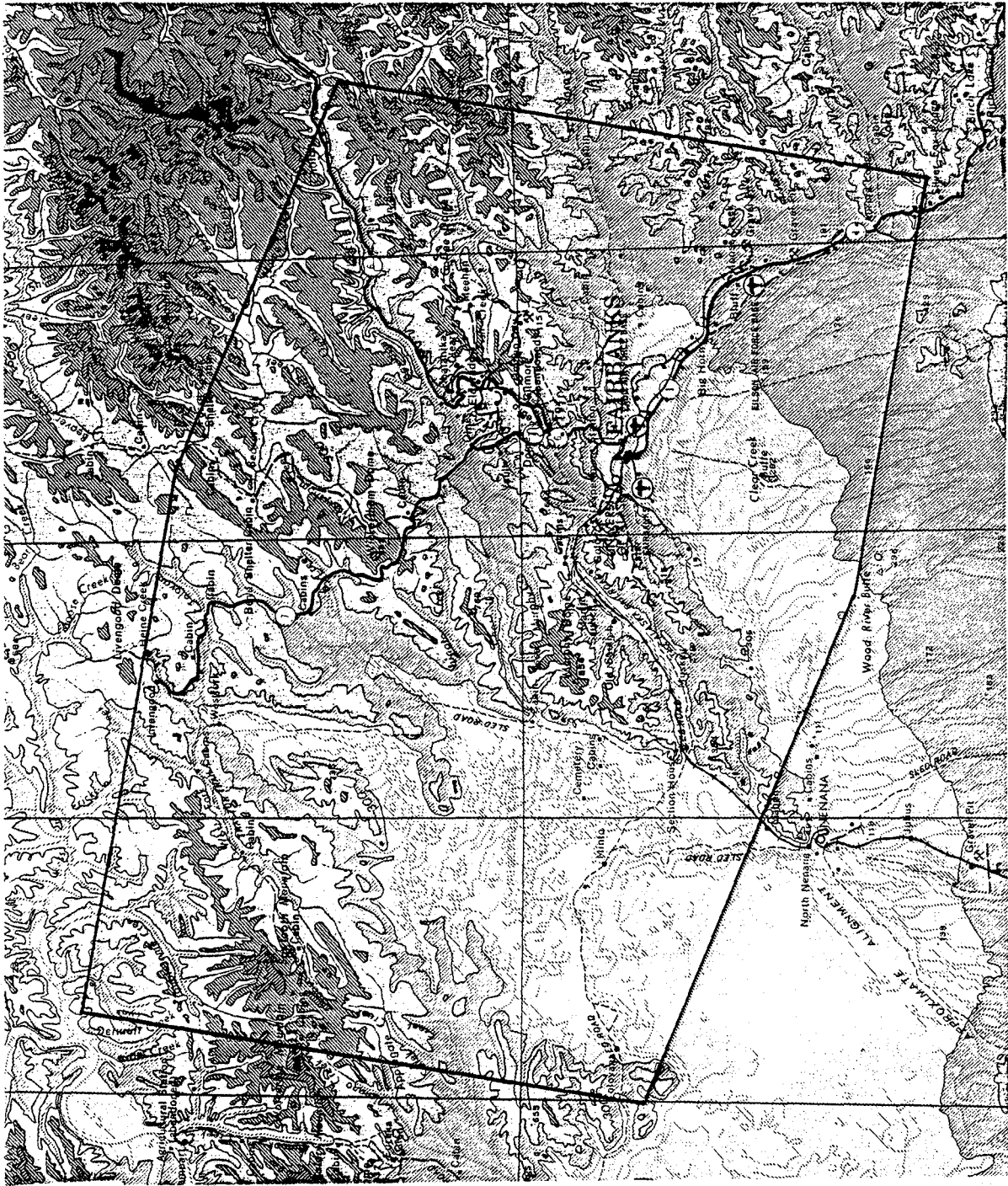


Figure 1. Locational Map of Study Area. Fairbanks, AK. 1:1,000,000 Map.

## Scope of the Final Report

This report documents the efforts and accomplishments of the Forestry Timber Resource Project from its inception through its completion. The Tanana Project is part of a cooperative three year program undertaken by the National Aeronautics and Space Administration (NASA) and various state and local government agencies. The first phase of this three year Applications Systems Verification and Transfer (ASVT) program, INTRISCA, involved a demonstration of remote sensing technology in southcentral Alaska. Phase II, the Tanana project is comprised of two subprojects: generation of a regional land cover map of most of the Tanana River Basin using Landsat digital data and a more detailed timber type forest resource mapping effort for an area northwest of Fairbanks. This final report documents the Tanana forest resource mapping effort.

Chapter 1 of this report provides information concerning project objectives, participants and responsibilities. An overview of the technical approach, study area, classification system and desired output products are discussed in Chapter 2. A detailed description of digital processing steps for the timber type mapping follows in Chapter 3, while Chapter 4 describes the fire hazard model and Chapter 5 summarizes the significant results and findings of the analysis. This document is intended to assist agency participants in assessing the utility of remote sensing technology for meeting specific state inventory requirements.



federal, state and local agencies all have jurisdiction over of lands within the basin.

### Classification Scheme

The initial classification scheme desired by ADNR was modified to reflect the training information, photo interpretation of color infrared (CIR) photography during the evaluation phase, and spectral separability of the MSS data. Two levels of information were specified to reflect ADNR's primary and secondary objectives: delineation of major forest types by crown closure and stand size class. The classification scheme developed for this project and based on Landsat satellite data is summarized in Table 1.

Interior forest types are generally not pure stands, but mixtures of the five major species: white spruce, black spruce, paper birch, quaking aspen and balsam poplar. Of the above five species, black spruce is not commercially important and white spruce forests are generally recognized as the climax tree on most commercial sites (Lutz, 1956). Being tolerant of shade, white spruce often appear in the understory of hardwood stands, eventually becoming the predominant species while birch and aspen are the primary successional tree species following fire, and balsam poplar occur mainly along river valleys.

The forest and land cover categories are described according to dominant lifeform, site moisture, and other associated landscape elements. Forest stands have been classified on the basis of predominant species or those species that account for 50% or more of the crown cover. Therefore, hardwood forests with a spruce understory will not be differentiated from pure hardwood forests. The modified classification scheme for this project resulted in the following fifteen categories:

#### Conifer 2/3

This class encompasses both black and white spruce forests with crown cover densities of 40-100% (Code 2 and 3). Principally poletimber and sawtimber white spruce with smaller stand size (sapling and seedling) for black spruce. Mixed forests of sawtimber stands with a majority of conifers are also included in this class.

#### Black Spruce 2

Mainly composed of black spruce seedling stands with a smaller component of sapling and poletimber trees. A

PRINCIPAL COVER

CROWN

STAND SIZE

Forest Land

White and Black Spruce	2 and 3	All
Black Spruce	2	Sapling (Seedling)
Black Spruce Bog	1	Sapling (Seedling)
Aspen and Birch	3	Poletimber, Sapling
Aspen and Birch	2 and 3	Poletimber (Seedling)
Aspen and Birch	3	Poletimber
Aspen and Birch	2 and 3	Poletimber (Sawtimber)

Non Forest Land

Shrubland

Shrub Tundra (Includes Tussocks)  
Alpine Tundra (Sparsely Vegetated)  
Barrens  
Shrub Bog  
Sedge and Grass  
Deep and Clear Water  
Shallow and Sedimented Water  
Urban

Table 1. Classification Scheme.

majority of these stands have a crown closure density of 40-69% (Code 2) with a smaller number of Code 3 closure.

#### Black Spruce Bog

This type is comprised of open black spruce stands with a crown closure of 25 -69% (Code 1 and 2). Saturated substrate over permafrost supports a moist mat with numerous prostrate shrubs (willow, birch, ledum, berries, etc).

#### AB3Pole/Sap

A mixed aspen and birch forest with a crown closure greater than 70% (Code 3) comprise this class. Stand size class for the hardwoods include both sapling and poletimber stands.

#### AB3Pole/2Seed

This class is primarily comprised of aspen and birch poletimber with a variable crown cover (Code 2 and 3). A smaller component of aspen seedlings with a crown cover of 40-69% are also included.

#### AB3Pole

Aspen and birch poletimber stands with a crown closure of 70-100% dominate this class.

#### AB3Pole/2Saw

This class is composed of two types of mixed aspen and birch forests. Poletimber stands with a crown closure of 70-100% and sawtimber stands (40-69% crown closure) are equally represented.

#### Shrubland

Encompasses those communities with a major vegetative component of shrubs (alder, willow, birch and aspen seedlings), grasses and sedges. This class occurs in areas recently burned, along drainages and in cleared areas (timber cuts and abandoned agricultural fields).

#### Shrub Tundra

This type is found above the treeline and is dominated by dwarf birch and other prostrate shrubs along with various grasses, sedges (tussock) and forbs.

## Alpine Tundra

Basically composed of mat and cushion, low-lying vegetation commonly found above shrub tundra and dominated by dryas, crowberry, bearberry, sedge, grass, lichen and other forbs.

## Barrens

All bare rock or soil surfaces with less than one-third vegetative cover. Includes bare rock outcrops on the major mountain peaks, floodplains, sandbars, mine tailings and fallow fields.

## Shrub Bog

This cover type is dominated by a thick moss ground cover supporting grass, ericaceous shrubs, salix, blueberry and open stands of black spruce (with less than 25% crown cover) in a saturated and/or frozen substrate.

## Sedge and Grass Bog

This class is found in depressional areas, often in standing water, or above the treeline as dry meadows. Hydrophytic plants, as well as, low birch and willow shrubs occurring on boggy ground.

## Deep and Clear Water

Includes many of the hundreds of lakes and ponds found in Minto Flats and open water within the Tanana River.

## Shallow and Sedimented Water

This type includes shallow lake shelves, turbid lakes, and rivers with high sediment loads. Emergent and aquatic vegetation may also be present.

## Urban

This class is comprised of residential, commercial and transportation facilities (airports, highways) within the Fairbanks area.

The information classes were generalized, when necessary to maintain a high level of reliability. Spectrally separable classes differentiating birch and aspen were developed during

clustering. However, these same classes could not be consistently identified with CIR photography over the entire data set and therefore, were grouped into a more generalized mixed hardwood class.

### Output Products

Upon completion of the analysis, NASA/Ames agreed to provide ADNR with a number of products of both the full data set (1:250,000) and the Livengood A-3 quad (1:63,360) as follows:

#### Forest Timber Type Classification

- Set of color coded prints (to scale)
- Acreage summaries
- Digital data
- Viewgraph and slide set
- Negatives and positives

#### Digital Terrain Data (slope, aspect and elevation)

- Set of versatec plotter maps (to scale)
- Digital data
- Viewgraph and slide set

#### Fire Hazard Model

- Set of color coded prints (to scale)
- Digital data
- Viewgraph and slide set
- Negatives and positives

The digital data were registered to a UTM projection and reformatted for compatibility with Alaska Land and Resource System (ALARS). A secondary series of products were delivered with the final report to other participating agencies and divisions for evaluation.

### Training

To fulfill overall project objectives, NASA/Ames provided training in digital image analysis and aerial photographic interpretation for agency participants. The workshop in air photo interpretation (highlighting CIR photography) provided the basis for an understanding of multispectral image analysis. Hands-on experience was emphasized in each workshop.

Principles of aerial photographic interpretation were presented to agency participants at a workshop presented by NASA in June of 1980. High altitude color infrared, low altitude

natural color, and black and white aerial photography were used for analysis. Reconnaissance visits to the field were made to verify and develop photo interpretation keys. Another advantage to this reconnaissance phase of the training was to familiarize agency personnel with the study area, learn ground data collection techniques and identify major vegetative species.

An introductory digital image analysis workshop was held at the EROS Field Office in Anchorage in October of 1980. A digital data set encompassing Fairbanks was analyzed prior to the workshop to develop a series of instruction aids, laboratory exercises, and output products. A course syllabus, aerial photography and several products were distributed to each participant. Access to the EROS IDIMS system provided the basis for a balanced series of lectures and hands-on experience. Both unsupervised and supervised classification techniques were discussed.

## CHAPTER III TECHNICAL ANALYSIS METHODOLOGY

Digital analysis refers to the steps involved in the generation of a classified Landsat scene. Simply stated, in the digital process the reflectance characteristics of each picture element are correlated with resource categories. This is possible because the reflectance values are recorded in a digital (numerical) format easily manipulated with computer software programs. Basically, the purpose of digital image classification is to group a large number of pixels of similar reflectance values into a smaller number of meaningful resource categories. This chapter describes the various steps in the digital analysis of forest resource data in an area north of Fairbanks (see Figure 2).

Digital analysis of the data sets utilized for this project encompassed six major steps: preprocessing, clustering, classification evaluation, stratification, and generation of output products. Preprocessing involved the registration of the two Landsat scenes and reformatting of data tapes. MSS data from 134 training sites were extracted and clustered - creating mean and variance statistics for each cover type. These statistics were then utilized in the classification of the MSS data, a process in which each picture element (pixel) is assigned to the cluster it most nearly resembles. Evaluation of the classification involved identifying the spectral classes by comparing the classes with color infrared photography. Classification errors, identified during the evaluation workshop, were the result of spectral confusion between two distinct land cover categories. Stratification techniques using digital terrain data involve renaming "problem" classes within specified areas. Upon completion of the stratification step, output products, color coded maps and acreage summaries, were produced.

### Imagery Aquisition

The initial step in the digital analysis of Landsat data involves the acquisition of imagery and ground data information, and ancillary materials. Classification of the study area north and west of Fairbanks required the following data inputs:

- Landsat digital data (CCT's)
- Landsat false-color composite prints
- Field data
- Color-infrared U-2 photography
- Digital terrain data, and
- Topographic maps

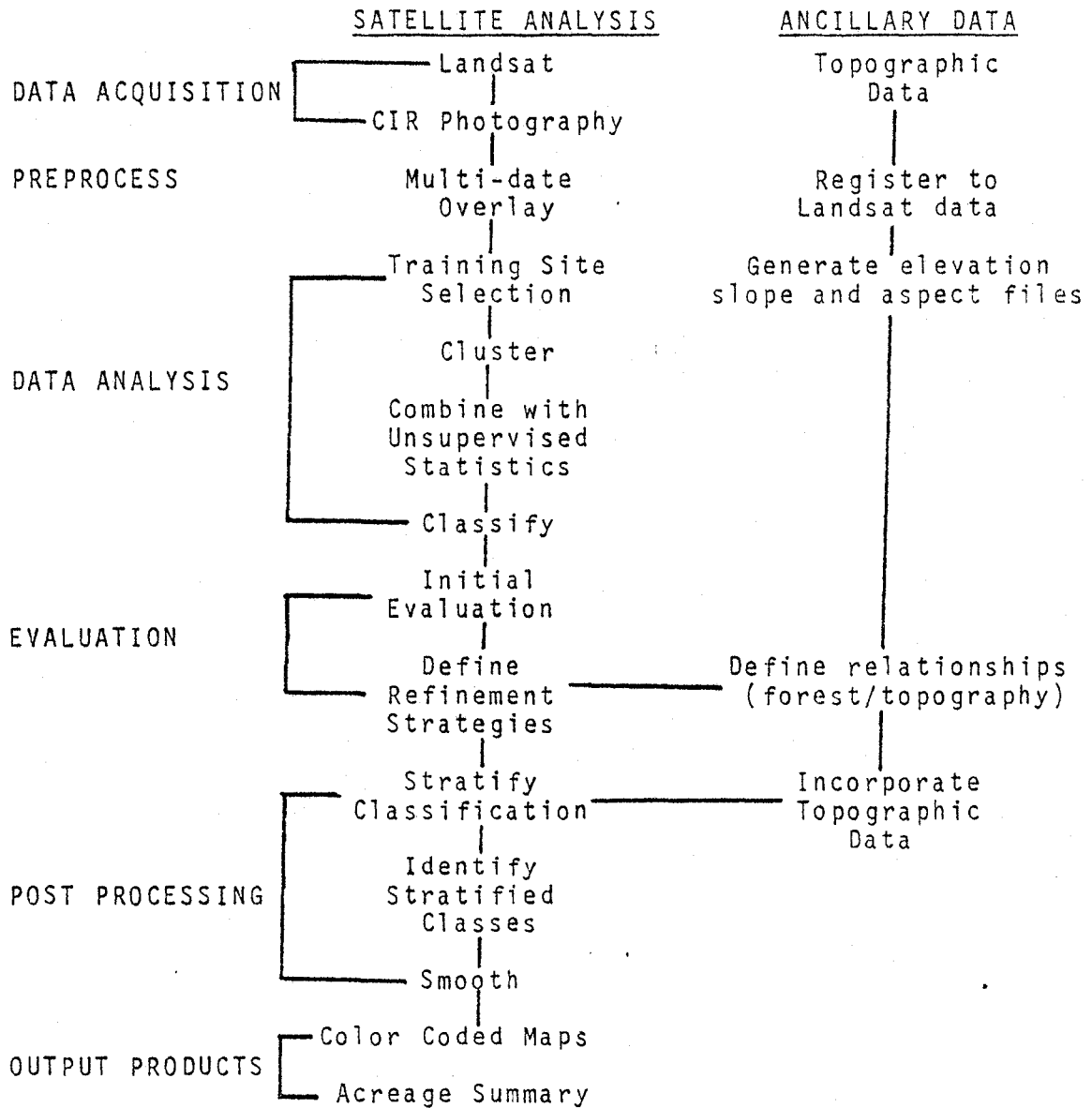


Figure 2. Major Analysis Steps.

