VEGETATION CLASSIFICATION OF WILD TURKEY HABITAT IN UMPQUA NATIONAL FOREST USING COLOR AERIAL PHOTOGRAPHY

by

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TABLE OF CONTENTS

SUBJECT	PAGE
1. **Introduction**	1
A. Rio Grande Wild Turkey Project	1
B. Purpose of this Study	2
C. The Study Area	2
2. **Remote Sensing Options**	6
3. **Basis of Work**	8
A. Historical Background of Aerial Photography with Emphasis on Forestry Applications	8
1. Aerial Photography	8
2. Color Film	11
B. Air Photo Interpretation Principles	12
1. Interpretation	12
2. Recognition Elements	12
3. Stereoscopic Viewing	13
4. Photo Interpretation Keys	14
5. Photo Scale	16
6. Season and Time of Day Considerations	16
7. Radial Distortion	17
8. Tree Height Measurements	18
C. Equipment and Materials	19
1. Stereoscope	19
2. Kail Reflecting Projector	20
3. Topographic Maps and Orthophotoquads	21
4. Measuring Devices and Drafting Materials	22
5. Photo Interpretation Guides	23
6. Global Positioning System	23
D. Development of Classification System	24

4. South Umpqua Test Project

A. Classification System Development 33

B. Delineation of Project Area and Test Site 34

C. Interpretation, Classification, and Transfer of Data 34

D. Ground Truthing 35

E. Work and Cost Estimates 36

5. Project Execution 36

A. Interpretation and Classification 36

B. Transfer of Information and Final Product 36

6. Results and Conclusions 38

7. References 41

8. Appendices

1. Trees of the South Umpqua Basin 46
2. Interpretation Guides 50
3. Delineation of Effective Area 54
4. Work and Cost Estimate 59
5. Final Project Maps (Reduced) 60

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Abstract

This project focuses on the classification of vegetation as a habitat for wild turkeys. The vegetation classification discussed here is only one part of a study looking at habitat requirements, seasonal use patterns, and brood-rearing habits of wild turkeys in Southern Oregon. The vegetation classification was performed for an area of approximately 260 square miles in the South Umpqua Drainage Basin, largely within Tiller Ranger District, Umpqua National Forest. Traditional air photo interpretation methods were used with emphasis on those techniques which were fast and reasonably accurate.

1. INTRODUCTION

A. **Rio Grande Wild Turkey Project:** The native range of Rio Grande wild turkeys is the south-central plains of the United States. The breed was first introduced in Oregon in 1975, with 20 birds released near Medford (Durbin, 1975, 8). In 1982 and 1983, birds were inserted into Umpqua National Forest (UNF) at two locations; the first in the vicinity of Nichols Ranch and the other near Joe Hall Creek. From 1985 to 1989, birds continued to be released into suitable habitats within and around UNF (Keegan, 1989, 1).

In 1989, Professor John A. Crawford (Professor of Wildlife Ecology, O.S.U.) and Thomas W. Keegan (Graduate Research

Assistant, O.S.U) began an extensive study of Rio Grande wild turkeys within the western portion of the Tiller Ranger District, UNF. Their research goals focused primarily upon determining the birds' habitat requirements and seasonal use patterns. Additionally, roosting, nesting, and brood-rearing habits were analyzed. Between 1989 and 1991, extensive field work was conducted by Keegan, with most efforts centering on radio-telemetry to track birds within the study area.

B. **Purpose of this Study**: The purpose of this project was to perform a vegetation classification of the Rio Grande wild turkey study area, utilizing remote sensing techniques and augmented by a limited amount of ground truthing. No recent or current vegetation classification maps exist for the study area at a suitable scale. Vegetation classification maps produced during this project are being used as a tool to evaluate the movements and habits of wild turkeys in the study concurrently being conducted by Thomas Keegan. A significant factor in planning the execution of this project was a time constraint specified by Keegan. Due to his doctoral thesis requirements, the vegetation classification and final product had to be completed by March 31, 1993. This impacted directly on techniques used to perform the project. The major phases of the project are displayed on the next page (Figure 1).

C. **The Study Area**: Keegan's field work was centered around Nichols Ranch, approximately 12 km northeast of Tiller, in Douglas County, Oregon. Limits of the study area were determined by the movements of radio-equipped turkeys. The majority of the land within the study area boundaries is administered by the National Forest Service or the Bureau of Land Management. Small, privately owned parcels are intertwined amidst government land on the west side of UNF.

PROJECT PHASES
1. Defining the project requirements / goals.
2. Determining the best data source.
3. Preliminary preparation / knowledge honing.
4. Development of classification system.
5. Gather equipment and materials.
6. Perform test project to determine feasibility within time limits, ground truthing of classification system, and cost estimate.
7. Photo interpretation and classification.
8. Transfer of classification to overlays.
9. Generation of final product.

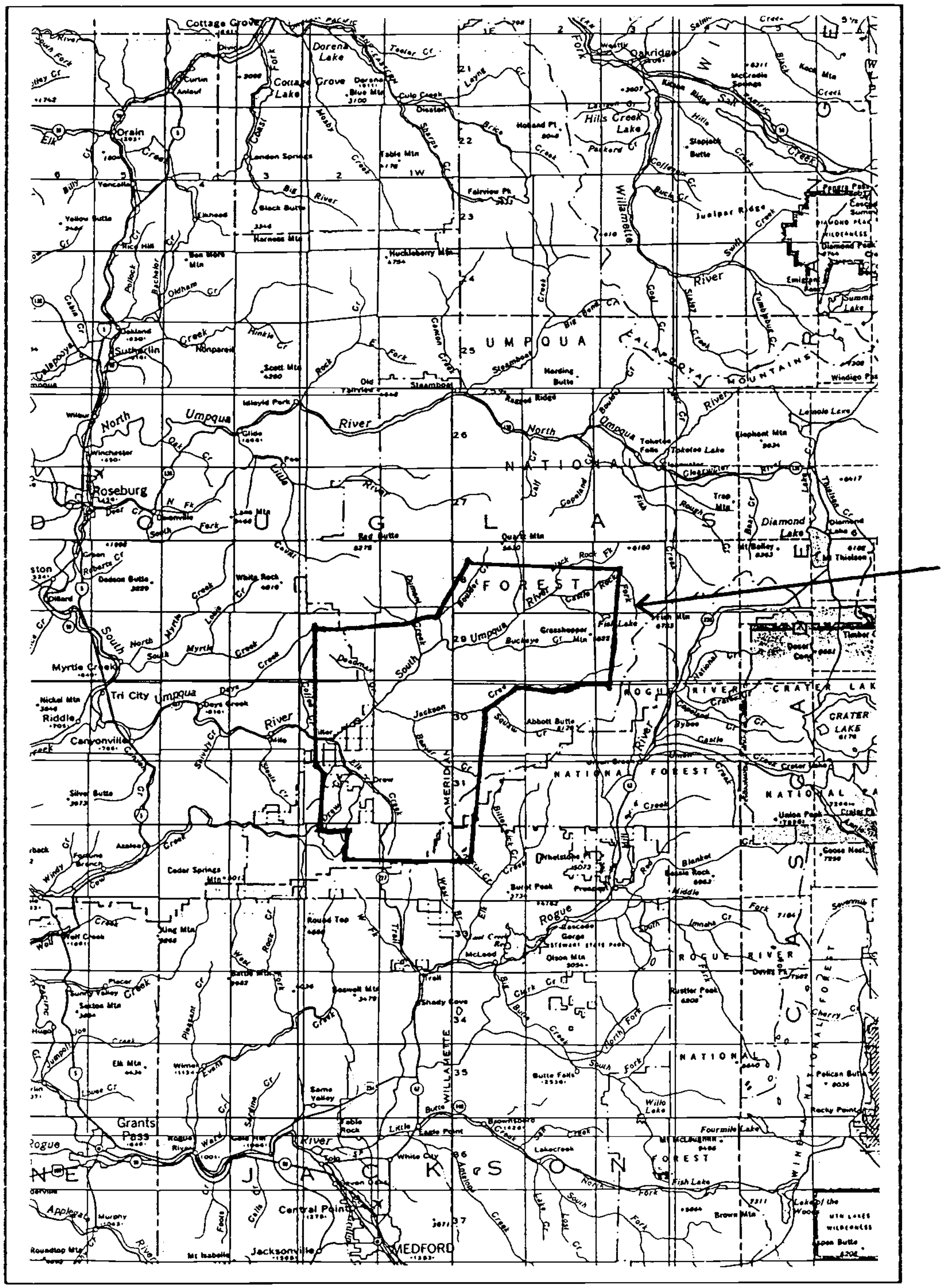
Figure 1

The area is located on the western slopes of the Southern Cascades within the South Umpqua River basin. It occupies an area of approximately 260 square miles (Figure 2). A series of dissected east-west ridges breaks the mountainous terrain into three smaller drainages, consisting of Jackson Creek, Elk Creek, and Buckeye Creek. Elevations range from 325 meters in the southwest to over 1790 meters in the northwest. Winters are cool and moist with higher elevations normally receiving significant snowfall. Summer weather is typically hot and dry with more than 80% of all precipitation falling between 1 October and 1 April (Franklin, 1973, 137).