A Landsat search was utilized to locate potential scenes for analysis. An early spring scene prior to leaf burst and a summer scene were initially sought. However, no high quality, early spring scenes (1977 - 1980) were found. As a result, the multi-date approach was modified to include parts of four readily available scenes from 1979. Coverage of the study area was obtained with portions of the following Landsat scenes:

24 August 1979	30537 - 20434	Path 76	Row 14
24 August 1979	30537 - 20436	Path 76	Row 15
11 September 1979	30555 - 20433	Path 76	Row 14
11 September 1979	30555 - 20435	Path 76	Row 15

The August scenes had lush vegetation throughout, while the leaves of the deciduous species had already turned by the September date scenes. It was hypothesized, that two bands (one IR, one visible) from each scene, combined to form a new four banded image, would facilitate the separation of spectral responses from different forest types. Computer compatible tapes (CCT's) and Landsat false color composites were purchased from the EROS Data Center (EDC). A description of Landsat MSS data characteristics can be found in Appendix B.

A search of available CIR photography was made at the U-2 Data Facility located at Ames Research Center. Flight lines of all CIR photography falling within the study region were plotted and then selected, dependent on a number of considerations. Photography with excessive cloud cover was eliminated from consideration. Generally, every other frame was selected to reduce the cost of ordering a large number of photographs, while still covering the entire study area. Color-infrared photography (CIR) provided a necessary link between ground visits and the Landsat digital data. The development of photo-interpretation keys allowed the extrapolation of information gathered during ground visits over larger areas. The CIR photography is primarily useful for collection of ground data and spectral class verification.

Digital Elevation Models (DEM) produced by the Defense Mapping Agency (DMA) were purchased from the EROS Data Center in Sioux Falls, South Dakota. The data, which comes as computer tapes of selected 1:250,000 quadrangles in Alaska, were purchased for areas corresponding to the Fairbanks and Livengood quads. This data was useful for stratifying vegetation types based on their slope, elevation, and aspect positions.

### Computer Systems

Digital data analysis of the Fairbanks scene utilized several computer systems available at NASA/Ames Research Center. The EDITOR (ERTS Data Interpreter and TENEX Operation Recorder)

software package developed by the Center for Advanced Computation (CAC) provided the foundation for interactive image processing and analysis. The EDITOR package is available on the TENEX PDP-10 at the computer facility of Bolt, Berenak, and Newman (BBN) in Boston, and is accessed through telephone lines via the ARPA (Advanced Research Projects Agency) Network. Initially supervised clusters were selected using the IDIMS (Interactive Digital Image Manipulation System) software and Comtal display, implemented on the HP 3000 Series III computer housed at Ames Research Center. Pre-processing and reformatting were completed using the IBM 360/67 and the CDC 7600 was used for classification and smoothing. Integration of the digital terrain data and fire hazard modeling was accomplished with the Environmental Systems Research Institute (ESRI) software package. Access to several computer software systems allowed use of the the most efficient system for each specific processing task.

### Field Data Collection

The accurate classification of land use and land cover characteristics utilizing Landsat multispectral data requires the careful collection of ground data throughout the study region. In a supervised or modified classification of Landsat data, cluster statistics are derived from the MSS data for each ground site. In an unsupervised clustering approach, ground data provides the basis for identification and evaluation of spectral classes. In addition, ground field data coupled with identification of cover types on aerial photographs adds greatly to photo-interpretation for selected areas.

To familiarize agency personnel in the recognition of major vegetation species, a photo key was developed containing ground photos of major tree species along with floristic descriptions. In addition, data collection forms and a preliminary classification scheme (based on Vierecks) were also included in the ground data collection package. During July 1980, ground truth forms (Appendix C) were completed for each of a number of training sites along with ground photographs, taken to provide a permanent record of each site.

A supervised clustering and classification approach requires the selection of known ground truth sites which must meet certain basic criteria. Most importantly, field sites must encompass all known cover types, as well as all possible variation within each cover type. These sites must be uniform in spectral response and representative of a homogeneous cover type, which can include a uniform mix of species. Transitional areas, such as ecotones or boundaries were avoided. Sites must be least ten acres in size. Finally, training sites should encompass all possible variations (slope, species, age, crown closure etc.) within each cover type. With completion of the field season, copies of all ground

truth forms, location of sites, and ground photos were sent to NASA for evaluation. Typical vegetative communities in the study area are shown in Figure 3.

Ground site data was collected over two field seasons in 1980 and 1981. Two foresters from ADNR collected ground data in support of this project in the summer of 1980 and two analysts from NASA accompanied three ADNR foresters to collect additional ground site information and overfly the area in the summer of 1981. Data regarding species composition, crown density, stand size class and other terrain elements was collected for seventy-five field sites. To facilitate accessibility in the area, all field sites were located along the road between Fairbanks, Livengood, and Manley Hot Springs, and were supplemented with non-forest types (an additional 59 sites) located with CIR photography. The ground site information is summarized in Table 2. Detailed ground site information can be found in Appendix D. This field site data were supplemented with survey plots collected by the Forest Sciences Laboratory (PNW Experiment Station) which was photo-interpreted from large scale black and white photography in 1968 and 1969. However, this information was not felt to be reliable because of its age and significant changes which have occurred due to fire, logging and natural succession.

### Preprocessing

Preprocessing steps are done before image analysis or image classification, to remove noise, bring into registration, and/or enhance images. Beginning in 1978, standard processing of Landsat MSS data at the EROS Data Center (EDC) involved radiometric correction, haze removal, and geometric correction to a 57 square meter pixel size. Therefore, registration of the two scenes utilized in the analysis was the only preprocessing step required.

Complete Landsat coverage of the study area for this project required two different Landsat images abutting one another. The images were first mosaicked together on the VICAR (Video Image Communication And Retrieval) system. Image number 30537-20434 (August 24, 1979), the southern image, was mosaicked to 30537-20436 (August 24, 1979), the northern image. The same mosaicking function was done for the two September 11, 1979 scenes over the same area (30555-20433 and 30555-20435), thus creating two mosaicked scenes (one August and one September). These two mosaicked scenes were then registered to one another. Bands 5 (visible) and 6 (near infrared) of the August and September scenes were combined to create a new four banded image consisting of spectral information from two dates.





Figure 3a. Typical vegetation communities. Area of Wickersham Dome fire. Shrub and grasses in foreground, burned black spruce in background.

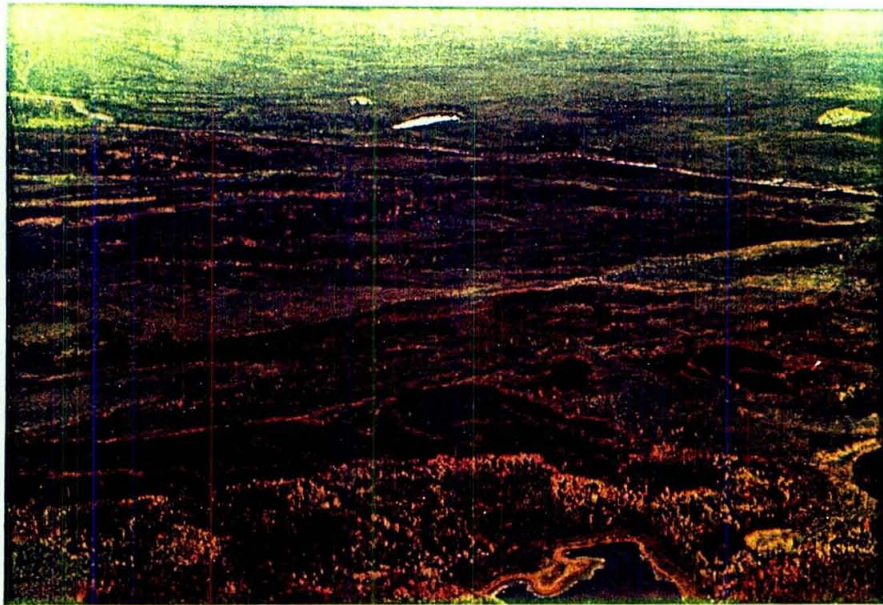


Figure 3b. Aerial photo of a recent burn northwest of Fairbanks. Note fireline stops where deciduous trees begin.



Figure 3c. Ground photo of poletimber size aspen on a test area north of Fairbanks.



Figure 3d. Ground photo of vegetation interfaces. Grass and tussock tundra in foreground, short black spruce in middle and mixed hardwoods in background.



Figure 3e. Aerial photo of area corresponding to 3d. The tussock tundra can be seen as the medium green patch along the haul road (center of print). The black spruce to the left of the tussocks (between the road and the pipeline) are a darker green, and the hardwood forest upslope (to the left) are a brighter mottled green (high percentage crown cover).



Figure 3f. Aerial view of a dense conifer cover on a north-facing slope along the haul road. Notice the interface with the taller deciduous trees to the left in this picture.

<u>Training Site Designation</u>	<u>Dominant Species</u>	<u>Stand Size</u>	<u>Site No.</u>	<u>Canopy Code</u>
ASP3SAP	Aspen	Sapling	52	3
ASP2SED		Seedling/Sapling	41	2
ASP3POL		Pole/timber	1,4,5-7	3
ASP2SAW		Sawtimber	59	2
BIR3POL	Birch	Pole	25,37,11,13,15,29,45,51,61	3
BIR2SAW		Saw	50	2
BIR3SAP		Sapling	28,43,65	3
BIR2POL		Pole	31	2
AB2SED	Aspen/Birch Mix	Seedling	47	2
AB3POL		Pole	6,23,48,35,40,42,55,56,60	3
AB3POSA		Pole/Sapling	33,36	3
BS3SED	Black Spruce	Seedling	3,9,16,21	3
BS1SED		Seedling	12	1
BS2SED		Seedling	18,22,38,75,39	2
BS3SAP		Sapling	19,69	3
BS2POL		Pole	74	2
WS3SAW	White Spruce	Sawtimber	58	3
WS3POL		Pole	49	3
WS2SAW		Saw	53	2
MIX3POL	Mixed C/D Forest	Pole	10	3
MIX2SAW		Sawtimber	54	2
Shrub tundra			17,70	
Tussocks			24,32,72,73,71	
Shrub			26,27	

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Canopy Cover Code    Code 1 25-39%    Code 2 40-69%    Code 3 70-100%  
Stand Size (DBH)    Seedling 0-1"    Sapling 1-4.9"    Pole 5-8.9" spruce, 5-10.9" hardwoods  
Sawtimber 9" and greater spruce, 11" and greater hardwoods

Table 2. Ground Site Information Summary.

## Training Site Selection

Utilization of the COMTAL display facilitated training site selection through visual examination of the MSS data. The MSS data for each site were displayed and outlined using a cursor; the coordinates for the vertices of the irregular training sites were then stored by the system under a user-designated training class name. Refinement of site boundaries and editing of questionable sites (difficult to locate or too small) was facilitated by use of the display. In addition, anomalies occurring in the data were obvious and therefore were avoided. Training class designation and number of sites per class are shown in the Table 2.

General land cover categories were not represented by a sufficient number of training sites. These categories (nonforest land) were supplemented with training sites determined through photo-interpretation of CIR aerial photography. However, some forest classes still had too few pixels or sites. Clustering of cover classes with too few pixels often produces a cluster with extremely high or extremely low variances - both extremes are unsatisfactory for a maximum likelihood classifier and were eliminated. In addition, there were no training sites for Balsam Poplar, and open hardwood forests. All variation of crown cover and stand size for forest classes were not represented in the ground data and therefore, resulted in a more generalized classification scheme.

## Clustering and Classification

The supervised clustering approach develops statistical cluster groups based on the spectral content of selected land cover sites. Success of this approach is based on the quality of the ground data, spectral separability of desired cover types, and the analyst's ability to refine clusters. All tasks related to clustering, cluster development and evaluation were accomplished using EDITOR software.

The MSS data for each site were retrieved from the Landsat data tape and grouped by cover class. The MSS data of each of these cover classes were displayed in the form of a frequency distribution (histogram) to analyze the data for homogeneity and to determine the optimal number of clusters present. Within each cover class there may be many spectral clusters, with different clusters representing differences in slope, aspect, crown closure or other vegetative characteristics.

Generally, the histogram is analyzed to determine the number of nodes or peaks in the distribution of the data, the dispersion of spectral values about the mean, and the range of spectral values. The histograms shown in Figure 4 have a signature characteristic of a birch forest--low reflectance in the visible (red) band and a higher reflectance and greater range in the infrared band. The infrared bands are much more sensitive to green vegetation and are, therefore, a better tool for differentiating vegetation types than the visible bands. The visible and near infrared histograms for the same training site for the September date are also shown on the right half of Figure 4. In comparison to the August data, the senescent vegetation in September has higher reflectance values than the same lush vegetation in August. Similarly, the near infrared reflectance values for the September scene are not as bright as the August bands, having lost most of the chlorophyll in the leaves. These changes in spectral reflectance, due to the phenological changes in the vegetation, serve to increase the spectral separability between particular cover types and, as a result, the multi-date analysis data set increases the probability of correctly classifying forest types in comparison to a single scene.

Clustering was performed on each file of MSS data to develop cluster statistics -- means, variances and separabilities (a measure of distance between clusters). Following clustering, the statistics were examined. Clusters representing the same land cover category with extremely low variances and low separability were pooled, while clusters with high variances and a low number of pixels were reclustered or deleted. Initial clusterings which resulted in clusters with low variances, low separability and a low number of pixels were unsatisfactory. This data was reclustered, as necessary, to develop a preliminary set of statistics representative of all land cover categories found in the training sites. For further analysis, each statistics file was graphically displayed as a two dimensional plot representing means and variances. As shown in Figure 5 the axes represent the reflectance values in the red (Band 5) and near-infrared bands (Band 6). Means are represented by the cluster number (alpha-numeric) and variances by the surrounding circle. Potential problems, such as clusters with high variances or low separability, were easily identified on the plot.