Geologically, the area is more than 75 percent pyroclastic rocks. Soils developed from pyroclastic parent materials are largely poorly drained and susceptible to mass wasting. Where andesites and basalts are found, soils tend to have better

TURKEY PROJECT

REGION MAP



Study Area

SCALE 1:500,000

SOURCE: USGS, OREGON, 1982

Figure 2

drainage and are more erosion resistant. Steep slopes along the river and creeks are commonly covered by poorly developed, gravelly clay loams (Franklin, 1973, 24).

Due to massive logging operations, native vegetative cover has been severely disrupted. The area enduring the heaviest impact is the western portion of the region, especially within 10 kilometers of Tiller. This section of the study area is generally lower in elevation, has more privately owned land, and timber has been harvested for a longer period of time. Regeneration of seedling conifers has often been inferior, especially on slopes with a southern or western aspect. In an effort to improve regeneration, timber companies have started using shelterwood cuts, supposedly to supply better protection for seedlings (Franklin and Dyrness, 1975, 132). In poorly regenerated tracts, or in ones not planted at all, a heterogeneous group of trees and plants have slowly taken hold. Seedlings on the cooler northern slopes have done much better, largely due to lower temperatures and higher soil moisture levels. The northeast portion of the region is less diverse. Logging for a shorter period of time, higher elevations, and increased moisture levels have led to a more homogenous vegetative cover. The climax cover for the study area is conifer forest, dominated by Douglas Fir. Figure 3 shows the predominant tree species of the area and their relative tolerance to moisture stress. This equates to species with high tolerance being more common to drier, lower elevations, while species with less tolerance have developed better in cooler, higher elevations. See Appendix 1 for detailed tree descriptions.

TREE SPECIES OF THE SOUTH UMPQUA BASIN AND THEIR MOISTURE TOLERANCE

SPECIES	MOISTURE TOLERANCE
Oregon White Oak	High
Ponderosa Pine	↓
Pacific Madrone	
Incense Cedar	
Douglas Fir	
Western White Pine	
White Fir	
Mountain Hemlock	
Western Hemlock	Low

(Franklin and Dyrness, 1973, 130)

Figure 3

2. REMOTE SENSING OPTIONS

Remote sensing is a broad term encompassing many forms of earth observation techniques. Avery and Berlin define it as "the technique of obtaining information about objects through analysis of data collected by special instruments that are not in physical contact with the objects of investigation" (1992, 1). Those instruments obtaining information are collectively referred to as remote sensors. Photographic cameras, mechanical scanners, and radar systems are all sensor systems of this type. Sensors normally operate on fixed-wing aircraft, helicopters, or earth-orbiting satellites.

The term "remote sensing" was first used in the 1960's by Evelyn L. Pruitt, while working as a geographer at the Office of Naval Research (Gaile and Wilmott, 1989, 746). The scientific community accepted the term after a series of symposia, studies, and publications produced by the University of Michigan and sponsored by the Office of Naval Research (Reeves, 1975, 27). Many techniques of remote data acquisition fell under this new term but the roots of the field are traced back to the dawn of aerial photography.

Due to the size of the project area, remote sensing utilizing satellite imagery is the preferred data source for classification. Tom Keegan initially pursued this avenue of approach with the Environmental Remote Sensing Applications Laboratory at Oregon State University. Several attempts were made to map the area using the 30 meter resolution capability of the **Landsat Thematic Mapper** (TM) system. Due to the extreme vegetative diversity of the South Umpqua Basin and the resolution required, TM was deemed unacceptable by Keegan. Satellite imagery from the French "**Earth Observation System**" (SPOT) might meet project requirements for resolution size since it is capable of 10m pixels using panchromatic mode and 20m pixels in multispectral mode (Avery and Berlin, 1992, 148). The cost of images, lack of adequate software, and insufficient training precluded this method of classification.

After investigating and considering the capabilities and costs of other remote sensing systems, such as U.S.G.S. High Altitude Photography, contract aerial photography, and video imagery, it was decided that the only viable option was to use existing U.S. Forest Service color aerial photography. The Tiller Ranger Station maintains one set with an average photo scale of 1:12,000, taken during the summer of 1989. The photographs utilize the standard square format size of 23 cm x 23 cm and were taken with a 208.181mm focal length lens. Not only are these photographs at a suitable scale for classification, they are available for use at no cost.

3. BASIS OF WORK

In order to develop a classification system, perform the interpretation of project aerial photographs, and transfer the interpretation to a map overlay, it was important to lay a foundation of knowledge. The substructure was established by 1) looking at the history of remote sensing with emphasis on forest practices; 2) analyzing photo interpretation techniques and photogrammetry basics; 3) researching the best equipment, materials, and interpretive aids; and last, 4) an analysis of the basic techniques used in the creation and utilization of a classification system.

A. Historical Background of Aerial Photography with Emphasis on Forestry Applications.

1. Aerial Photography: The first aerial photographs were taken in 1858, nineteen years after the first recorded photograph. Gaspard Felix Tournachon used aerial photos, taken from a balloon, to construct a crude topographic map (Reeves, 1975, 27). These experiments were extremely cumbersome due to the necessity of taking the entire photographic development apparatus into the air. In 1871, film based on sensitized silver halide emulsions was invented. The new film created a latent image when exposed and could be developed after the photo flight (Reeves, 1975, 27). The invention of silver halide emulsions and the development process it required, still serves as the basis of all photography. The first documented use of aerial photography for forestry was recorded in 1887. In Germany, foresters took

photographs from hot-air balloons to make forest maps (Spurr, 1954, 551).

Despite continuing advances in the field, scientists were unable to make consistent use of aerial photographs until the development of the airplane in the early 1900's. On 24 April 1909, Wilber Wright, the father of aviation, took the first photograph from a plane. The use of airplanes for taking aerial photographs indicated a new period was at hand.

The beginning of World War I, in 1914, truly triggered the renaissance period of aerial photography. It revolutionized the art of military reconnaissance and had a direct impact on battle strategy. By 1917, allied forces were taking and printing over 10,000 photos per day. The Germans were adding up equally remarkable numbers and, by the end of the war, were photographing the entire Western Front every two weeks with over 2,000 aerial cameras (Reeves, 1975, 32).

Following the war, thousands of soldiers and airmen having used aerial photography, flooded back to their civilian livelihoods, taking newly learned skills and ideas with them. One of the first to realize the importance of aerial photography to forestry applications was a Canadian flyer by the name of Lieutenant Lewis. In 1919, he wrote in the Canadian Forest Journal his ideas on how aerial photography could be employed for forest inventories (Lewis, 1919, 110). That same year, Ellwood Wilson, a fellow Canadian, began extensive mapping of forest stands from airplanes (Spurr, 1954, 552). In 1922, the U.S.

Geological Society issued the first quadrangle map based upon aerial photography (Birdseye, 1940, 9). Concurrently, stereophotography techniques, used for stereoscopic viewing, were being developed. Using stereopair aerial photographs to interpret topographic relief instantly made maps cheaper and more accurate.

During the 1920's, dynamic foresters in Germany began using stereopairs for identification of species, tree height measurements, and forest type classification (Kung, 1962, 2). Working at the German Forestry Research Institute in Tharandt, under the direction of Reinhard Hugershoff, foresters refined the theories of parallax measurements and prepared the first stand volume tables (Spurr, 1954, 552). In the U.S. during the 1920's and 1930's, the Corps of Engineers, the Bureau of Reclamation, and the National Park Service, all began using aerial photography to map watersheds and remote areas (Birdseye, 1940, 10-11). It wasn't until almost 1940 when volume estimating techniques started to be extensively used in the United States (Spurr, 1954, 553). Like World War I 25 years earlier, the end of World War II brought thousands of

AIR PHOTO APPLICATIONS IN FORESTRY AND NATURAL RESOURCE MANAGEMENT

* Vegetation Classification
* Wildlife Habitat Management
* Mapping
* Snow Surveys
* Transportation Planning
* Recreation Site Analysis
* Forest Inventory - Volume
* Insect and Disease Damage
* Navigation

Figure 4

in the civilian establishment. Today, there are many uses for aerial photography in forest and natural resource management. A number of uses are highlighted above in Figure 4.

In 1934, the American Society of Photogrammetry was formed, publishing its first journal, Photogrammetric Engineering. By 1944, the society published a comprehensive text titled The Manual of Photogrammetry. In 1960, the society went on to publish The Manual of Photographic Interpretation, the most comprehensive book ever published dealing with the interpretation of aerial photography. The American Society of Photogrammetry and Remote Sensing (its present title) continues to be a driving force in the acquisition and analysis of all forms of remote sensing.

2. **Color Film**: In 1895, du Hauron began color film experiments utilizing color separations of red, green, and blue pigments (Hyatt, 1988, 3-4). His work was the basis for the eventual development of modern color film. Applying the principles of scientists such as du Hauron, Mannes, and Godowsky, Kodak marketed the first color film in 1935 (Hyatt, 1988, 4). Because of problems with haze, processing, and slow film speeds, aerial color photography did not become common place until the late 1950's and early 1960's. During this period, many of these problems were resolved and, in the last two decades, color film has taken over as the preferred film for aerial photography (Reeves, 1975, 31). Color film is easier than black and white to interpret due to the increased number of color shades the human

eye can distinguish. The human eye can accurately distinguish about 200,000 colors using hue, value, and chroma. The tonal contrast of black and white film is limited to between 100 and 300 identifiable tones (Becking, 1959, 561). In addition, black and white film has steadily climbed in price due to regular increases in production costs.

B. **Air Photo Interpretation Principles.**

1. **Interpretation**: The Manual of Remote Sensing defines image interpretation as "the act of examining images for the purpose of identifying objects and judging their significance" (1975, 869). In Avery and Berlin's, Fundamentals of Remote Sensing and Airphoto Interpretation, they stress interpretation is more of an art than a science and how a certain amount of subjective judgement is required (1992, 51). Almost like a detective, the interpreter must look at the clues he or she has before them, then use scientific tools, proper methodology, and deductive reasoning to make a determination. As was quickly discovered during interpretation of project photography, experience, imagination, and a thorough knowledge of the area, were critical to accurate interpretation.

2. **Recognition Elements**: A firm understanding of the eight recognition elements is extremely important. These characteristics are constantly utilized both consciously and subconsciously in the evaluation of visual cues. The Manual of Remote Sensing or "**Avery and Berlin**", provide excellent descriptions and examples of the eight recognition elements.

Figure 5 contains the eight recognition elements and short descriptions of each.

THE RECOGNITION ELEMENTS	
SHAPE	- Distinctive external form or configuration
SIZE	- Relative size comparisons, measurements
PATTERN	- Spatial form of related features, repetition of objects
SHADOW	- Profile views and enhancement of topography
TONE/COLOR	- Tonal variations in black and white; hue, chroma, and value in color / reflectance
TEXTURE	- Impression of roughness and smoothness
ASSOCIATION	- Genetically linked to other objects
SITE	- Location of objects in relation to environment

(AVERY AND BERLIN, 1992, 52-53)

Figure 5

3. <u>Stereoscopic Viewing</u>: Stereoscopic vision played a leading part in the interpretation of project photography. The ability to see an image in depth, or three-dimensions, provided invaluable information in respect to slope, aspect, and vegetation height. When studying vegetative patterns in the South Umpqua Basin, slope and aspect were key attributes enabling more accurate classification. Terrain with a southern aspect is usually much drier and warmer than north facing slopes. These conditions lead to different vegetation patterns with more moisture resistant species, or to increasingly diluted stand conditions. Steeper slopes sometimes lead to poor soil conditions resulting in weak forest stands. During any interpretation session, the ability to see the relative height of trees is key to identifying the ageclass of a forested area. Forest Service and BLM aerial photography used for this project usually contained a standard endlap of 60 percent and a standard sidelap of 30 percent. These percentages allowed for full stereoscopic coverage of all ground locations. Even though these were the planning parameters, it was obvious the airplane flying

the mission experienced minor problems in maintaining these planning restrictions.

4. <u>Photo-Interpretation Keys</u>: Forest interpretation keys are a valuable tool in identifying various tree species, especially when stereograms accompany the key. For maximum effectiveness, a key will normally focus in on various tree species within one region. In this way, the field of possibilities is narrowed, simplifying the selection procedure. There are two general types, selective and elimination. Selective tree keys consist of standard silhouettes and overhead views of crowns, with descriptions (figure 6 and 7). Once the interpreter finds the closest facsimile of the tree being

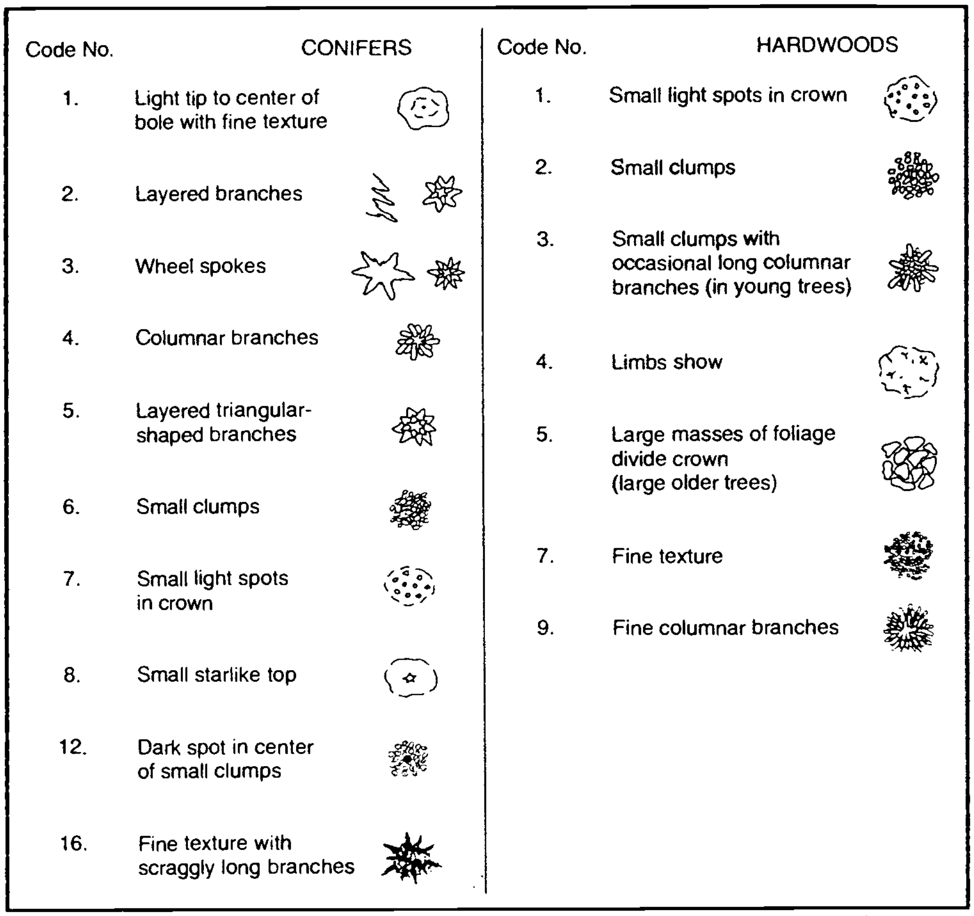


Figure 6 (Avery and Berlin, 1992, 271)

observed, this is the classification that is made. Elimination keys use a step-by-step procedure, eliminating possible trees as the process is performed. In the end, if all decisions were made correctly, the correct tree is identified.