Confusion between clusters of different land cover categories was examined next. Spectral confusion results when two distinct land cover categories encompass the same spectral reflectance values in the four bands. Statistics files representing different land cover categories were merged and the separability measure was used to determine possible spectral confusion. Confusion clusters were either pooled, deleted, or reclustered. Each analyst has developed a method for analysis based on experience, training, and intuition. Invariably, this portion of the analysis, i.e., development of the spectral

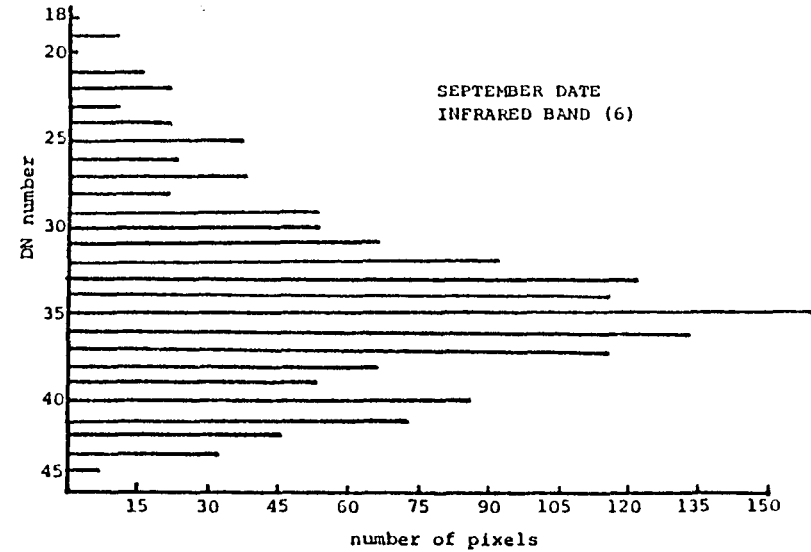
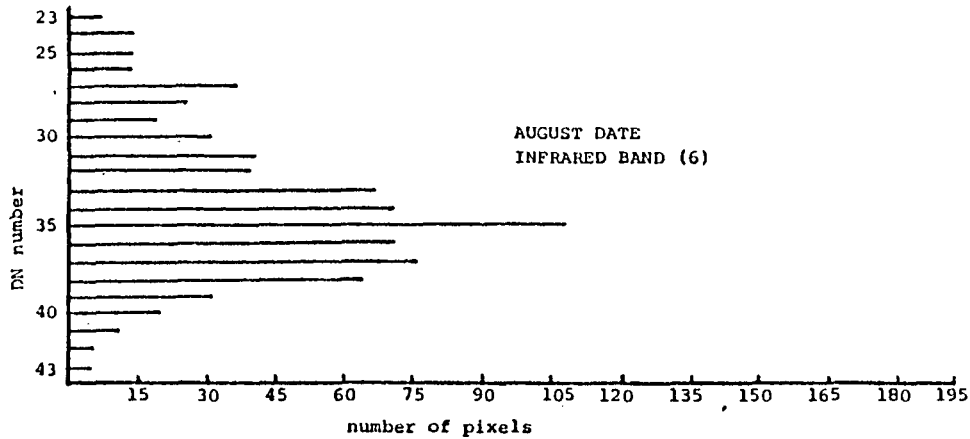
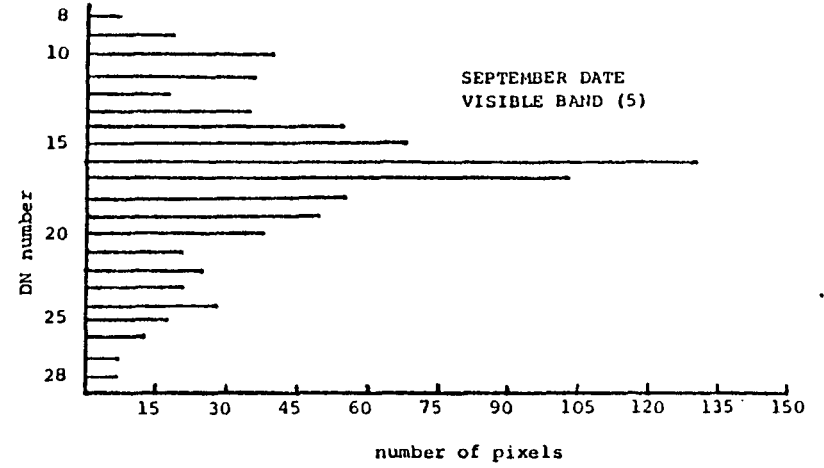
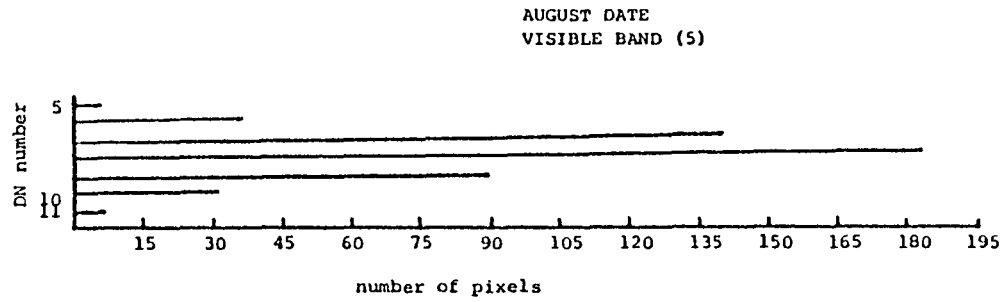


Figure 4. Histogram of a Birch Forest (crown cover = 3; stand size = pole) For August and September Dates. The spectral ranges (DN number) are noticeably different for the two dates, therefore aiding discrimination of cover types using multi-date imagery.

## Position of Information Classes in Spectral Space Cluster Diagram

Landsat has four (4) channels; however, one cannot imagine four-dimensional space in graphical terms. By using two channels, a two-dimensional representation of spectral space can be produced. In Figures 5 and 6, Channel 1 corresponds to Band 5 (0.6-0.7 microns) and Channel 2 corresponds to Band 6 (0.7-0.8 microns). Spectral classes tend to group in a triangular shape beginning in the lower left corner and spreading to the upper right. Various types of land cover spread out along the horizontal axis (conifers, mixed forest, deciduous forest, grasses). This is because most types of vegetation are equally low in red light reflectance (Channel 1) and very different in infrared reflectance (Channel 2). Along the 45° diagonal axis (lower left to upper right) the spread of water classes, barren areas, snow, ice and clouds occur. On the plot, numbers represent cluster means and the surrounding circle represents the variance of each cluster.

Attachment for Figures 5 and 6 (next two pages).



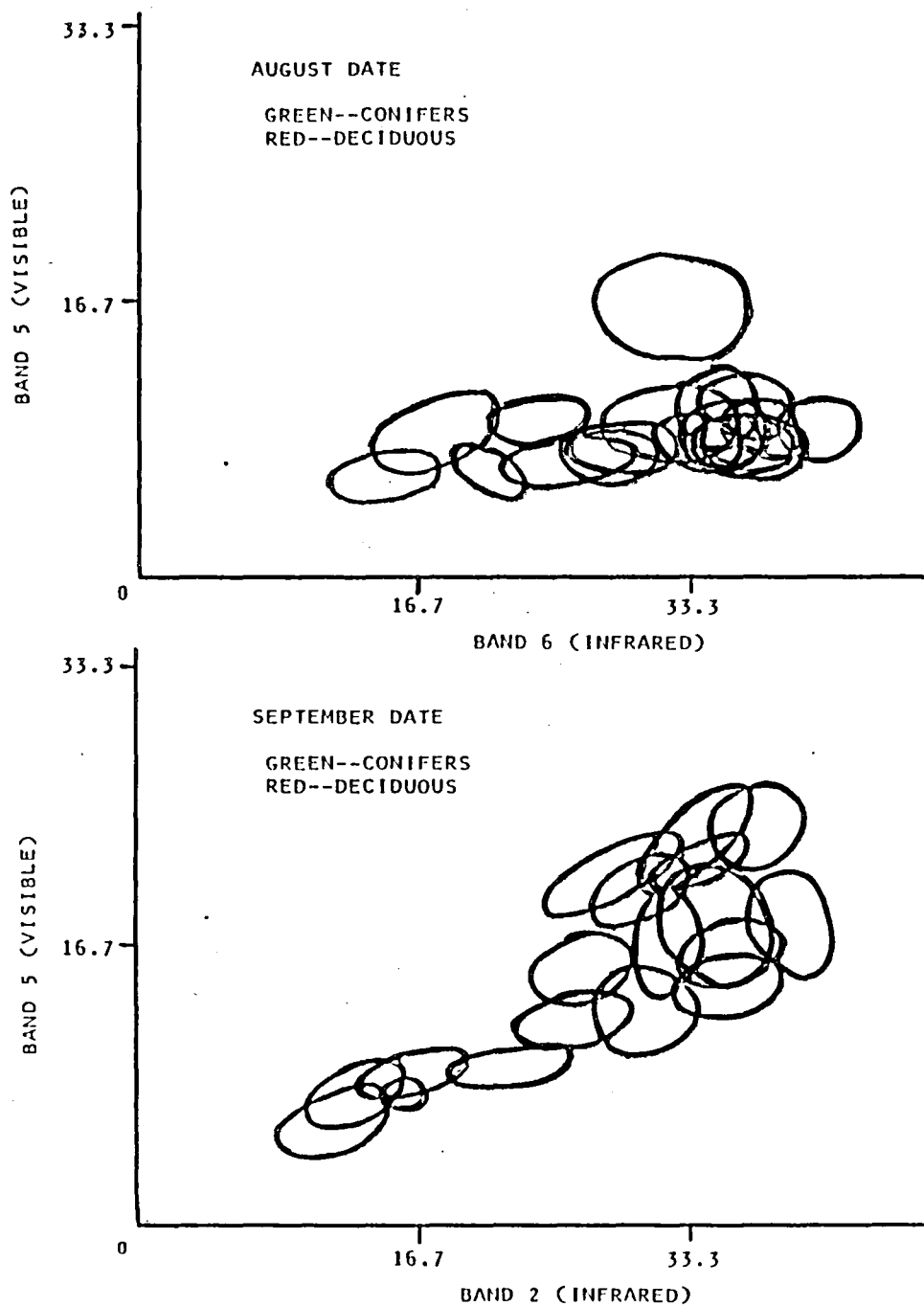


Figure 5. Statistic Plot of Forest Types. August data is shown on top, September is below. Cluster ellipses in Green represent Conifers, while those in Red represent Deciduous types.



clusters, is the most difficult task and can produce a wide range of results. This process of merging statistics files, editing, and rechecking continues until all statistics files have been merged into a composite statistics file.

To evaluate the integrity of the statistical clusters, the training sites were classified with the composite statistics file representing all land cover categories. Tabulations resulting from classification of the training sites by land cover category gave an indication of the number of pixels correctly classified within each land cover category. Based on these tabulations, spectral confusion was evident between aspen and birch forest classes and also between shrub, grass and tundra classes. The analyst had to determine at this point whether the confusion was due to 1) inadequate training site selection (heterogeneous sites), 2) conflicting land cover classes which were spectrally identical and therefore not statistically separable, or 3) overlapping land cover category descriptions leading to overlapping class names which represented the same cover type (for instance, shrub and shrub tundra). Spectral confusion which existed between shrub, grass, and tundra classes was determined to be due to confusion in classification terminology. On the uplands, the training sites labeled tundra actually consisted of shrub and grass occurring above the treeline. Once again the statistics were modified by deleting, pooling, or reclustered and then used to reclassify the training sites. The iterative editing process continued until the analysts felt that the statistics were as spectrally distinct as the MSS data would allow. The composite supervised statistics cluster plot for the forestry data is shown in Figure 6.

The usefulness and quality of training sites utilized in the clustering process directly determine the likelihood of correctly classifying the full data set. Although a great number of sites were visited in the field and photo-interpreted, it is almost impossible to verify that the training sites utilized do indeed encompass all possible spectral variation present in the Landsat scene. Therefore, the supervised statistics were merged with statistics generated during unsupervised clustering of the scene, to improve the chances for representing all possible types. In an unsupervised clustering approach, the MSS data are partitioned into an analyst selected number of spectrally distinct groups or clusters. The unsupervised clusters were statistically compared to the supervised clusters and merged as determined by the analyst.

The composite statistics file (supervised and unsupervised clusters) were utilized on the CDC 7600 to classify the full multi-date image. The initial classification consisted of forty-three (43) classes. The classes included forest cover types, barrens, shrubs, alpenes, bogs, grasses, deep water,

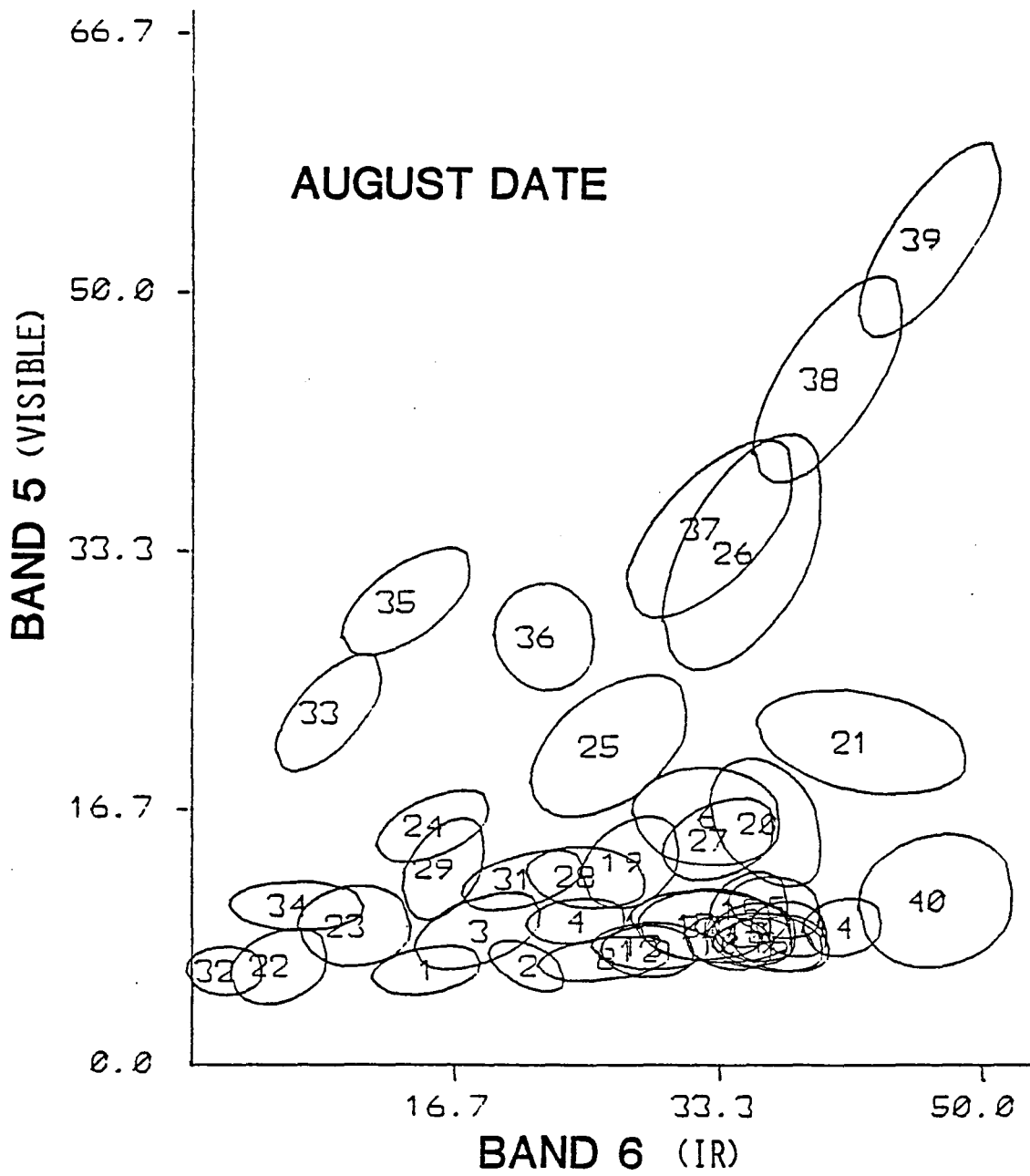


Figure 6a. Composite Statistic Plot For The August Date.