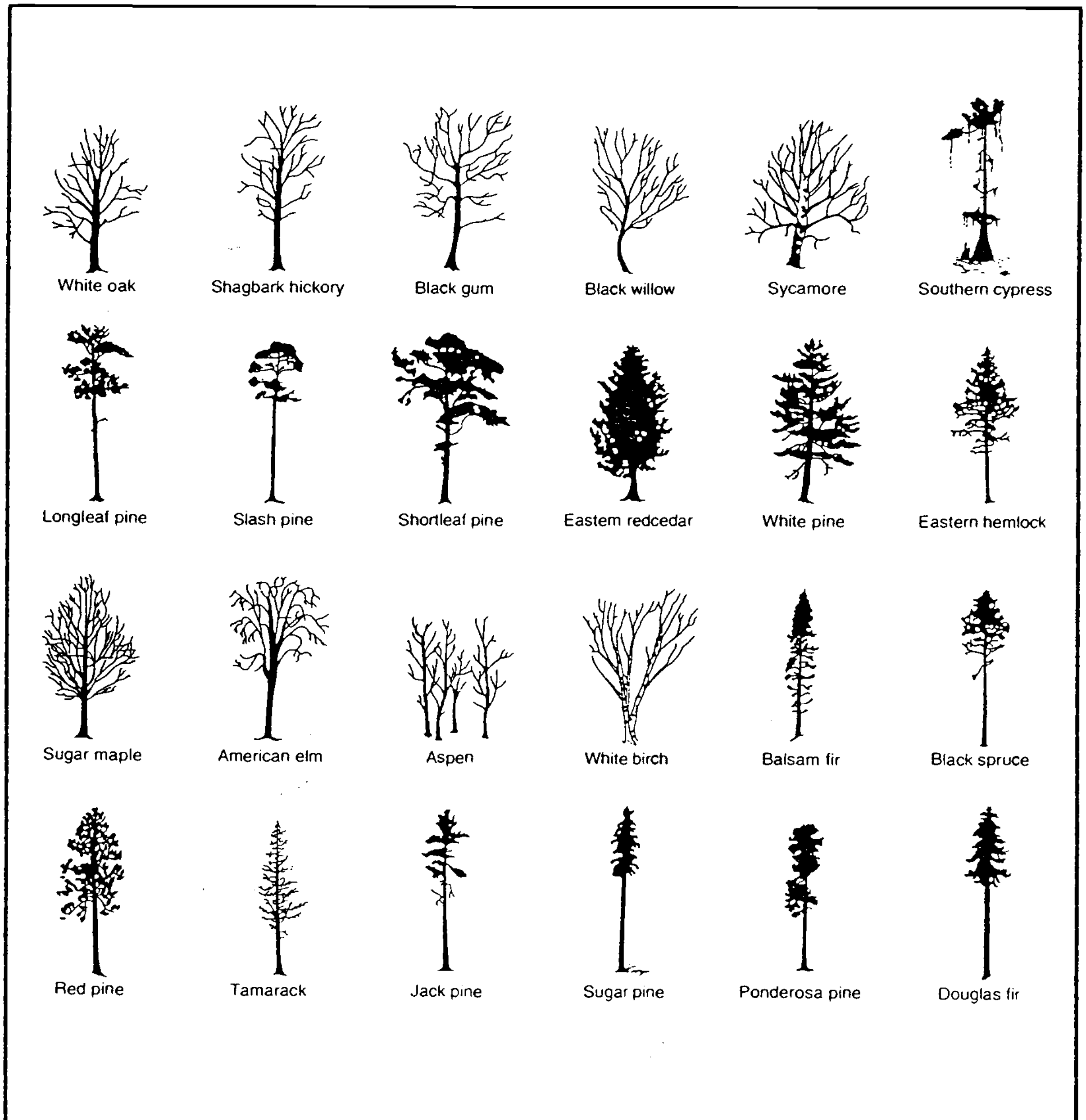


Figure 7 Silhouettes of 24 Forest Trees. When shadows fall on level ground, they often permit identification of individual species (Avery and Berlin, 1992, 270)

5. **Photo Scale**: The importance of using aerial photographs with the proper scale cannot be over emphasized. Using a scale which is too large will assist interpretation but severely restrict photo ground coverage. As a result, the number of photos to be interpreted will multiply, slowing the project and increasing costs. If photo scales used are too small, the interpretation and classification will suffer. Project photos at an average scale of 1:12,000 were perfect in maximizing the ground coverage while at the same time achieving accurate classification. Average scale should be stressed since variation constantly occurs across each photograph. Scale is a function of the focal length of the camera divided by the flying height above ground level (RF = 1/(Height AGL/Focal Length). The focal length remains constant but the flying height above terrain varies. Higher ground elevations result in areas with larger scale than lower elevations. The South Umpqua Basin is a mountainous area of constantly changing ground elevations. Despite an average planned photo scale of 1:12,000, project photographs usually varied in scale from 1:11,000 to approximately 1:13,500.

6. **Season and Time of Day Considerations**: Utilizing aerial photography taken during a certain season will usually optimize the classification. Project photography was taken during the summer when foliage was in a "leaf-on" status. The identification of deciduous trees versus coniferous trees would have been simplified by having the pictures taken in the fall, in what is referred to as a "leaf-off" status. All photography was

taken during the period of least shadows, between the hours of 10:00 a.m. and 2:00 p.m. The presence of some shadows on all flight line sets assisted interpretation. Shadows, when viewed under the zoom monocular scope, often provided perfect silhouettes of trees. The presence of too many shadows is not desired since they will tend to block out important features. When the incorrect season and time of day are selected, a phenomenon known as hotspots can occur. Hotspots cause a loss of photographic detail and happen when a straight line from the sun passes through the camera lens and intersects the ground inside the area of photo coverage (Avery and Berlin, 1992, 98). Hotspots were common on some flight lines, especially flight line #1788.

7. Radial Distortion: Radial distortion is the linear displacement of objects to or from the principal point (Pp) of the photograph. Since objects at different angular distances from the Pp undergo different magnifications, they tend to appear as if they were leaning away from the center of the picture. Though not cited much, radial distortion proved very valuable often as interpretive tool. As trees radially were displaced away from the Pp, they displayed more and more of an oblique appearance, thus making identification easier. Near photograph borders, radial distortion eventually became a hindrance more than a help, as trees became too distorted to accurately identify.

8. <u>Tree Height Measurements</u>: At the beginning of the project and then occasionally thereafter, measuring tree height was helpful for classification. Though a number of methods are available such as the object **displacement method** or the **shadow method**, I used the most common and accurate method of height determination, stereoscopic **parallax**. The technique requires a stereopair, parallax measuring device, stereoscope, and a scale for measuring straight-line distances. Three figures are required to perform the formula; (1) height of aircraft above ground level (Hagl), (2) absolute stereoscopic parallax at the base of the object being measured (P), and (3) differential parallax (dp). Hagl can usually be obtained off the border information of the photograph. If this is not available, Hagl can be calculated with the focal length and photo scale.

As defined by the <u>Manual of Photogrammetry</u>, absolute stereoscopic parallax is "the apparent displacement of the position of a body, with respect to a reference point or system, caused by a shift in the point of observation" (1980,

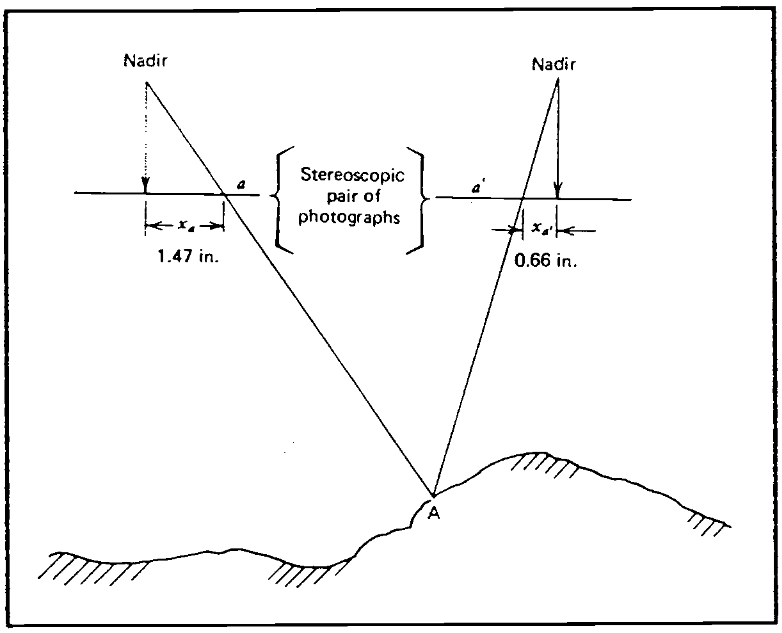


Figure 8 (Paine, 1981, 47)