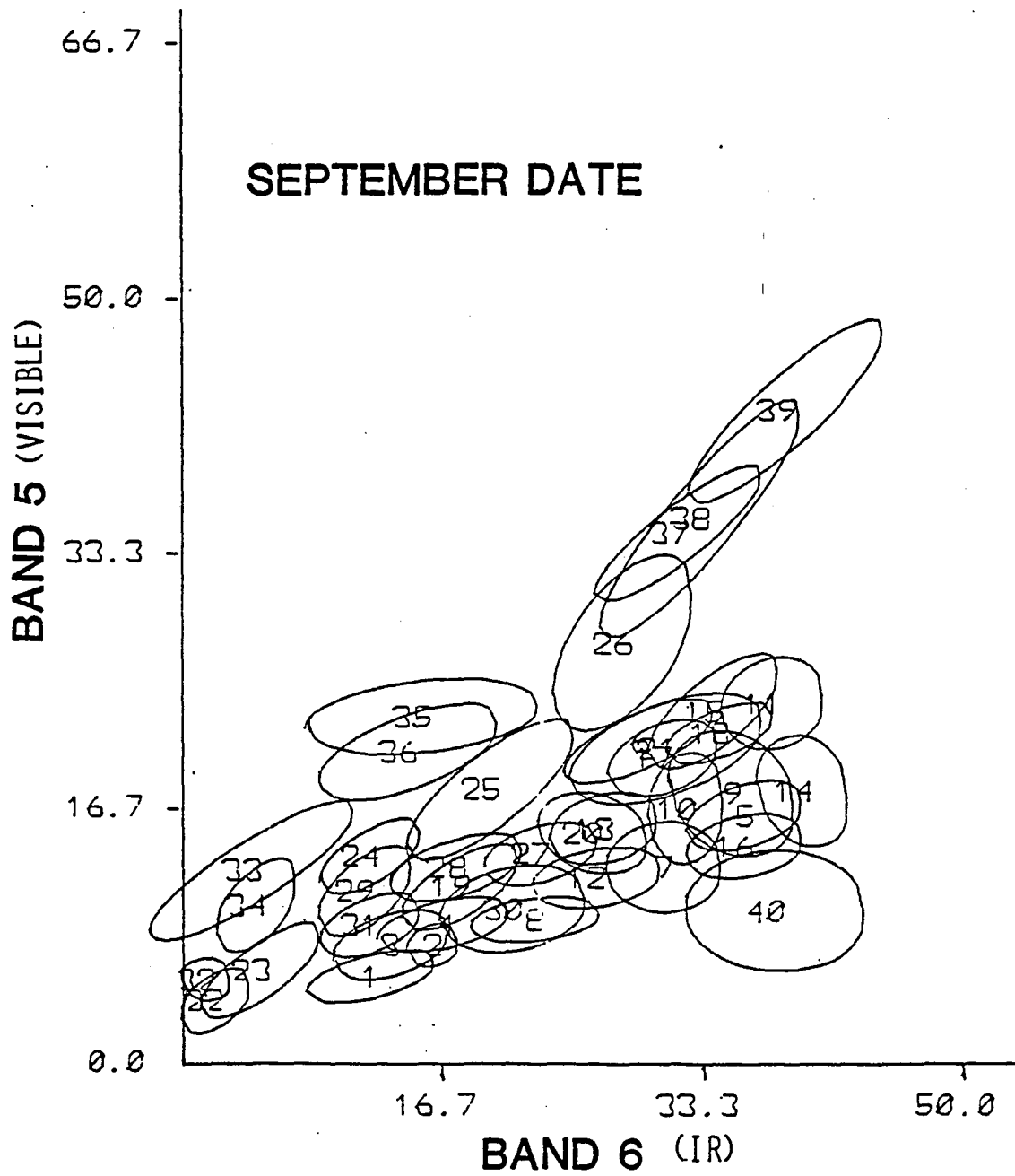


Figure 6b. Composite Statistic Plot For The September Date.

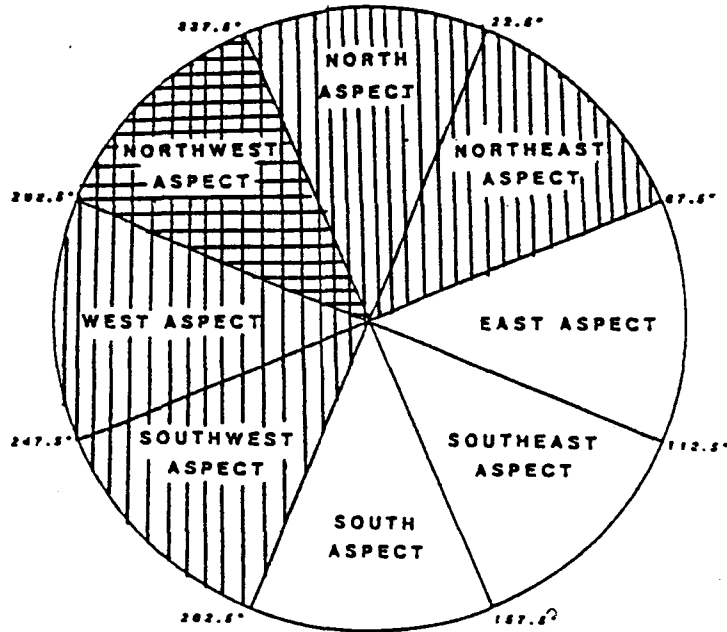
shallow/sedimented water, agriculture and urban. The forest cover categories were distinguished by type, density (crown closure), and size (DBH measurements).

### Evaluation Of Classification

An evaluation workshop was held at the EROS-IDIMS facility in Anchorage, during the week of October 18, 1981. Personnel from ADNR were briefed on the classification by NASA personnel and an evaluation of the spectral classes was completed. It was noted that initially there was no real mixed conifer/hardwood forest classes because there were not enough training sites (two) and therefore, too few pixels were used in the clustering algorithm. A mixed conifer/hardwood forest class was classified as a hardwood type. In the evaluation of the data some other discrepancies were also noted. In the Minto Flats area west of Fairbanks, sedimented/shallow water was confusing with barren (what appeared as barrens on the image were actually areas of sedimented/shallow water identified from CIR aerial photographs). In the Fairbanks urban area, commercial/industrial confused with barrens, and residential conflicted with shrub. In the Wickersham Dome burn area, bog and black spruce were confusing with shrub, and a few north facing slopes were classified as deep water. After evaluating the entire data set strategies were developed to make the required corrections. A number of confusion classes could be stratified using the DEM data (elevation, slope, and aspect gradients), but others were stratified manually using the ZIP function available on IDIMS. In all instances changes were made only when ancillary information proved the original classification incorrect.

Contingency tables comparing ground truth sites with slope, aspect and elevation were run to provide the basis for characterizing land cover types by topographic position. These tables were analyzed to determine significant vegetation/terrain relationships. This analysis provided the basis for a statistical description of the distribution of each forest cover type in terms of elevation, slope and aspect (see Figure 7). These same ground truth sites were also compared with the spectral classification to identify spectral confusion classes. Results from these two sets of contingency tables were utilized in the development of decision rules for stratification of the classification.

## ASPECT RANGES



## SLOPE RANGES

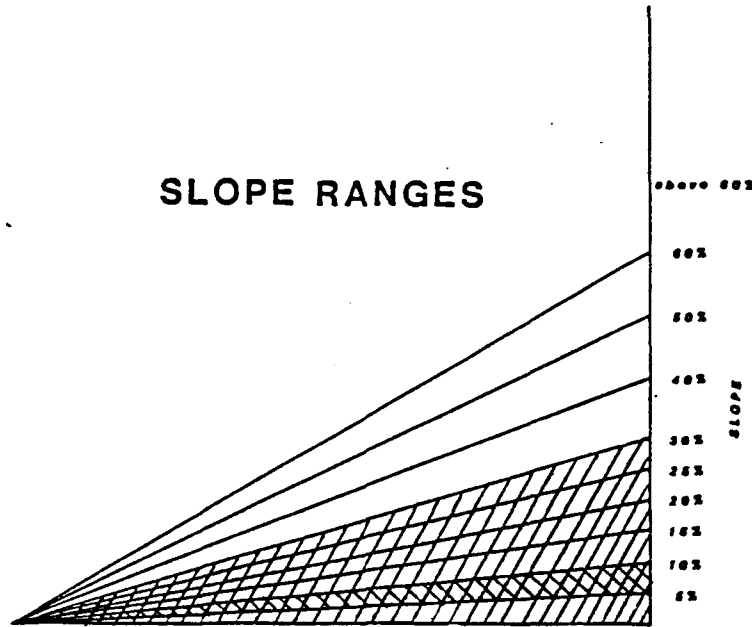


Figure 7. Aspect and Slope Ranges of Black and White Spruce. The distribution of Black Spruce is displayed as solid lines while White Spruce is shown as cross-hatched lines. With respect to slope and aspect, White Spruce is a subset of Black Spruce and therefore cannot be distinguished with DEM data.

## Integration Of Digital Terrain Data

Elevation data, in the form of computer tapes for selected areas, were purchased from EDC/National Cartographic Information Center (NCIC) at Sioux Falls, South Dakota. Data were acquired for two 1:250,000 scale quadrangles (Fairbanks and Livengood). Because of the unavailability of software at Ames, the DEM data was reblocked at the EROS Field Office in Anchorage and then reformatted in a format compatible with the Ames system.

The DEM data is comprised of three (one degree by one degree) blocks for each quadrangle. Each block had to be mosaicked before further processing. Once the data (three blocks per quad) were entered on the IDIMS system, each set of three (one degree by one degree) blocks for first the Fairbanks quad then the Livengood quad, were mosaicked, creating two data sets (Fairbanks quad and Livengood quad). The two data sets were then mosaicked together at abutting edges in order to create one data set. This DEM data set was then reduced to an area consisting of the northern half of the Fairbanks quadrangle and the southern half of the Livengood quadrangle (the approximate area of the study region).

Registration of the digital terrain data to the MSS data required the selection of a number of corresponding points from both data sets. Control points were selected from the August date of the multi-date image to be used to register the DEM data to the classified scene; a total of thirty-five control points with identifiable locations were selected. Control points for the DEM data (in line-sample coordinates) were converted to latitude and longitude coordinates, to match the MSS data control points and registered to the classified data. The transformation program on IDIMS was then run to create a transmatrix file with matching control points from both data sets. A third order polynomial transform was used to create the file. The DEM data set was then registered to the classified image using a bilinear interpolation algorithm. All that existed at this time was elevation data in integer format with each meter in elevation representing one integer value. Since the data set included elevations up to approximately 1450 meters, there were 1450 integer values.

Slope and aspect data were then generated from the elevation file using the ESRI software package on the HP-3000 Series III computer at Ames. The data sets were resampled to a 57 square meter pixel or grid cell size to be compatible with the classified data set. Therefore, every pixel cell of classified data had one cell value for elevation, one for slope, and one for aspect (three registered ancillary data sets). Both slope and aspect were derived using the eight way vector sum algorithm available in the ESRI "GRIDTOPO" program.

Following creation of the slope, aspect and elevation data sets, each file was converted from integer to byte data, and grouped into meaningful levels. Since the elevation data set actually consisted of elevations from 80 to 1450 meters (0-1500) it was mapped into 30 fifty-meter levels (0-49, 50-99, 100-149, etc.) (see Figure 8). The aspect image was mapped to 360 byte-levels corresponding to the 360 degree of a compass. The final aspect image was then grouped to 8 forty-five degree levels; NORTH, NORTHEAST, EAST, SOUTHEAST, SOUTH, SOUTHWEST, WEST, and NORTHWEST (see Figure 9). The slope data set was grouped to eleven levels in five percent increments from 0% to 30%, in 10% increments from 30% to 60%, and there was one class representing slopes greater than 60% (see Figure 10). Each of these three data sets was then integrated with the classified data in order to stratify vegetation classes by their relative position on the landscape.

### Post-Processing

Post-processing refers to digital processing steps which are performed after classification include stratification for refinement of the classification, grouping of the spectral classes into desired resource categories, and smoothing to simulate a minimum mapping unit.

During the evaluation workshop held in Anchorage with ADNR foresters, spectral confusion classes were noted and strategies devised to correct the problem areas (Table 3). There are two basic sources of classification error: 1) Spectral confusion (distinct land cover categories with similar spectral characteristics), and 2) misidentification of spectral classes. In order to correct for misclassification, three strategies were designed to improve the classified data. The three strategies were:

- Manually stratify
- Rename or relabel categories
- Stratification with digital terrain data

Manual stratification involves identifying misclassified pixels and reassigning them to new classes by changing the category numbers for pixels which fall within user defined polygons drawn on the data set. Manual stratification works well when spectral confusion can be identified within clearly defined boundaries. Most identified problem classes occurred either in the Minto Flats area, along the Tanana River lowlands, in the Fairbanks

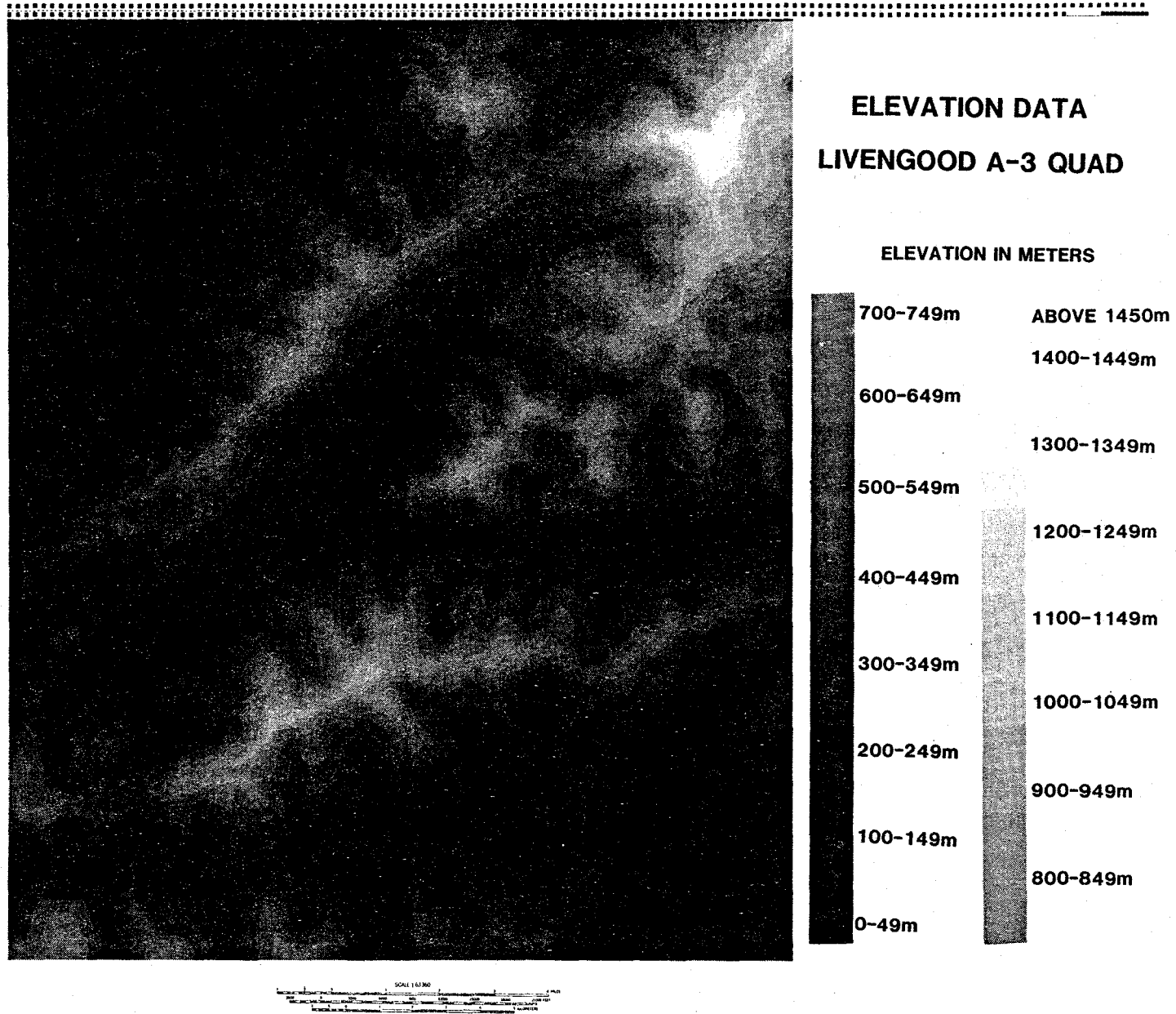


Figure 8. Elevation Data For The Livengood A-3 Quad.