1030). This apparent shift in position by an object when looking in stereo, is the basis for parallax height measurements. It is measured by taking the sum of the distances between the base of the conjugate objects and their respective nadirs on a line parallel to the flight line Figure 8 above graphically displays this relationship (Paine, 1981, 47). Average photo base-length is commonly substituted for absolute parallax since it is easier to measure and if the photos are vertical, approximately the same distance. To do this, the distance from the principal point to conjugate principal point on each photo is measured. This measures the photo base of each photo. When added together and divided by two, the result is the average photo base length. Differential parallax is an extremely precise measurement made with a parallax bar or parallax wedge. It is the difference in absolute parallax between the top and bottom of an object as displayed in figure 9 (Avery and Berlin, 1992, 78-79). The basic stereoscopic parallax formula is also shown below.

$$h = \frac{dp}{P + dp} \times Hagl$$

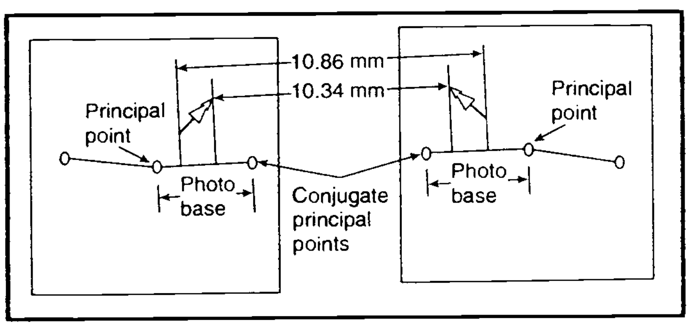


Figure 9 dP = .52mm

C. Equipment and Materials.

1. Stereoscope: A stereoscope focuses normally converging lines of sight towards two separate targets. In this way, both

eyes are looking at a separate image, transmitting a slightly different message to the brain for each. In the brain, these two images meld into one three-dimensional stereoscopic view.

There are three common types of stereoscopes: (1) lens or pocket stereoscopes; (2) mirror or reflecting stereoscopes; and (3) zoom stereoscopes. The lens type are cheap, portable, durable, and commonly capable of 2x or 4x magnification. Mirror stereoscopes use a system of prisms and mirrors with better quality optics and a wider field of view than the lens type. While a lens stereoscope is capable of viewing a common area approximately 6.4 cm x 23 cm in size, the mirror stereoscope can see an area approximately 14 cm x 23 cm. Though there is no magnification with standard mirror stereoscopes, binocular attachments are available in the range of 3x to 8x magnification. For laboratory or office use, the zoom stereoscope with high-quality optics is usually preferred. At considerable expense, it provides continually variable, in-focus magnification from 2x to 100x (Slama, 1980, 541). A mirror and zoom stereoscope were used extensively during interpretation of project photography.

2. Kail Reflecting Projector: The Kail Reflecting Projector is used to transfer overlay information to a base map. The system consists of a double reflecting projector built into a table. Classified images are placed image down on one of two glass plates. The information from the image is reflected by a tilted mirror, through a lens, and onto another tilted mirror. This second mirror reflects the image up onto the other glass

plate. Here the image is traced at the scale of the base map using a translucent material such as mylar. The table uses two 150 watt reflector flood lamps as a light source. Scale of the image on the second glass plate is controlled by a worm gear, shaft, and cable, while focus is controlled by sprocket and chain (Slama, 1980, 590). Though usable, the Kail Projector belonging to the Department of Geosciences was not extensively used during the Turkey Project. Alternate means were developed which proved faster and just as accurate. The Kail Projector should not be discounted, though, as a means of information transfer.

3. Topographic Maps and Orthophotoquads: U.S.Geological Survey 7.5 minute topographic and orthophotoquad maps were critical to project accomplishment. Without the Orthophotoquads, this project could not have been performed within the time constraints. Nine different orthophoto quadrangles were used during both interpretation and information transfer procedures. Orthophotoquads are produced from orthophotographs. Orthophotographs are reconstructed airphotos showing natural and cultural features in true planimetric positions. Orthophotoquads are usually made from single orthophotographs and then prepared in a standard quadrangle format. The map scale and accuracy are comparable to standard 7.5 minute topographic maps. West German foresters were the first to use them, beginning in the 1960's (Heller, 1985, 22). Topographic maps, though useful for this project, were not essential until the final map product was created.

4. **Measuring Devices and Drafting Materials**: In addition to the parallax bar already described, an engineer scale and steel metric ruler were used to measure linear distances. If curved measurements were needed, a opisometer was available. Area measurements were not required but are easily made using a dot grid or polar planimeter. The accuracy of all measurements is severely degraded in areas of steep topography. In order to be accurate, new conversions must be made for each large change in land elevation (Avery and Berlin, 1992, 82).

Mylar was used for all classification overlays. Several types of clear and semi-clear acetates were tested and mylar was found superior for ease of marking, erasure, and general flexibility. A standard mechanical pencil with .5mm "B" lead was used on the draft classification map overlays. A final copy was made of each overlay using fine-tip Staedtler Lumocolor alcohol-based markers. Initial classification on the aerial photographs was done by Staedtler Lumocolor water-soluble markers. Clear plastic covers on the photography made it possible to do the initial classification on the photograph. Drafting quality rapidograph pens were tested and found to be much slower than the Staedtler markers with a only a small increase in line quality.

Two types of erasers were used during the project. During pencil work, a high quality Staedtler white eraser was used with an erasure shield. For work with permanent markers, a Staedtler eraser was used containing an ink solvent within the eraser material. This eraser proved very effective in removing permanent lines, while limiting the amount of scuff on the mylar acetate.

5. <u>Photo-Interpretation Guides</u>: In addition to interpretation keys, other inexpensive devices are available for making measurements or to aid interpretation. These devices are normally printed on clear acetate and assist in procedures such as measuring distances (conversion scales at the proper RF), parallax wedges and bars for measuring heights using differential parallax, dot grids for area estimates, crown coverage scales, and dot wedges for measuring crown diameter (Speer, 1963, 37). Appendix 2 contains examples of interpretation guides.

6. <u>Global Positioning System (GPS)</u>: A valuable field tool for this or most any other forest project is a Global Positioning System (GPS). A GPS provides all-weather, three dimensional, global positioning, with sub-meter accuracy capability. Although intended primarily as a navigation system, GPS surveying is quickly becoming the preferred means for measuring and determining ground locations. It is usually faster than traditional surveying methods and has the potential to be far more accurate. Three-dimensional conventional surveying requires two operations (horizontal traverse and level loop), while GPS surveying performs the same function faster in only one operation. Another plus for GPS surveying is intervisibility of points is not a requirement. Forest applications of GPS technology include navigation, mapping, surveying, ground

control, wildlife management, and integration with forest remote sensing systems. In development for almost 10 years, the Department of Defense operated system will soon be fully operational with a constellation of 24 satellites.

The heart of any GPS is its receiver. Trimble Pathfinder Basic, Pathfinder Plus, and Community Base Station receivers were used during field ground truthing for the Turkey Project. Receivers assisted in navigation, area or linear measurements, and ground control. Much of the study area lacks good horizontal control points; GPS technology would be instrumental in providing ground control for mapping and controlled photo mosaics.

This project served as the test bed for the Geoscience Department's new community base station and Pathfinder Plus receiver. From its known surveyed location over 150 miles away at Oregon State, the base station determined a correction factor for the field receiver. Field measurements with the Pathfinder Plus were then differentially post-processed using base station correction factors to accuracies of under 3 meters.

The best tactic for maximum accuracy is: 1) make a GPS plan prior to leaving for the field and use pre-planning software to chart position recording at times when the best constellation is available; 2) use locations with good "windows to the sky" so satellite signals are not disturbed; 3) record 300 positions at each field control point; 4) following differential post-processing correction, average the corrected positions. GPS components utilized during this project were:

* GPS Pathfinder Plus w/internal antennae.
* Trimble Community Base Station.
* Piseon Data Logger.
* Base Station antennae system (surveyed).
* External antennae w/magnet (car).
* DOS compatible GPS software.
* Various power sources / cords.
* Hard plastic case for storage / transport.