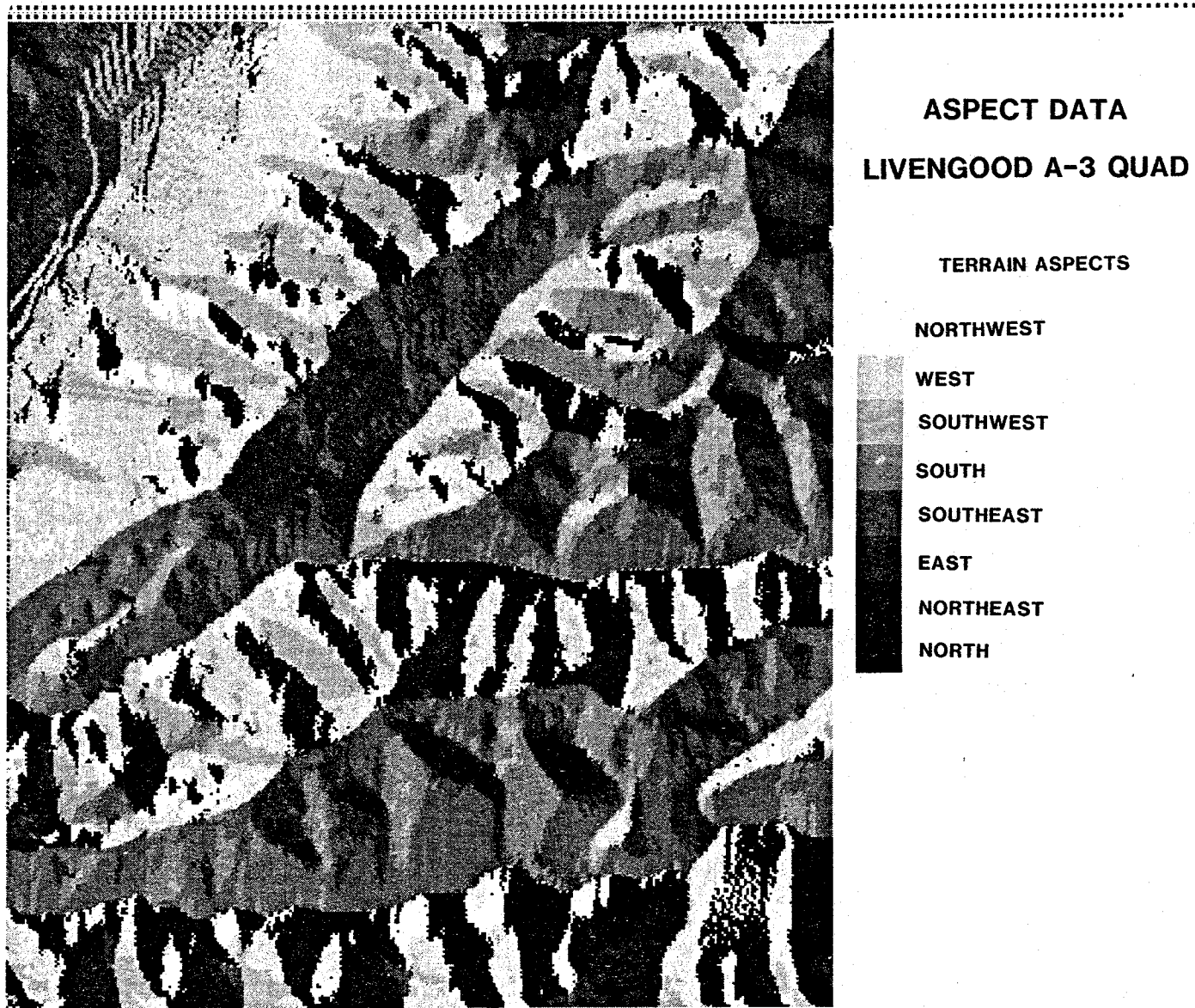


Figure 9. Aspect Data For The Livengood A-3 Quad.

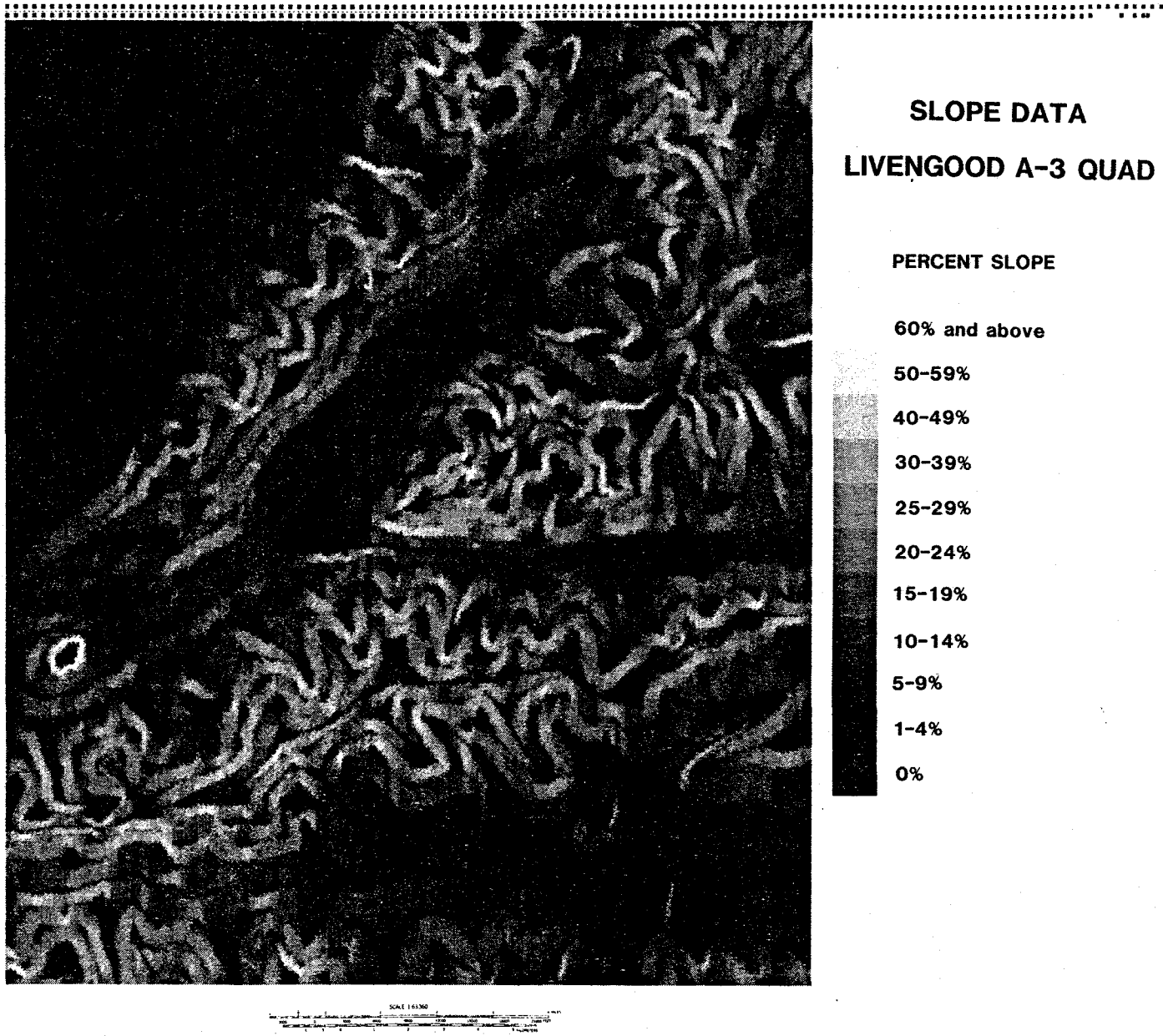


Figure 10. Slope Data For The Livengood A-3 Quad.

<u>Class</u>	<u>Principal Cover Type</u>	<u>Type</u>	<u>Decision for Stratification</u>	<u>New Class</u>
1	WS2/3 SAW and BS2/3	DEM	above elev. 8 - BS2/3	50
2	WS/BS3	Rename		
4	Black Spruce Bog	Rename		
5	AB3POLE/SAP	Rename		
6	AB2POLE/SAP	Rename		
8	AB3POLE/2SAW	Rename		
12	AB3POLE/2SAW	Rename		
15	AB2POLE/SEED	Rename		
19	Shrub	DEM	elev. 1-4 - shrub bog above 13 - alpine	51 52
20	Shrub tundra	DEM	elev. 1-4 - shrub	53
22	Barren	DEM	elev. 1-4 - deep water elev. 4-11 - shrub	54 55
23	Barren	DEM	elev. 1-2 - deep water elev. 3-11 - black spruce	56 57
24	Barren	DEM	elev. 1-4 - grass/sedge	58
25	Barren	Manual		
27	Shrub	DEM	elev. 3-11 - shrub above elev. 11 - shrub tundra	59 60
28	Shrub bog	DEM	above elev. 11 - shrub tundra	61
29	Grass and sedge	DEM	above elev. 9 - shrub tundra	62
30	Shrub	Rename		
31	Shrub bog	DEM	elev. 4-13 - shrub above elev. 13 - alpine	63 64
32	Deep/clear water	DEM	above elev. 6 - barren	65
34	Shallow/sedimented water	DEM	above elev. 4 - barren	66
38	Barren	Rename		
39	Barren	Rename		
40	Shrub	Rename		

Table 3. Stratification Decisions.

urban area, or in higher elevations of the White Mountains/Wickersham Dome area. The correct identification of spectral classes is required prior to stratification and is dependent on two major factors: availability of CIR photography for checking classes and the experience and ability of the photo-interpreter.

Manual stratification of the three scenes was completed on IDIMS using the ZIP function. Areas of misclassified pixels were located and isolated within polygons by using the COMTAL display and the track ball to locate vertice points. Pixels within the specified polygons were then reassigned to a different spectral class (either an existing class or a new one). The new spectral classes were then assigned to actual land cover categories, thereby correcting the initial spectral confusion. A few confusion classes in Minto Flats had to be changed from barrens to sedimented water; some barren classes were also confusing with commercial/industrial classes in Fairbanks; some minor misclassification problems were also identified and corrected along the Tanana River.

Renaming categories involves changing a specific category or a number of categories to a more representative general class name. A good example of this would be to combine two confusion classes aspen and birch into one class, hardwood. A number of confusion classes were renamed during the stratification process into a more generalized class or a composite class. A black spruce class with a low stand density (code 1) was renamed as black spruce bog because of the domination of a low shrub understory. By further grouping categories, an even more generalized cover type map can be developed.

Another method of correcting for misclassified pixels throughout the scene involves the use of ancillary data sets. With the development of DEM terrain data, vegetation can be identified by its topographic position. With knowledge of cover type characteristics and their responses in differing topographical environments, classification errors can be identified by comparing the distribution of spectral classes with ground truth information (Figure 11). In this project, three data sets were developed from the DEM files to aid in the classification of the cover types. The three data sets, elevation, slope, and aspect were used as individual layers with the classified data. DEM stratification is employed in a manner similar to manual stratification except DEM boundaries correspond to terrain variables. Each elevation level, aspect direction or percentage of slope is actually a polygon. If the elevation range of black spruce is known to be zero to nine hundred meters (0-900m) and there are pixels for this class above 900m then a simple stratification process can be used to correct the misclassified data and give it a new class name. Using the two

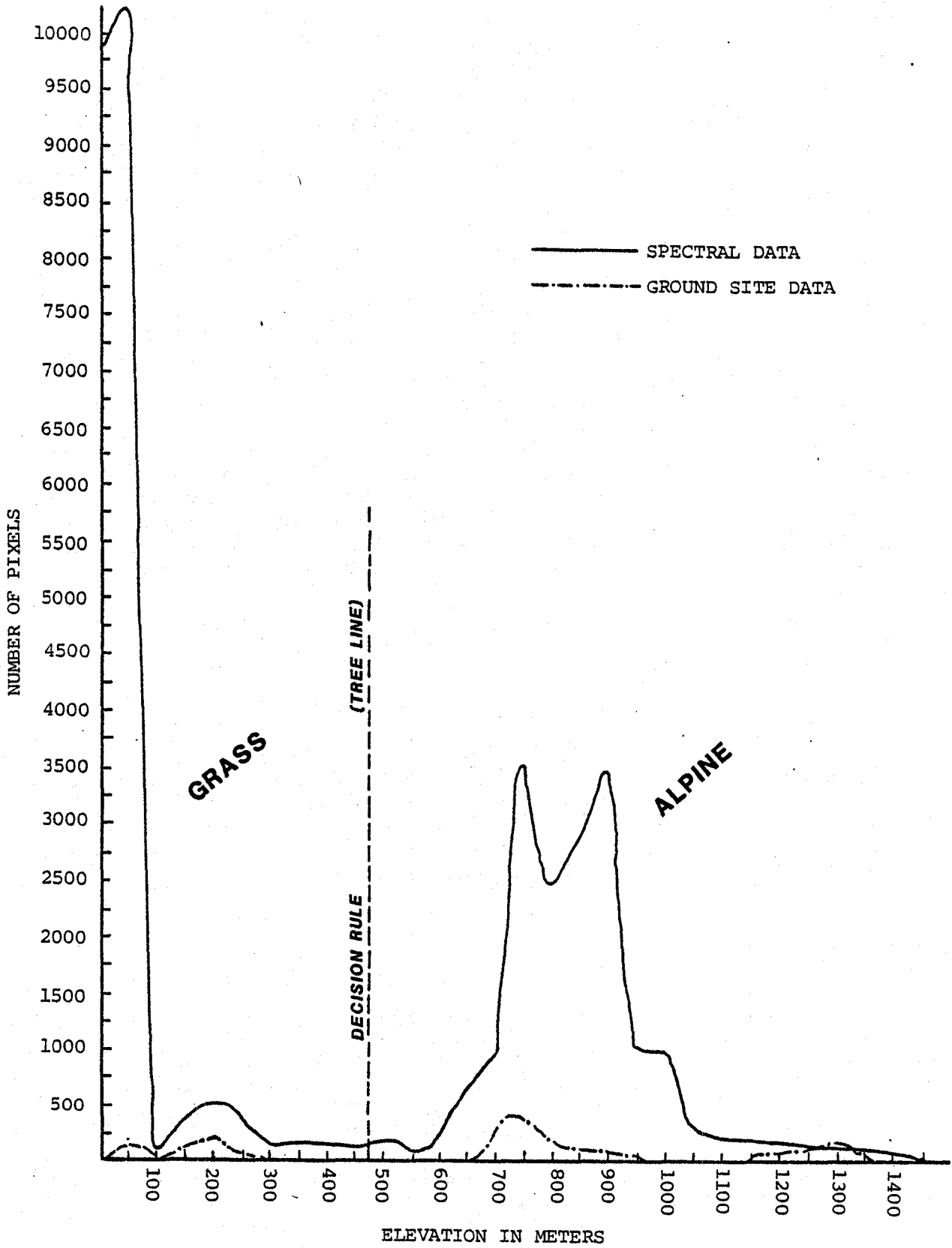


Figure 11. Determination of DEM Stratification Rules.

data sets -- classified data and topographic elevation data, a simple stratification model can be constructed. In simple terms, the two data sets are overlaid and the user specifies that wherever the computer locates black spruce pixels above 900m (or the area represented as being above 900 meters) to reassign those pixels to a new class. The same procedure can be followed with any data set as long as the analyst has enough information about the classes and vegetation/topographic relationships in order to develop the model.