Pathfinder Plus and Base Station

D. **Development of a Classification System.**

The term, vegetation, refers to the total plant cover of an area, place, or region. Complex interactions between geographic location, topographic position, soils, and climate all work to form a mosaic of plant life (Trieber, 1984, 294). Without external influences, the vegetative pattern will eventually reach a climax state, or in the case of most of our study area, Douglas Fir coniferous forest. As already discussed, man-induced influences such as logging disrupt the natural vegetative mosaic, creating the distorted pattern existing today. This pattern of vegetation usually consists of discernible units or mappable areas. These units are the subject of this study.

Numerous vegetation classification systems exist, each serving various purposes or intents. Classification systems usually fall into one of four broad categories: (1) physiognomic, (2) ecological, (3) floristic, or (4) combinations of the three. Physiognomic systems are based upon the form and structure of vegetation (i.e. height, general tree types, etc..). Ecological systems look at vegetation but also include environmental factors like climate. Floristic systems focus on species composition and plant classification schemes (Trieber, 1984, 295). For the purpose of this study, a physiognomic classification system was required. A physiognomic system permits direct observations and measurements as a basis for classification. Map representation is simplified, floristic and scientific names are minimized, thereby reducing the level of knowledge required of the interpreter.

Numerous advantages exist for performing classification with remote sensing / aerial photography. A number of these are (Sabins, 1987, 357):

1. Large areas are covered rapidly.
2. The type of sensing system can be matched with the degree of resolution required.
3. Surface access is no longer a problem.
4. Aerial views complement ground views, at times being more advantageous.
5. Interpretation is often faster and less expensive than ground surveys.
6. Images provide a permanent record of surface conditions at a given point in time.

Despite a significant list of advantages, there are instances when remote sensing is a negative factor. Disadvantages include: normal aerial views lacking the horizontal perspective which is valuable in identifying some cover types, and the cost of using imagery for a small area might be too expensive or uneconomical.

In 1976, James Anderson and others, published a land-use and land-cover classification scheme for use with remote sensor data (U.S.G.S. Prof. Paper 964). This scheme and the guidelines identified by the authors, now serves as an outline for most new classification systems in the United States. Repeatedly, this article is referenced in almost all textbooks and journal articles dealing with vegetation classification. In creating the classification system for the Turkey project, requirements and guidance presented by Anderson and his colleagues were considered. The following criteria were used as guidelines:

1. Clearly defined mapping units.
2. Clear terminology.
3. Mapping units pertinent to the customers requirements for use and resolution.
4. Clear logic so different interpreters can obtain similar results.
5. Classification has to be obtainable with Forest Service 1:12,000 aerial photography.
6. System categories must be identifiable and clear on the final map product.

The following is the classification system developed and then approved by Keegan for this project.

VEGETATION CLASSES

Code		ID	Class
1.	**CLEARCUT**:		
	Less than 5% canopy, 0 - 10 yrs since cut. Clearcut greater than 10 years old with no regeneration to include a rock-shrub field.	CC	1
2.	**NATURAL GRASSLAND / OTHER**:		
	Less than 5% trees / grass, built-up areas, areas affected by humans but not due to recent logging, and water inundated areas.	NG	2

3. **ROCK-SHRUB FIELD**:		RS	3
Less than 5% canopy with a predominant ground cover of rock and shrub-like plants.			
4. **SAPLING / POLE**:			
10 - 30 year old trees Areas with saplings having experienced poor regeneration, also an area in the initial stages of regeneration.	LT 70% Stocking	SP-	4
10-30 year old trees Sapling or pole regeneration is occurring at a normal rate and will eventually develop into a normal plantation forest.	GT 70% Stocking	SP+	5
5. **YOUNG MIXED CONIFEROUS FOREST**:			
30 - 80 year old trees	GT 70% Canopy	YC+	6
Natural or commercially thinned YC > 70%		YC+ (T)	7
	LT 70% Canopy	YC-	8
6. **MATURE MIXED CONIFEROUS FOREST**:			
Over 80 year old trees	GT 70% Canopy	MC+	9
Natural or commercially thinned MC > 70%		MC+ (T)	10
	LT 70% Canopy	MC-	11
7. **MIXED OAK-CONIFEROUS FOREST**:			
All ages of trees / grass	GT 40% Canopy	OC+	12
understory likely	LT 40% Canopy	OC-	13

TOTAL CLASSES = 13

It is important to note all classification systems will contain some error. The normal goal for accuracy is 85%, as established by Anderson in his article, "Land-Use Classification Schemes" (1971, 381). An increase in the amount of ground truthing will usually result in increased accuracy. Larger-scale photos also tend to increase accuracy percentages, as does the criteria for the classification itself. During the Turkey Project vegetation study, classes were designed to maximize accuracy by utilizing a more general definition. By only using the precision required for this study, it not only made the classification more accurate, it decreased time requirements for interpretation and classification.

Possible sources of error in classification are the inability of classification systems to categorize mixed classes, transition zones, or dynamic systems. Other sources include poorly defined classes, human subjectivity, and the expertise of the interpreter (Lunetta, 1991, 681). There are numerous situations when a particular area is not easily defined. This is often true even if the interpreter happens to be sitting in the middle of the area in question. Some sites are just difficult to label with a specific category class.

4. SOUTH UMPQUA TEST PROJECT

The test project was conducted to determine the feasibility of performing the entire vegetation classification project. Strict time limits were required for project completion, thus work and cost estimates were critical. The steps in performing the test project were as follows:

1. **Classification System Development:** Development of the classification system consisted of two parts. The first portion was conducted by researching and comparing other classification systems. The system for this project did not need to be

1. Work with the customer to establish a suitable classification system.
2. Delineate the project area on maps, then determine a suitable site for the test project.
3. Acquire maps, aerial photography, equipment, interpretive aids, and drafting materials.
4. Delineate effective area on photographs.
5. Perform interpretation and classification.
6. Transfer classification to map overlays.
7. Perform ground truthing / verification of classification overlays in field.
8. Perform work and cost estimates based upon test project.
9. Project meeting with customer to determine whether to proceed with project.

complicated or detailed. It was geared only for Keegan's analysis of Rio Grande Wild Turkey habitat. After two meetings, a classification system was agreed upon. This system was fast, simple, and provided the level of accuracy and detail required. The method has direct correlation to existing systems now being used in Oregon and California forests, but in a simpler form, geared toward this study. The resolution of classification was largely based on scale restraints of the 1:24,000 topographic quadrangles. Areas too small to be transferred and identifiable on the topographic maps were not identified. This resulted in an area no smaller than 30m x 30m being interpreted.

Key to accurate identification of classes was in remembering and using standard recognition elements. At scales of approximately 1:12,000, tree crowns and branching patterns are not always usable for interpreting the class of an area. In this case, photographic tone, texture, and shadow pattern played increasingly significant roles. Variables such as altitude of the sun, length of exposure, method of printing and developing, atmospheric haze, and camera mechanics all impact on accurate classification (Sayn-Wittgenstein, 1961, 793).

Clearcuts were easily identified on the aerial photography. Differentiating clearcuts from rock / shrub fields was often difficult. Rock / shrub fields either consisted of (1) areas with poor soils, lots of rock, and poor vegetative cover; or (2) clearcuts which failed to regenerate after a reasonable period of time. The lack of regeneration could be attributed to many things, such as poor tree planting techniques, no tree planting at all, bad soils, or low moisture levels. A south facing slope of an old clearcut can be notorious for its inability to regenerate well. This is especially true for lower, warmer elevations. Shelterwood cuts are an attempt by loggers to provide shade on these warmer slopes, thereby increasing seedling mortality rates. Shrub fields in the color photography were often identifiable by a pale orange color.

The natural grass and "other" category of classification simplified the process. The South Umpqua Basin has little human habitation and classifying it as "other" was not a problem for Keegan. Other items falling under this class were water bodies, forest fire scars, and small agricultural areas. Natural grass fields stood out based upon its bright tan color. It differed from clear cuts in its shading, lack of timber scars, and normally irregular shape. A major effort was made to identify small natural grass openings because of its usefulness to turkeys as fly-ways into and out of forest canopy.

For sapling / pole classes, stocking and size were the main discriminators. Good regenerating sapling / pole stands, with over 70 percent stocking levels, were identified as SP+. Poorly stocked sapling / pole tracts, or very small saplings, were classes as SP-.

Instead of stocking levels, canopy closure was used for conifer forest stands. Canopy closure is a common discriminator for classification systems and 70 percent is a normal separation point in classes. Canopy closure can be estimated with an interpretation aid, but after some experience is gained the decision is based more and more upon interpreter discretion. There were no requirements to differentiate conifer types for this project. Given more time, experience, and ground truthing, stands could have been identified by species type and species composition. Young mixed coniferous forests were identifiable from its difference in height, smooth canopy, immature crowns, and slightly lighter green color. Mature conifer stands were identified by a rough canopy appearance, dark green color, mature crowns, shadow outline, and height.