The elevation data was found to be most useful of the ancillary data sets for stratification. Twelve classes were changed using the elevation data set as a stratifying layer. Sixteen new classes were created from the twelve confusion classes. Upon completion of the final DEM stratification, 66 spectral classes were grouped into 16 land cover categories and then smoothed to a ten acre minimum mapping unit. Grouping is the process where numerous classes are grouped together and generalized to desired resource categories. Class assignments are still reliable with groupings but it effectively eliminates more detailed information known about each spectral class. Table 4 shows how the 66 classes were grouped to 16 land cover categories. Once the data had been grouped it was ready for smoothing.

Smoothing of the 16 category classified data was carried out on the CDC 7600 using the program RECLAS. In the RECLAS program a nine pixel block window, is passed over the classified data. The window centers on the middle pixel of the nine pixel block, and each center pixel is compared to its eight surrounding neighbors and reassigned based on the dominant values of those neighbors. Smoothing enhances the classified data visually by removing the random, isolated occurrence of single pixels and thus generalizing land cover patterns. This post-processing step simulates a ten acre minimum mapping unit.

### Output Products

Final output products for the Forestry Project include color coded maps and tabular acreage summaries for the Livengood A-3 1:63,360 quad and the full classified data set. Positive and negative 4 x 5" film transparencies were generated using the DICOMED film recorder and a set delivered to ANDR to facilitate reproduction requests. In order to meet the requirements of ADNR, the final smoothed classification was reproduced at a scale of 1:250,000 (see Figure 12), and the Livengood A-3 quad data reproduced at a scale 1:63,360 (see Figure 13). Elevation, slope, and aspect were also reproduced for the Livengood A-3 quad as versatec plotter maps.

-77-

<u>FINAL LAND COVER CATEGORIES</u>	<u>CANOPY COVER</u>	<u>STAND SIZE</u>	<u>SPECTRAL CLASSES</u>
1 Conifer 2/3	40-100%	All	1,2,47,50
2 Black Spruce 2	40-69	Sapling	3,57
3 Black Spruce Bog	25-39	Seedling/Sapling	4
4 Aspen and Birch3Pole/Sapling	70-100	Poletimber/Sapling	5,13,14
5 Aspen and Birch2Pole/Seedling	40-69	Poletimber/Seedling	6,15,48
6 Aspen and Birch3Pole	70-100	Poletimber	7,9,10,11,16,17,18
7 Aspen and Birch3Pole/2Saw	70-100	Poletimber	8,12
8 Shrubland	40-69	Sawtimber	19,27,30,40,53,55,59
9 Shrub Tundra			20,60,61,62,63
10 Alpine Tundra			21,52,64
11 Barrens			22,23,24,25,26,37,38,39,65,66
12 Shrub Bog			28,31,51
13 Sedge and Grass			29,58
14 Deep and Clear Water			32,33,44,54,56
15 Shallow and Sedimented Water			34,35,36,45,49
16 Urban			46

Table 4. Grouping of the Spectral Classes Into Cover Categories.





Figure 12A. Color Legend for the Forestry Classification.

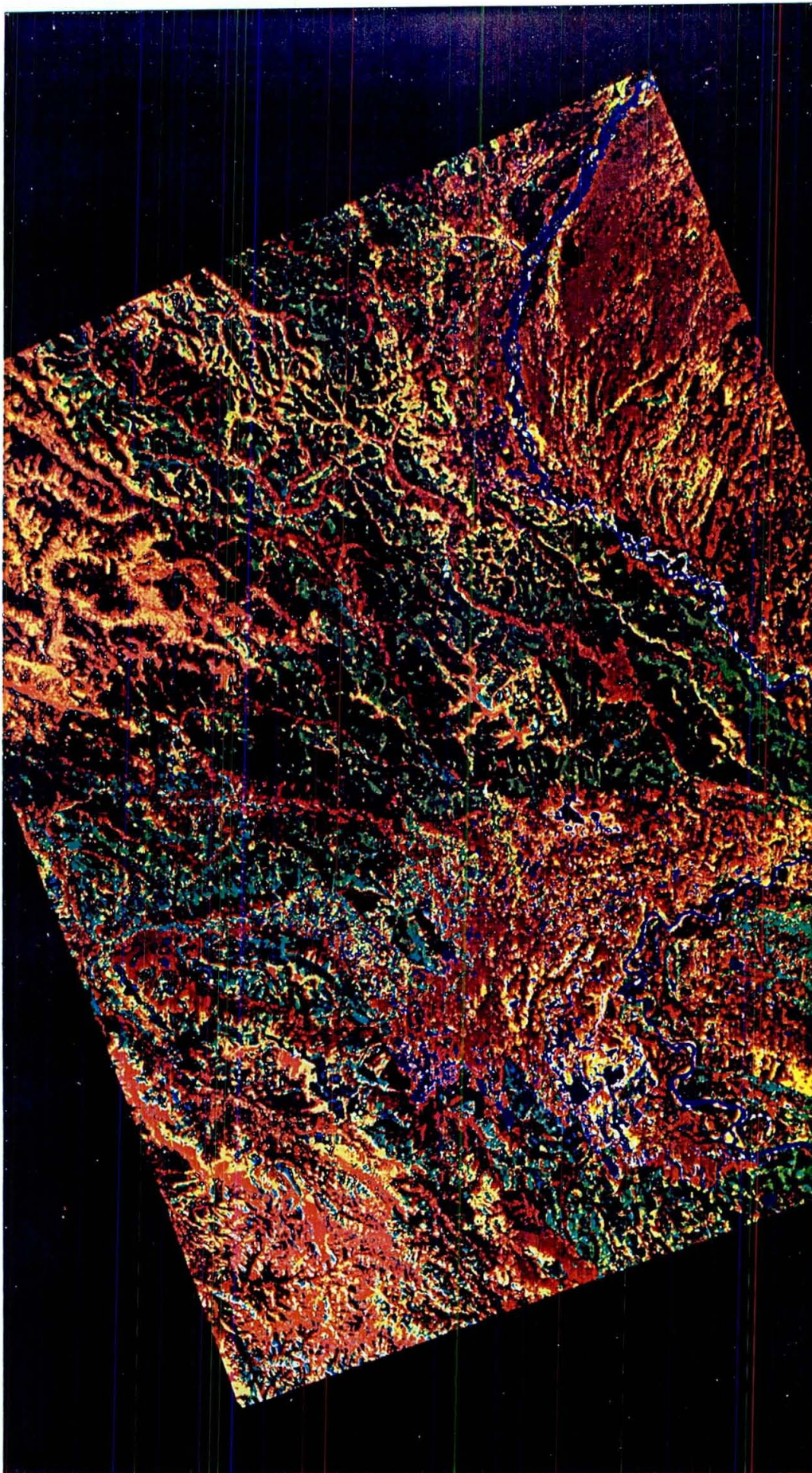


Figure 12B. Classification of Full Data Set.

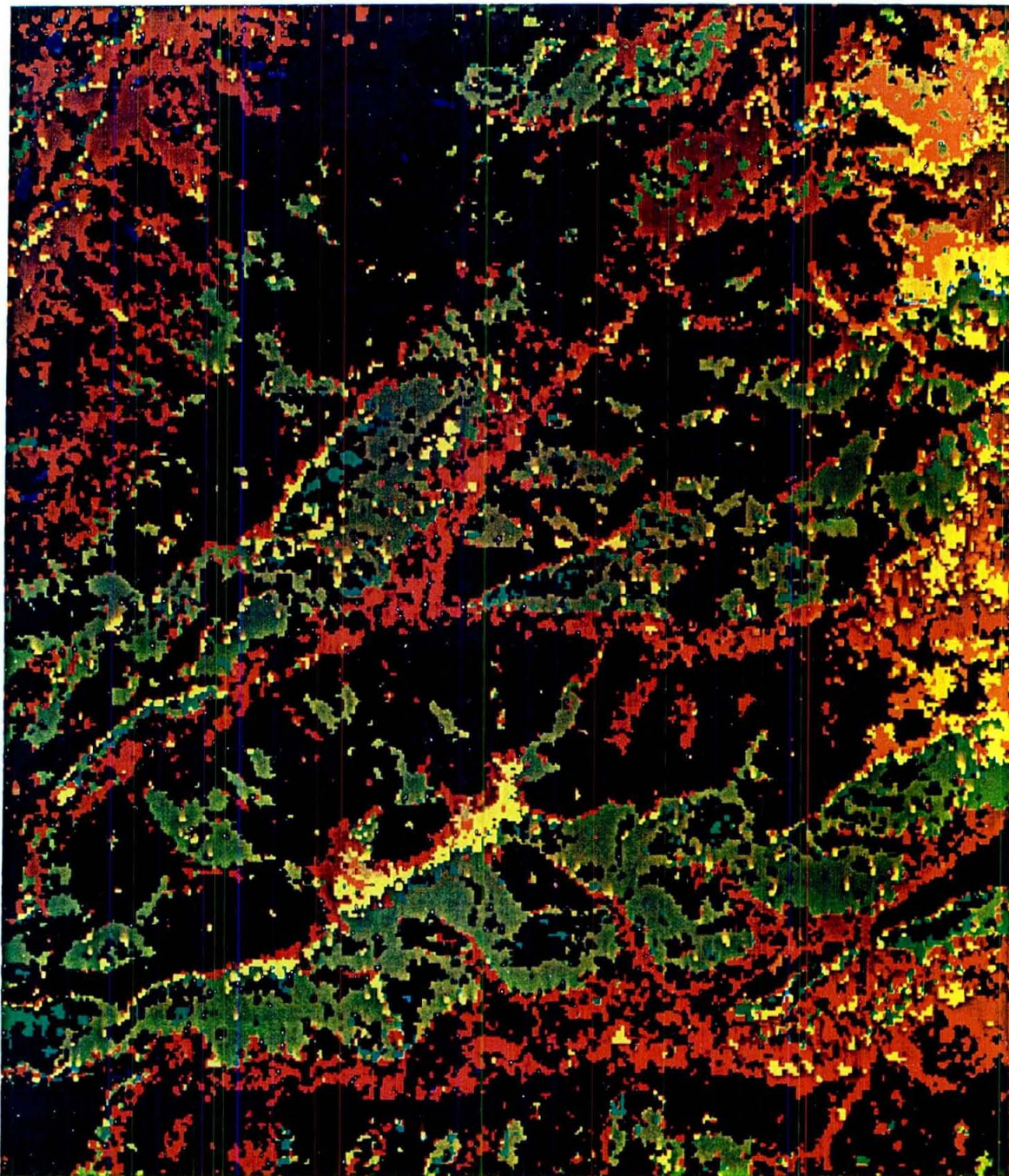


Figure 13. Classification of the Livengood A-3 1:63,360 quad.

Tabulation by land cover category, acreage and percent of total, were generated for the full data set and the Livengood A-3 quad (see Tables 5 and 6). Within the study area, forests cover about 2.2 million acres or 63% percent of the total area. Roughly another 32.3 percent consist of shrubs, bogs and tundra. The balance is barren rock and soil at high elevations and along the Tanana River. Although forests are found throughout the study area, the better stands are generally confined to the lower slopes and valleys of the larger rivers and their main tributaries. A summary of the distribution of cover types by slope, aspect and elevation can be found in Table 7.

Full Data Set

<u>Cover Type</u>	<u>Acres*</u>	<u>Percent of Total</u>
Conifer 2/3	293,937.2	8.5
Black Spruce 2	683,384.3	19.7
Black Spruce Bog 1	529,555.3	15.3
AB3Pole/Sapling	156,890.4	4.5
AB2Pole/Seedling	20,332.5	.6
AB3Pole	196,783.1	5.7
AB3Pole/2Saw	325,341.1	9.4
Shrub	279,183.3	8.0
Shrub Tundra	100,101.9	2.9
Alpine Tundra	33,940.8	1.0
Barrens	24,383.4	.7
Shrub Bog	667,154.9	19.2
Sedge and Grass	40,455.5	1.2
Deep and Clear Water	24,383.4	.7
Sedimented and Shallow Water	77,547.3	2.2
Urban	<u>15,671.5</u>	<u>.4</u>
TOTAL	3,469,234.3	100%

Livengood A-3 Quad

<u>Cover Type</u>	<u>Acres*</u>	<u>Percent of Total</u>
Conifer 2/3	38,289.5	23.9
Black Spruce	50,171.0	31.3
Black Spruce Bog 1	19,600.3	12.2
AB3Pole/Sapling	2,905.3	1.8
AB3Pole/Seedling	95.5	.1
AB3Pole	5,431.7	3.3
AB3Pole/2Saw	24,089.6	15.1
Shrub	4,558.3	2.8
Shrub Tundra	2,637.2	1.7
Alpine Tundra	1,000.3	.6
Barrens	260.9	.1
Shrub Bog	10,620.2	6.6
Sedge and Grass	537.9	.3
Deep and Clear Water	187.8	.1
Sedimented and Shallow Water	139.7	.1
Urban	<u>0</u>	<u>-</u>
TOTAL	160,525.2	100%

\*Based on .8028 acres per pixel.

Table 5. Acreage Summaries By Cover Type For The Full Data Set And The Livengood A-3, 1:63,360 Quad.

<u>Cover Type</u>	<u>Acres</u>	<u>Percent of Total</u>
<u>Forest Land</u>	2,206,224.4	<u>63.7%</u>
Conifer	1,506,879.3	43.5
Hardwood	699,345.1	20.2
<u>Non-Forest Land</u>	<u>1,263,009.9</u>	<u>36.3%</u>
Shrubland	279,183.3	8.0
Shrub Tundra	100,101.9	2.9
Alpine Tundra	33,940.8	1.0
Barrens	24,383.4	.7
Shrub Bog	667,154.9	19.2
Sedge and Grass	40,455.5	1.2
Deep and Clear Water	24,571.3	.7
Sedimented & Shallow Water	77,547.3	2.2
Urban	<u>15,671.5</u>	<u>.4</u>
TOTAL	3,469,234.3	100%

Table 6. Acreage Summaries for Aggregated Land Cover Categories (Full Data Set).

COVER CLASS	ELEVATION		SLOPE		ASPECT	
	RANGE	MEAN	RANGE	MEAN	RANGE	MEAN
(1) CONIFER 2/3	150-699 meters	500-549 m	5-49%	20-24%	N, NE, E, SE, S, SW	SE
(2) BLACK SPRUCE 2	100-799 m	500-549 m	1-39%	20-24%	E, SE, S, SW, W, NW	NW
(3) BLACK SPRUCE BOG	50-499 m	250-299 m	1-49%	20-24%	W, NW, N, NE, E	N
(4) AB3POLE/SAP	100-699 m	550-599 m	1-49%	20-24%	E, SE, S, SW, W	S
(5) AB2POLE/SAP	100-549 m	350-399 m	5-39%	20-24%	NW, N, NE, E, SE	NE
(6) AB3POLE	200-699 m	550-599 m	5-59%	25-29%	N, NE, E, SE	NE
(7) AB3POLE/2SAW	200-699 m	450-499 m	5-49%	20-24%	E, SE, S, SW	S
(8) SHRUB	100-549 m	300-349 m	1-49%	20-24%	SE, S, SW, W, NW, N, NE	W
(9) SHRUB TUNDRA	150-649 m	350-399 m	5-59%	30-39%	N, NE, E, SE	NE
(10) ALPINE TUNDRA	650-1299 m	1100-1149 m	0-29%	5-9%	NE, E, SE, S, SW	SE
(11) BARRENS	0-599 m	250-299 m	0-24%	10-14%	N, NE, E, SW, W, NW	NW
(12) SHRUB BOG	0-99 m	300-349 m	5-59%	20-24%	E, SE, S, SW, W, NW	SW
(13) SEDGE & GRASS (BOG)	0-49 m	150-199 m	5-59%	20-24%	E, SE, S, SW, W, NW	SW
(14) DEEP & CLEAR WATER	0-99 m	150-199 m	5-49%	20-24%	N, NE, SE, S, SW, W, NW	W
(15) SHALLOW & SEDIMENTED WATER	0-99 m	200-249 m	5-39%	15-19%	E, SE, S	SE
(16) URBAN	50-149 m	150-199 m	5-39%	20-24%	E, SE, S, SW	S

\* Based on 1 standard deviation from Mean (68.26%).