The "thinned" classification for young and mature conifers was adopted after the test project. Large tracts of land had obviously been commercially thinned and the identification of these areas became more important upon input from Keegan. Not all stands classified thinned were commercially thinned by loggers. In some instances, areas with naturally occurring fragmented canopy closure were placed into this category.

Mixed oak-conifer forest was very common in lower elevations, especially near stream courses in the bottom of valleys. This is a good example of the use of the recognition element "site". Tracts clearcut over 30 years ago and experiencing poor regeneration often have oaks developing among young conifer stands. The oaks stand out in photographs by their different color, crown shape, and shadow appearance.

2. **Delineation of the Project Area and Test Site:** The movement of turkeys determined the boundaries of the project area. For interpretation, Keegan defined a boundary based upon these movements and placed it on a 1:126,720 forest service map of Umpqua National Forest. After ten 7.5 minute topographic quadrangles were obtained, the area was placed on these maps. Since these maps were at a much larger scale of 1:24,000, a boundary was interpolated using identifiable features such as roads or state plane boundaries. The final boundary was approved by Keegan and all map sheets were acquired in both topographic and orthophoto types (see Appendix 5 for project area). At the same time, equipment, drafting materials, and interpretive aids were also being gathered.

The test site was centered upon Nichols Ranch on the Pickett Butte topographic map (Appendix 5 / Pickett Butte). This same area was used during attempts to classify vegetation using satellite data. Keegan wished to compare the results of the two studies and then make a final decision on whether any decent level of classification was possible in the time available. Aerial photography covering the test site was collected from Tiller Ranger Station, consisting of portions of flight lines 2588, 2488, and 1888.

3. **Interpretation, Classification and Transfer of Data:** Work immediately began on the test area using the new classification system. As discussed earlier, changes were made to the system as experience levels increased. Delineation of effective areas is described in Appendix 3. Interpretation was performed on the photographs using water-based markers. Plastic coverings on each photo protected the pictures. Once interpretation and classification were complete, data was transferred in pencil to mylar overlays covering the 1:24,000 orthophotoquads. The detail of the orthophotoquads usually provided the necessary reference points for transfer of data. The use of orthophoto maps during the transfer process made this project possible within the time allowed. A orthophoto map contains an abundance of detail not found on the normal topographic map. Except for being black and white, the orthophoto map closely resembles the aerial photography used for interpretation. It shows features at their true scale, allowing measurement of areas, distances, and bearings (Paine, 1979, 315). As needed, approximate measurements were taken of both distance and azimuth on the photographs. This technique closely resembles the radial line triangulation method as described by Paine (1979, 289-291). These figures were converted to the scale of the maps

and then plotted. Though time consuming, these measurements were often required to ensure horizontal accuracy in large homogenous areas. The Kail Reflecting table could have been used to transfer classification data. The availability of orthophoto quads made the process faster and easier in the method described.

4. **Ground Truthing:** Upon completion of the test site classification, ground truthing in the project area began. The project area is a diverse and rough piece of terrain. Moving through many areas required a four-wheel drive vehicle. Topographic maps and the GPS were used to locate preselected sample sites. Sample sites were not determined in a random manner. Access restrictions due to the road network, and snow, precluded passage into all areas. This method of sampling is called selective sampling. It allows for rapid collection of data at an inexpensive cost with a reasonable amount of accuracy (Reed, 1963, 21). Once sites were found, it was important to get out and walk the terrain. Vegetation along roads is often left less damaged by man in an effort to conceal forest logging practices. A series of transects through an area is useful in determining the status of the complete site. The GPS can also be used to navigate these transects by placing waypoints at either end. In a survey of 20 sample sites, 16 were found to be accurately classified (80%). During this field visit, portions of the entire project area were visited. This reconnaissance provided a better feel for ground conditions and, in the end, improved interpretation of photos not yet classified.

5. **Work and Cost Estimates:** A major factor in deciding to do this large project was determining the amount of time and costs it would require. It was estimated the project would take approximately 266 man-hours to complete and expenses for materials and travel would be about $300. By estimating the amount of time which could be dedicated to the project between initiation and completion, I decided I could complete all work by March 30, 1993. Based upon these figures, the estimated completion date, and those in Appendix 4, I quoted a price of $4,300 to Keegan. After reviewing the classification work done during the test project and considering my offer, Keegan agreed to this estimate.

5. PROJECT EXECUTION

A. INTERPRETATION AND CLASSIFICATION:

The set of aerial photographs required for covering the project area consisted of over 500 photographs on portions of 28 different flight lines. It was crucial the set be organized and stored correctly to facilitate work productivity and protect the photography. Photographs were first arranged by flight line. Pictures not being used within each flight line were removed and stored separately. The remaining photography was filed in a steel file cabinet by flight line and the topographic map in which it appeared. The forest service index map provided with the photography was of very poor quality; though useful, topographic maps of Umpqua National Forest were also used to track flight line coverage.

Flight lines were interpreted as a group. In this way, effective areas were easily identified and stereoscopic viewing was possible. Photographs from adjacent flight lines were sometimes used to define the east/west portion of the effective area. The east/west effective area eventually averaged out to a one or two inch strip on each side of the picture. Most flight lines had endlap exceeding the standard 60 percent. To speed interpretation, every other photograph was classified. This increased the effective area on each photograph but reduced by half the number of photos needing to be interpreted. Alternating photos were still used for stereoscopic viewing.

As the project progressed, expertise grew and speed of work increased. The project areas vegetative diversity made some areas much more difficult to interpret. As difficulty increased, the time required increased. This was especially true for sites in the southwest and central portion of the study area. These sites were often victims of modern logging management. Heavy influence of logging on some sites resulted in a greater hodgepodge of vegetative covers. As interpretation work moved to the northeast portion of the study area, the vegetation regime was less disturbed and more homogeneous. Work speed increased dramatically during this phase.

In an effort to exercise some quality control, work periods were kept to under two hours at one sitting. Beyond this, general fatigue would quickly degrade the caliber of work.

Sunspots on some flight lines were a problem. By observing the same area on different photographs, the effect was minimized.

B. **TRANSFER OF INFORMATION AND FINAL PRODUCT:**

Transfer of work to pencil drawn mylar overlays was performed just like the test project. These draft overlays were used to make a final ink drawn mylar overlay of each original. These final overlays were then sent to **Consolidated Reprographics** in Irvine, California. There, a photographic process was performed combining the classification overlay and the standard 7.5 minute topographic map. The result was a laminated map displaying the classification overlay superimposed over the topographic map. Appendix 5 contains reduced versions of the final project maps.

The making of the classification overlays from the interpretation on was a pain-staking process. Hundreds of small polygons were created on each overlay; each polygon with its own numbered classification symbol. Quality control during this phase was also important. It was very easy to make mistakes by creating like areas next to each other or not completing the full polygon. Prior to final completion of the pencil overlay, it became an informal policy to break for an hour, then return and review the overlay for errors.

6. RESULTS AND CONCLUSIONS

This project could easily be continued by putting this data into a geographic information system (GIS). By digitizing or scanning the data into a GIS, it could then be analyzed in a myriad of ways. The data in its present form could also be made into a computer generated map like that produced by an AUTOCAD system. GPS data is already in a digital form, suitable for inclusion into a computer generated map or GIS.

Many are starting to view aerial photography as an antiquated form of data collection. They see other space based remote sensing systems replacing photography as the preferred data source. It is hoped this project demonstrates one application for the continued usefulness of aerial photography. Aerial photography is still the dominant source of data for mapping and hundreds of other uses. It's available at the local level, at a reasonable cost, has good resolution capability, and is also easy to interpret. These reasons alone make it a valuable tool for decades to come.

The classification of turkey habitat in Umpqua National Forest was a substantial undertaking. The project lasted over 3 months, consumed approximately 250 man-hours, and cost the customer in excess of $4,000. The final vegetation classification overlays covered over 260 square miles of rugged terrain. Satellite based sensors had failed in defining an accurate classification of the local vegetation. Aerial photography, using standard Forest Service 1:12,000 scale photography, provided the answer to project completion. Significant points in the execution of this project were:

1) Design the final product to meet the customer's requirements.