TABLE 7. ECOLOGICAL ATTRIBUTES OF THE TANANA FORESTRY PROJECT COVER CLASSES.

## CHAPTER IV FIRE HAZARD MODEL

The Tanana Valley has been subject to extensive and repeated fires (Lutz, 1956). Relatively low precipitation, long hours of sunshine during the summer and high air temperatures increase the fire hazard. Fire is one of a number of factors responsible for the great complexity of vegetative patterns in the valley. Sharp boundaries between vegetation types are most frequently caused by fire; those caused by topography represent a gradual change. Historical fires have to a large degree determined the present distribution of forest stands throughout the study region. The economic importance of timber resources has led to an increased awareness of fire protection planning and the need for accurate data showing the spatial occurrence of specific cover types.

To further demonstrate the utility of remote sensing technology used in conjunction with a geo-based information system (GIS), NASA and ADNR developed a fire hazard model for the study area using the timber type map and digital terrain data. This hazard classification can be a valuable tool for initial attack planning, and determining the need for and location of fuel and firebreaks. The fire hazard classification employs a relative ranking of vegetation and slope - factors which contribute to the spread of fire, destructive potential, and difficulty of control or suppression.

There is general agreement that the most important natural factors influencing wildfire behavior are fuels, topography, and weather (Moore, 1981). Fuels are generally based on broad vegetation types which display similar burning characteristics. For example, certain vegetation types are known for their high crowning potential. These include hardwoods after leaf fall and black spruce forests. In contrast, green hardwoods and tundra pose a relatively low hazard. The study region falls within one hot and dry climatic zone based on the precipitation effectiveness index (Trigg 1971). More detailed climatic data for the study region was not available, thereby necessitating a simplified hazard model. Topography affects wildfire behavior in a variety of ways (Moore, 1981), indirectly through its influence on fire suppression activities. Increasing slopes produce increasing difficulties and time delays in fire control efforts. On level ground or slopes up to approximately 30 percent of the full range of tools and tactics are available to the fire fighter. Between 30% and 60% slope, bulldozers can still be used, but safety hazards increase with slope. On slopes in excess of 60%, firefighting requires hand crews and aircraft. Slope, therefore, greatly affects fire suppression efforts.

Cover type classes were combined with slope classes to create the fire hazard model. The modeled data consisted of fourteen classes, developed from six generalized land cover classes and three slope levels. The timber type vegetation classes were grouped into five fire fuel categories based on an Alaskan adaptation of the National Fire-Danger Rating System (Barney, 1969). The cover categories are ranked according to fuel rating beginning with conifers (highest fuel rating) and progressing to the lowest hazard level as follows:

- Conifers
- Hardwoods
- Shrubs (including Shrub tundra)
- Shrub bogs
- Other (barren, urban)
- Water

Water, barrens, and urban were rated as no hazard (based on the burning index) while the four vegetative cover types were rated as high, intermediate or low hazard depending on the severity of slope on which each class was located. Slope was grouped into three generalized classes similar to the proposed National Wildfire Hazard Classification System (Moore 1981). The lowest hazard class was comprised of slopes from 0-9%, with an intermediate hazard from 10-29% slope, and a high hazard represented by slopes greater than 30%. These slope classes are representative of the degree of accessibility of certain types of fire fighting equipment. The hazard modeling was completed on the HP-3000 computer using the ESRI software module "GRDMDLN". The fire hazard model is shown in Figure 14 (full data set) and Figure 15 (Livengood A-3 quad).

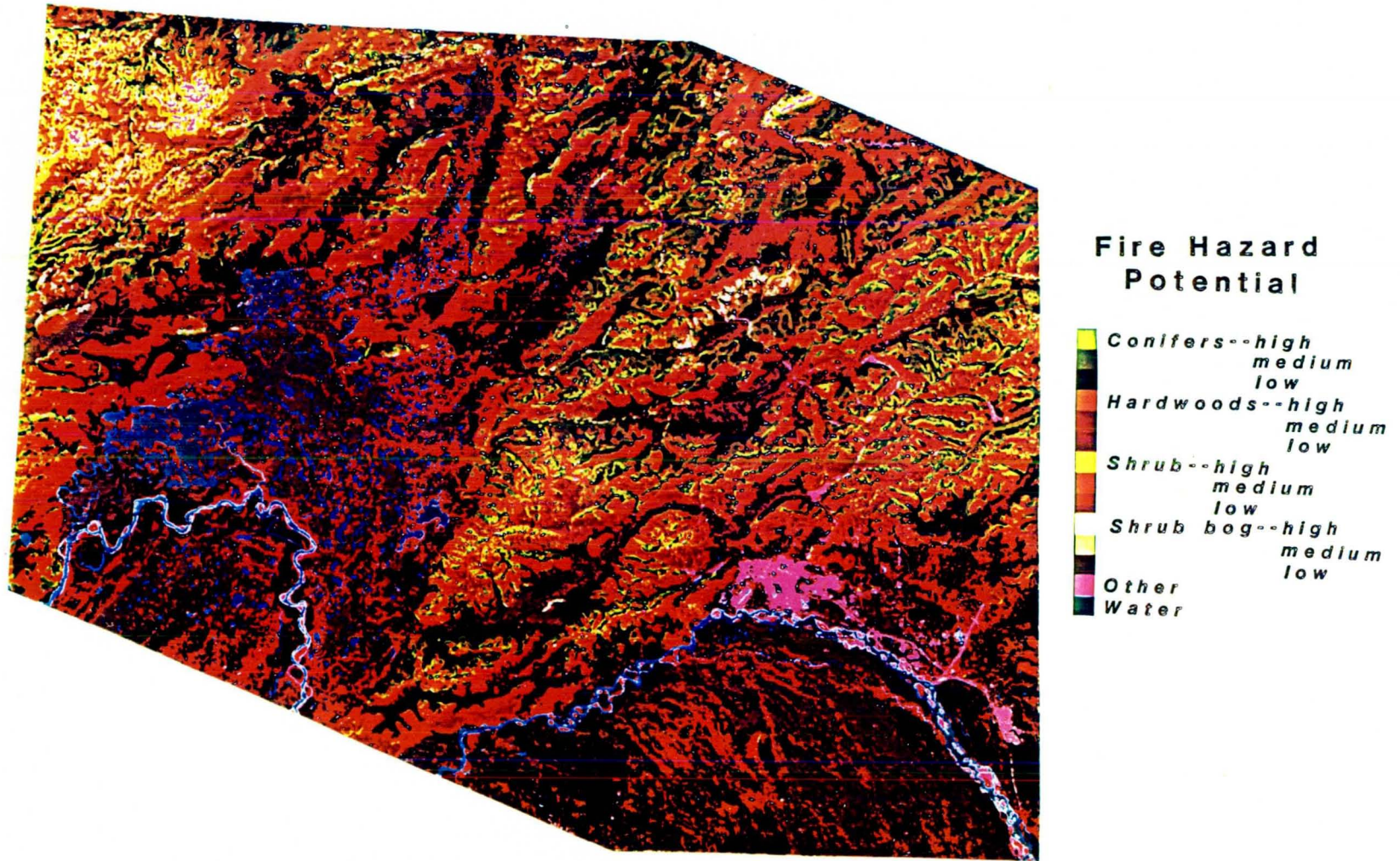


Figure 14. Fire Hazard Model for the Full Data Set. Classification was developed using cover type and slope data.

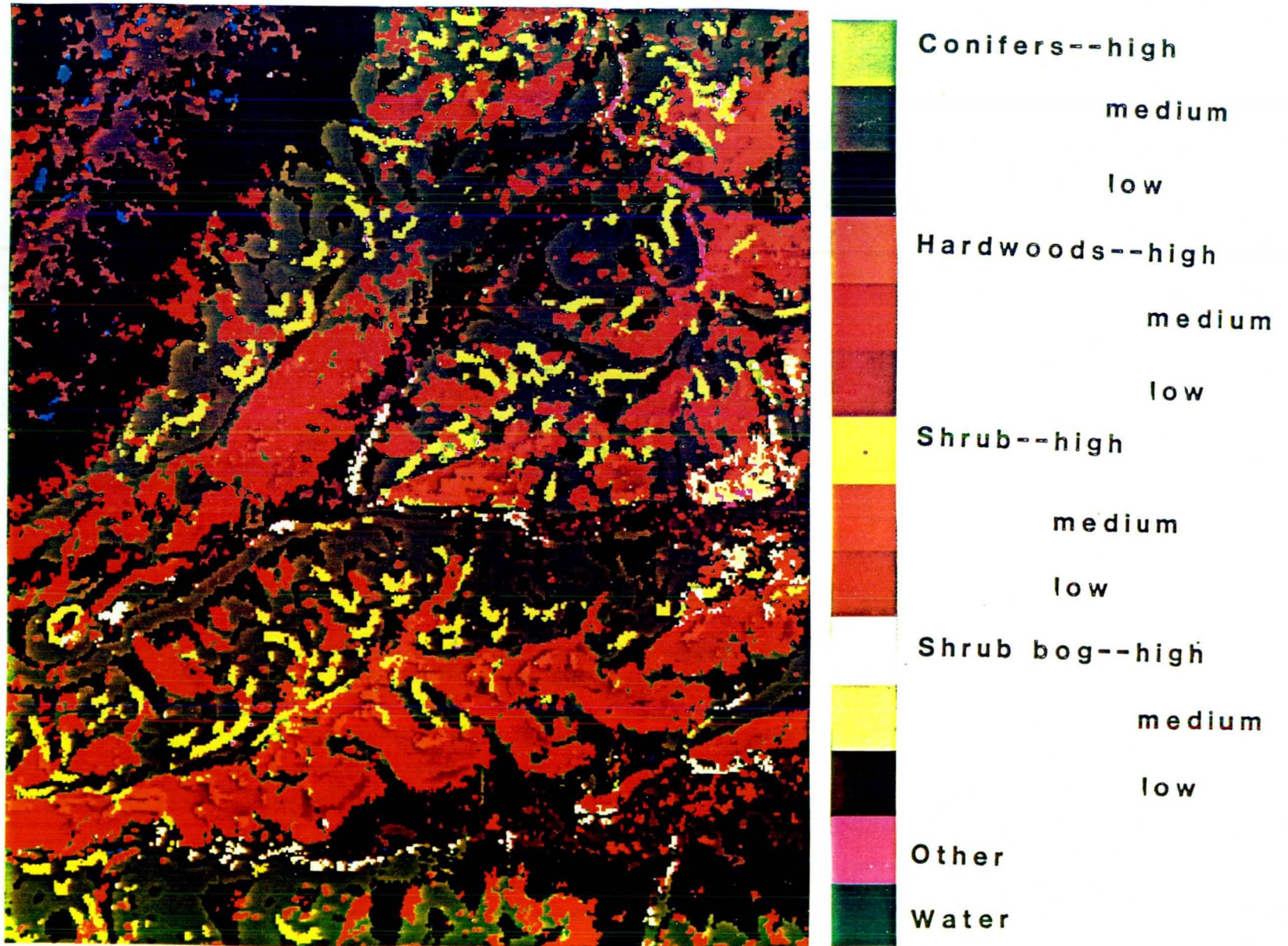


Figure 15. Fire Hazard Model for the Livengood A-3 Quad. Classification was developed using cover type and slope data.

## CHAPTER V CONCLUSIONS

### Results and Recommendations

Results indicate that the use of topographic data significantly improved the overall land cover classification reliability and enhanced the ability to discriminate forest cover types. Elevation data was found to be the most valuable terrain variable for distinguishing spectrally similar, yet unique cover types. Spectral separability between forest cover types showed significant improvement with the use of a multi-date data set representing two phenological stages. Spectral reflectance of deciduous trees and shrubs was high in the infrared bands and low in the visible bands for the August scene, exhibiting a lush, luxuriant green vegetation, in contrast to the senescent deciduous leaves of the September scene. Somewhat unexpectedly, separability of reflectance for forest types was better in the September scene than in the August scene. Further product evaluation and accuracy verification is to be completed by ADNR.

Ecological diversity and a complex mix of physiographic provinces made the determination of significant vegetation/terrain relationships difficult. For instance, the treeline ranged from 500 to 1100 meters, indicative of the vegetation variability within the study area. In addition, changing vegetation patterns resulting from previous fires, which serve to alter the underlying permafrost depth, further complicated the environmental relationships between vegetation and topographic position. The removal of litter by fire results in higher surface temperatures and a retreat in any underlying permafrost, thereby causing the vegetation to revert to an earlier successional stage.

Many shortcomings in the classification are directly related to the ground sites used in the development of cluster statistics. For instance, a mixed coniferous/hardwood forest class signature was not attainable due to limitations in training sites. One cannot characterize a specific forest type and evaluate the reliability of a spectral class based on only one ground observation. Even in cases where there were a small number of training sites (mixed and white spruce forest), all possible variations in slope, aspect and elevation were not included. Mapping improvements could have been realized with 1) randomly distributed ground sites (or photo plots) and 2) two sets of ground observations - one for cluster development and one for evaluation. Both of these improvements would have increased the cost of data gathering and were beyond ADNR agency budget constraints.

The Landsat derived forestry map developed for ADNR to demonstrate satellite technology also provides a data base (Figure 16) for specialized study needs. The usefulness of this data base can be extended beyond its primary use as a forest cover map. The application and inference of related environmental factors to forestry classes can provide the basis for:

- Land Suitability/Capability Mapping
- Habitat Evaluation
- Historical Fire Pattern Analysis
- Fire Fuels Mapping
- Harvestability/Accessibility Studies

A fire hazard model was developed to demonstrate the added utility of remote sensing technology when used in conjunction with terrain data in a geo-based information system. Five broad classes representing vegetation types with similar burning characteristics were mapped according to three generalized slope classes to determine fire fighting equipment routing and mobility. The fire hazard model will provide valuable information for initial attack planning equipment, routing and the location of firebreaks.

The analysis of multi-date Landsat digital data is an efficient and cost effective technique for reliably mapping timber resources over large geographic areas. Digital terrain data has been found to be beneficial for improving land cover mapping and providing increased capability for specialized modeling-fire hazard classification. The on-going success of this demonstration project will involve the continued support and determination of agencies within the state to incorporate remote sensing technology into their operational activities. ADNR will play a key role in utilizing this data base for resource planning and management.





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APPENDIX A. PROJECT PARTICIPANTS.

AGENCY PARTICIPANTS

JOE WEHRMAN  
DIVISION OF FORESTRY (ADNR)

DAN WIECZOREK  
DIVISION OF FORESTRY (ADNR)

MARTY WELLBOURN  
DIVISION OF RESEARCH AND DEVELOPMENT (ADNR)

TONY BURNS  
MUNICIPALITY OF ANCHORAGE

PEGGY MCNEES  
DIVISION OF RESEARCH AND DEVELOPMENT (ADNR)

JAMES A. ANDERSON  
DIVISION OF TECHNICAL SERVICES (ADNR)

STERLING POWELL  
SOIL CONSERVATION SERVICE (USDA)

RIKKI FOWLER  
DEPARTMENT OF ENVIRONMENTAL CONSERVATION

NASA/AMES RESEARCH CENTER

DONALD E. WILSON

LESLIE A. MORRISSEY (TGS)

VINCENT G. AMBROSIA (TGS)



## Appendix B

### CHARACTERISTICS OF LANDSAT SATELLITE DATA (1)

To provide the non-technical users of this document with an understanding of remote sensing, a brief description of the Landsat system is presented in this section.

#### LANDSAT SATELLITE DATA

Remote sensing is not a new concept in land use and resource management. Aerial photography has been used for many years as a basic tool in surveying land areas. The complete Landsat system consists of an observatory or observatories in near-polar Earth orbit and ground installations to receive, process and distribute the data provided by the sensors carried on the satellites.

The acquisition of remote-sensor imagery depends upon the detection and recording of electromagnetic energy reflected or emitted from surfaces of natural or man-made features that are within the field of view of the sensor. When energy (sunlight) strikes a feature it is either reflected, absorbed, or transmitted. The degree of reflection, absorption or transmission is a function of the properties of the material and the wavelength of the energy. Various earth resources and features respond differently to energy of various wavelengths depending upon their chemical and physical properties, surface configuration and roughness, intensity of illumination and angle of incidence. When earth resources and features are recorded on remote sensor imagery, the various responses of earth features form patterns which provide means for discrimination. Through analysis of these patterns and their relationships it is possible to deduce the identification of these patterns. Various types of remote sensors record in different energy bands. The multispectral scanner onboard Landsat records data in four different bands of the electromagnetic spectrum.

Landsat produces images of Earth--not with a camera but with a multispectral scanner (MSS). The multispectral scanner is a line-scanning device that uses an oscillating mirror to continuously scan perpendicular to the spacecraft's orbital path. The MSS records information in both visible wavelengths and in parts of the electromagnetic spectrum which are invisible to the

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(1) INTRISCA Final Report, NASA/Ames Research Center, 1981, 179 pages.

eye (near-infrared). The MSS records differences in sun reflectance from earth-surface features for each picture element. At an altitude of approximately 570 miles, Landsat circles the earth 14 times daily, scanning a particular geographic local every 18 days. This high volume of information, broad-area coverage, and repetitive sweeping provides a variety of opportunities for practical application of the data to resource and land use planning related tasks and problems.

Water, vegetation, minerals, and other natural and man-made features reflect light or emit radiation in different intensities for different bands of the electromagnetic spectrum. Each feature has its own unique reflection pattern, an identifying signature that makes it possible for remote sensors to differentiate surface features. The MSS takes four readings for each 1.1 acre area on the ground: one for the intensity of green light reflected, one for the intensity of red light reflected, and two for the intensity of infrared. These intensity levels are converted into electronic signals (digital form) that are sent to ground stations. This digital data is stored on computer tapes that can be used to analyze the 115 mile square Earth scene (although the MSS scans a continuous path, the data are blocked into a standard film format, thus providing a film product coverage for 115 miles on each side).

Landsat's singular advantage over conventional photographic systems is that it gathers data in a computer-compatible format that facilitates processing and use of the data. Landsat data can be used in either its photographic form or in its computer-tape (digital) form. If the photographic products are chosen for analysis the procedures are almost identical to those used for interpreting conventional aerial photographs. Compared to aerial photography, Landsat has been found to be a cost effective and reliable mapping tool. Approximately 5,000 frames of CIR photography (stereo coverage at 1:60,000 scale) is required to cover one scene of Landsat data. Computer processing (computer-aided analysis techniques) is more complicated than photo-interpretation but can be faster and can yield more detailed results. The computer can normally identify features of as small as 1.1 acre (pixel) while photo-interpretation techniques are generally limited to features of 5 to 10 acres or larger. Using the computer, data can be analyzed statistically and used to provide "classified" imagery highlighting specific types of land cover represented as color coded maps.

APPENDIX C. GROUND DATA FORMS.

Field No. \_\_\_\_\_

GENERAL

Observer \_\_\_\_\_ Date \_\_\_\_\_

Quadrangle \_\_\_\_\_ Latitude/Longitude \_\_\_\_\_

Locality \_\_\_\_\_

Photos Roll \_\_\_\_\_ Frame \_\_\_\_\_ CIR Frame and Date \_\_\_\_\_

PHYSIOGRAPHY (determine from topo map)

Elevation \_\_\_\_\_ Slope \_\_\_\_\_ Aspect N S E W

Position on Slope. (Toe, Mid, Upper, Ridge) \_\_\_\_\_

Macrorelief Lowland Transitional Mountainous Landform \_\_\_\_\_

VEGETATION (circle one)

Level I Forest Woodland Shrubland Tundra Grassland Bog Aquatic

Level II \_\_\_\_\_ Level III \_\_\_\_\_

Height	Community	Dominant Species		
_____	Overstory	1. _____	2. _____	3. _____
_____	Intermediate	1. _____	2. _____	3. _____
_____	Ground Layer	1. _____	2. _____	3. _____
_____	Surface Layer	1. _____	2. _____	3. _____

Cumulative Vegetative Cover \_\_\_\_\_ Forest Crown Cover \_\_\_\_\_ %

- |              |             |       |             |
|--------------|-------------|-------|-------------|
| 1. 95 - 100% | 4. 25 - 49% | _____ | Uniform     |
| 2. 75 - 94%  | 5. 10 - 24% | _____ | not uniform |
| 3. 50 - 74%  | 6. 0 - 9%   |       |             |

<u>Percentage Cover</u>	<u>Species according to dominance</u>
_____ Coniferous Trees	_____
_____ Deciduous Trees	_____
_____ Tall Shrubs (> 6 ft.)	_____
_____ Medium Ht. Shrubs (2-6 ft.)	_____
_____ Dwarf Shrubs (1/2-2 ft.)	_____
_____ Prostrate Shrubs (< 1/2 ft.)	_____
_____ Grass/Sedges	_____
_____ Forbs	_____
_____ Mosses & Lichens	_____
_____ Bare soil	_____
_____ Rock	_____
_____ Water	_____
_____ Litter _____ Other (specify)	_____

LAND USE (Circle one)

Level I Agriculture Residential Commercial/Industrial Level II \_\_\_\_\_

Soils: Sand Silt Clay Gravel Loam Stones Bedrock Peat

Soil Moisture: Dry Moist Saturated Standing water

COMMENTS: (over)



APPENDIX D. DETAILED GROUND SITE INFORMATION.

FORESTRY GROUND SITE INFORMATION

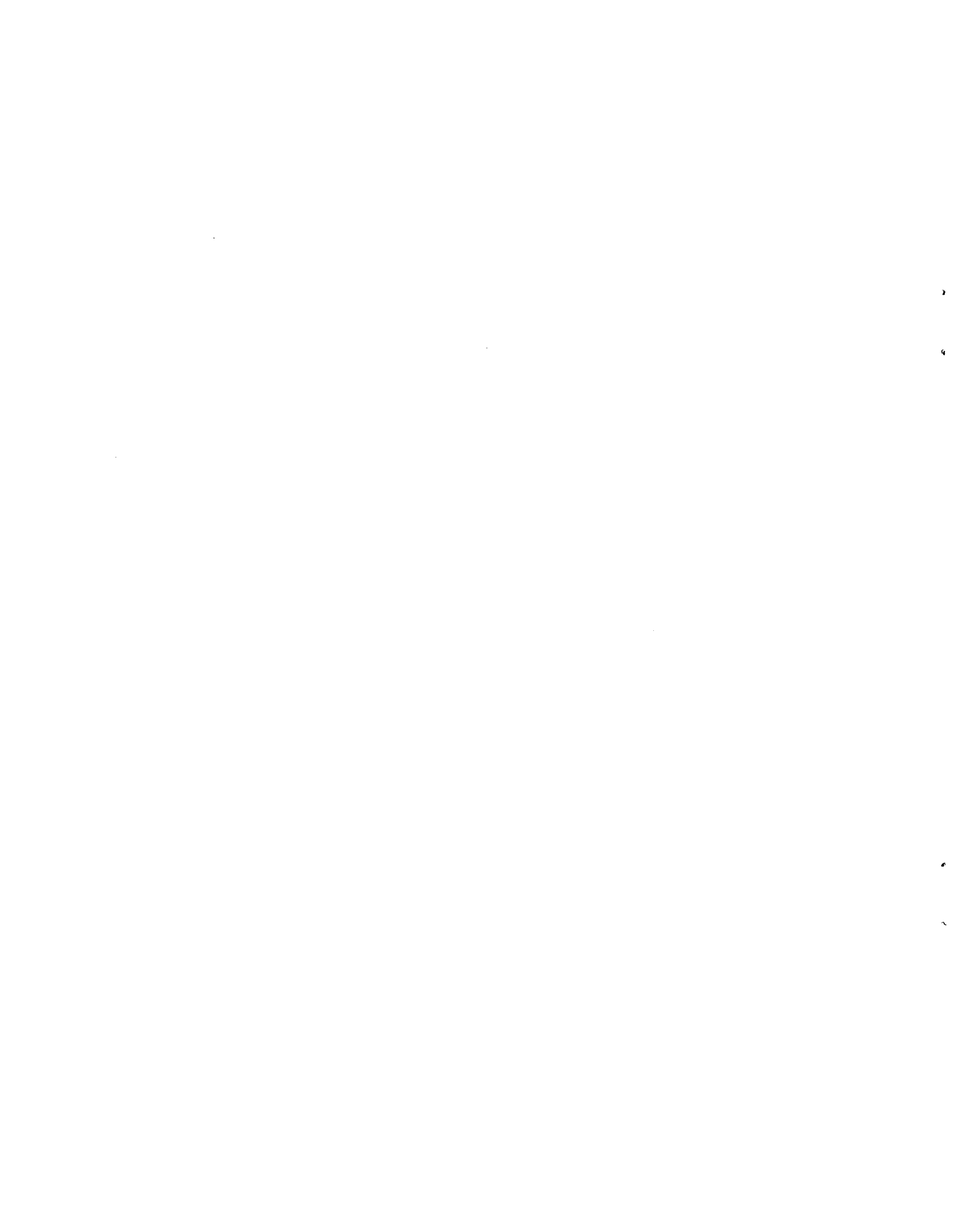
Site	CIR photo	Species	Crown Closure	Code	Stand Size	Ht.	Slope	Aspect	Elevation
1	8-3808	Aspen	90	3	Pole	3-55	17%	S	1400
2									
3	8-3810	Black Spruce	70	3/2	Seedling	6-25	10	NW	2120
4	8-3812	Aspen	95	3	Pole (small)	40-50	20	E	1130
5									
6	8-3812	Aspen/Birch	95	3	Pole (small)	30-45	10	SW	920
8									
9	8-3814	Black Spruce	80	3	Seedling	6-3	5	SW	1180
10	10-3910	Decid 50/bispr 30	80	3	Pole	8-35	25	SE	2020
11	10-3910	P. Birch	95	3	Pole	20-45	25	SW	1780
12	10-3910	25 b.s./shrub 65	25	1	Seedling	4-20	23	NE	2230
13	10-3906	P. Birch	90	3	Pole	30-45	18	SE	1670
14									
15	9-5505	P. Birch	95	3	Pole	35-55	15	SE	1520
16	7-5526	B. Spruce	70	3/2	Seedling	20-30	0	all	550
17	7-5528	Tundra (shrub)				2-6	0	all	430
18	6-3889	B. Spruce	50	2	Seedling	12-25	26	W	880
19	6-3895	B. Spruce	80	3	Seed/Sap	8-25	18	SW	2000
20									
21	6-3895	B. Spruce	85	3	Seedling	10-25	10	SW	1760
22	6-3895	B. Spruce	65	2	Seedling	8-20	15	NW	1740
23	5-5584	Decid Mix	70	3/2	Pole	30-40	15	SE	1500
24	5-5584	T. Tundra (shrub)				1/2-2	5	W	1810

## APPENDIX D. continued.

Site	CIR photo	Species	Crown Closure	Code	Stand Size	Ht.	Slope	Aspect	Elevation
25	5-5584	(P. Birch)	70	3/2	Pole	35-60	37	SE	1390
26	5-5582	Shrub	5			1/2-6	10	S	1760
27	5-5580	Shrub				1/2-6	10	SW	1800
28	4-3823	P. Birch	95	3	Sap	20-35	10	SW	830
29	4-3823	P. Birch	90	3	Pole	20-35	7	SW	750
30									
31	3-5611	P. Birch	60	2	Pole (small)	20-35	23	SE	1740
32	3-5611	Shrub				1/2	0		2420
33	3-5613	Aspen/birch	80	3	Pole/Sap	10-40	4	S	1540
34	3-5613	Shrub				1/2-6	0		1650
35	2-5666	Birch/Aspen	85	3	Pole (small)	20-43	0	SE	480
36	2-5666	Birch/Aspen	85	3	Pole/Sap	25-40	8	S	920
37	2-5670	Birch	95	3	Pole (small)	15-55	20	SE	
38	2-5670	Bk Spruce	50	2	Seed	2-30	15	NW	7360
39	1-5670	Bk Spruce	50	2	Seed/Sap	2-20	7	ESE	760
40	1-5688	Birch/Aspen	80	3	Pole	75-50	21	S	710
41	1-5688	Aspen	50	2	Seedling	8-20	32	S	1010
42	1-5688	P. Birch/Aspen	90	3	Pole	20-60	12	SSE	920
43	1-5690	P. Birch	90	3	Sap	15-55	15	E	1140
44	1-5690	Aspen/B. spruce	70	3	Pole	12-45	13	SSE	680
45	1-5690	P. Birch	90	3	Pole	40-55	20	S	1120
46	1-5690	White Spruce	60	2	Saw	50-80	0		450
47	1-5692	Aspen/Birch	60	2	Seedling	35-45	28	SE	1450
48	1-5692	Aspen/Birch	90	3	Pole (small)	12-40	12	S	970
49	22-9540	White Spruce	85	3	Pole	30-55	27	NW	1100
50	22-9540	Birch	70	3	Saw	6-80	13	ENE	1000

## APPENDIX D. continued.

Site	CIR photo	Species	Crown Closure	Code	Stand Size	Ht.	Slope	Aspect	Elevation
51	23-113	P. Birch	100	3	Pole	45-55	25		1200
52	22-9542	Aspen	100	3	Sap	20-30	15	SSE	1300
53	22-9542	White Spruce	60	2	Saw	80-100	10	SW	800
54	22-9542	W. Spruce/Birch	60	2	Saw	65-115	15	SSW	850
55	22-9542	Birch/Aspen	90	3	Pole	45-65	22	SE	1230
56	11-3750	P. Birch/Aspen	95	3	Pole	35-65	8	SE	880
57	22-9544	Aspen	80	3	Pole	60-70	20	SE	1000
58	22-9544	White Spruce	80	3	Saw	80-100	28	SW	1300
59	22-9544	Aspen	50	2	Saw	5-60	15	SSE	1200
60	22-9544	Aspen/Birch	85	3	Pole	55-65	18	ESE	900
61	22-9540	Birch	90	3	Pole (small)	35-40	32	NW	750
62	22-9540	Aspen	90	3	Pole	30	26	W	600
63									
64	22-9542	Rock					7	NE	1300
65	22-9542	Birch	95	3	Sap	20-25	25	ESE	1250
66	22-9542	Decid Mix	85	3	Pole	30-47	30	SE	1300
67	22-9542								
68									
69	2-5664	Black Spruce	90	3	Sap	35	8	E	1050
70	3-5611	Shrub Tundra				4	8	SW	2180
71	3-5611	Shrub Tundra				2	5	S	230
72	3-5611	Herb Tundra				1-1/2	1	N	1680
73	3-5613	Herb Tundra				1	1	SE	1520
74	5-5584	Black Spruce	50	2	Pole	20-30	12	SE	1260
75	1-5690	Black Spruce	40	2	Seedling	7-15	20	NE	970



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16. Abstract  As part of the third phase of the Alaska Applications Systems Verification and Transfer (ASVT) program, the National Aeronautics and Space Administration (NASA) and Alaska Department of Natural Resources (ADNR) embarked on a cooperative effort to test the feasibility of using Landsat digital data in conjunction with topographic data to map forest cover types in the Tanana River basin. The primary objective was to delineate commercial forests by stand size and crown closure. A modified clustering approach using two Landsat dates to generate an initial forest type classification was then refined with topographic data. To further demonstrate the ability of remotely sensed data in a fire protection planning framework, the timber type data were subsequently integrated with terrain information to generate a fire hazard map of the study area. This map provides valuable assistance in initial attack planning, determining equipment accessibility and fire growth modeling. The resulting data sets were incorporated into ADNR's geographic information system for subsequent utilization.					
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