2) Prior to accepting a job of this magnitude, perform a test project to determine project feasibility, a cost estimate, and time required.

3) To maximize success, research the topic and determine how others have approached the same problem. Increase the skill level of the interpreter(s) through training and adequate ground truthing of test results.

4) Utilize orthophoto quadrangles to maximize speed and provide a multi-temporal view during classification.

The objectives of this classification project were met. The customer's requirements were met with the final laminated classification maps. They were delivered on time and will meet project demands for a vegetation classification of wild turkey habitat in the South Umpqua basin.

REFERENCES

Anderson, James R. 1971. Land-use Classification Schemes. Photogrammetric Engineering, 37:379-387.

Anderson, James R. and Hardy, Ernest E. 1976. A Land-Use and Land Cover Classification System for use with Remote Sensor Data. U.S. Geological Survey Professional Paper 964, Washington: G.P.O.

Avery, Eugene T. 1966. Identifying Forest Types and Tree Species. U.S. Department of Agricultural Handbook # 308. Washington: G.P.O.

Avery, Eugene T. and Berlin, Graydon, L. 1992. Fundamentals of Remote Sensing and Airphoto Interpretation. New York: Macmillen Publishing Company.

Befort, W.M. 1986. Large-Scale Sampling Photography for Forest Habitat-Type Identification, Photogrammetric Engineering and Remote Sensing, 52:101-108.

Becking, Rudolf W. 1959. Forestry Applications of Aerial Color Photography. Photogrammetric Engineering, 25:559-564.

Birdseye, Claude H. 1940. Stereoscopic Phototopographic Mapping. Annals of the Association of American Geographers, 30:1-24.

Bright, Larry (Ed.) 1985. Managing of Wildlife and Fish Habitats in Forests of Western Oregon and Washington, Part 1. U.S.D.A. - Forest Service Pacific Northwest Region. Portland: Oregon Department of Fish and Wildlife.

Brockman, Frank C. 1986. Trees of North America. New York: Golden Press.

Durbin, K. 1975. California Import with a Texas Drawl. Oregon Wildlife, 30(4):8-9.

Fiorella, Maria and Ripple, William J. 1993. Determining successional stage of temperate coniferous forests with Landsat Satellite data. Photogrammetric Engineering and Remote Sensing, 59:239-245.

Franklin, Jerry F. and Dyrness C.T. 1973. Natural Vegetation of Oregon and Washington. U.S. Forest Service, Pacific NW Forest and Range Experiment Station, Gen. Tech. Report PNW-8, Portland, OR.

Gaile, Gary L. and Willmott, Cort J., ed. 1989. Geography in America. Columbus: Merril Publishing Company, 1989.

Green, Kass; Bernath, Steve, and Lackey, Lisa, 1993. Analyzing the Cumulative Effects of Forest Practices: Where Do We Start?, Geo Info Systems, 3(2): 31-41.

Heller, Robert C. 1985. Remote Sensing: Its State-of-the-Art in Forestry. Paper presented at the Tenth William T. Pecora Memorial Remote Sensing Symposium, Fort Collins, Colorado.

Hyatt, Edward. 1988. Keyguide to Information Sources in Remote Sensing. New York: Mansell Publishing Limited.

Keegan, Thomas M. 1987. Study Plan for Habitat use by Rio Grande Wild Turkey Hens in Southwestern Oregon. Doctoral Study Plan, Department of Fish and Wildlife, Oregon State University, Corvallis, OR.

Kuckler, A.W. 1947. Geographic System of Vegetation. Geographical Review. 37:233-240.

Kung, F.H. 1962. Photographic Interpretation in Forest Inventories. Masters Paper, Department of Forestry, Oregon State University, Corvallis, OR.

Laver, D.T. 1985. New Horizons in Remote Sensing for Forest and Range Resource Management. Paper presented at the Tenth William T. Pecora Memorial Remote Sensing Symposium, Fort Collins, Colorado.

Lewis, Lieut. 1919. Photographing Forest from the Air. Canadian Forestry Journal, 14:110-112.

Lillesand, Thomas M. and Kiefer, Ralph W. 1987. Remote Sensing and Image Interpretation, 2nd Edition. New York: John Wiley and Sons.

Lunetta, Ross and Congalton, Russel G. 1991. Remote Sensing and Geographic Information System Data Integration; Error Sources and Research Issues. Photogrammetric Engineering and Remote Sensing, 57:677-687.

Meisner, D. 1985. Color IR Aerial Video Applications in Natural Resource Management. Paper presented at the Tenth William T. Pecora Memorial Remote Sensing Symposium, Fort Collins, Colorado.

Meyer, Merle P. and Hackett, Ronald L. 1990. Airphoto Interpretation Skill Needs. Journal of Forestry, 88:12, pp. 10-15.

Pacific Meridian Resources, 1992. Classification Scheme for Western Oregon and Washington. Unpublished Technical Paper. Roseburg, OR.

Paine, David P. 1979. Introduction to Aerial Photography For Natural Resource Management. Corvallis, OR: Oregon State University Bookstores Inc.

Paine, David P. 1981. Aerial Photography and Image Interpretation for Resource Management. New York: John Wiley and Sons.

Poulton, Charles E. 1970. Practical Applications of Remote Sensing in Range Resources Development and Management. U.S.D.A., Forest Service Misc. Pub. 1147. Washington: G.P.O.

Poulton, Charles E. and Isley, Arliegh G. 1970. An analysis of State-Owned Rangeland Resources for Multiple-Use Management in SE Oregon. Range Management Program, Agricultural Experiment Station, Oregon State University, Corvallis, OR.

Poulton, Charles E. 1985. Evolution of Remote Sensing in Range Management, speculations on its future. Paper presented at the Tenth William T. Pecora Memorial Remote Sensing Symposium, Fort Collins, Colorado.

Reed, Clifford G. 1962. Aerial Photographs and Forest Inventory. Masters Paper, Department of Forestry, Oregon State University, Corvallis, OR.

Reeves, Robert J. ed. 1975. Manual of Remote Sensing. 2 Vols. Falls Church: American Society of Photogrammetry.

Ripple, William J. 1993. "GIS could make a difference in making life better on earth" GIS Interview, Geo Info Systems, 3(2):18-21

Sabins, Floyd F. Jr. 1987. Remote Sensing Principles and Interpretation, 2nd Edition. New York: W.H. Freeman and Co.

Sayn-Wittgenstein, L. 1961. Recognition of Tree Species on Air Photographs by Crown Characteristics. Photogrammetric Engineering, 27:792-809.

Slama, Chester C. (Ed.) 1980. Manual of Photogrammetry, 4th Edition. Falls Church, VA: American Society of Photogrammetry and Remote Sensing.

Smelser, R.L. 1975. Photointerpretation Guide for Forest Resource Inventories. NASA Tech. Report JSC-09977. Houston: Johnson Space Center.

Speer, J. and Harper, V.L. 1963. Aerial Photographs in Forest Inventories Applications and Research Studies. Munich, FRG: International Union of Forestry Research Organizations.

Spurr, Stephen H. 1954. History of Forest Photogrammetry and Aerial Mapping. Photogrammetric Engineering, 20:551-558.

Treiber, Miklos and Saterwhite, Melvin B. 1984. A Physiognomic Vegetation Classification Scheme For Use With Imagery For Military Applications. U.S. Army Corps of Engineers Technical Paper. Alexandria, VA: Topographic Engineer Center

Werth, Lee F. and Work, Edgar, A. 1991. Inventory and Monitoring Coordination Guidelines for the use of Aerial Photography in Monitoring. U.S. Department of Interior, Bureau of Land Management, Tech. Ref. 1734-1, Washington D.C.

Werth, Lee F. and Work, Edgar A. 1992. Applications of Large-Scale Photography for Rangeland Monitoring. Geocarto International, 7:11-18.

UNESCO, 1973. International Classification and Mapping of Vegetation. Paris: UNESCO.

Photographs:

1) United States Forest Service, Tiller Ranger Station, Umpqua National Forest. POC: Cindy Barkhurst, Resource Division, 27812 Tiller Trail Highway, Tiller, Oregon 97484 (503) 825-3201

2) United States Bureau of Land Management, Roseburg Office. POC: Chris Foster, Wildlife Biologist, 777 NW Garden Valley Blvd. Roseburg, Oregon 97410 (503) 440-4930.

Maps:

1) United States Geological Survey, 7.5 minute topographic and orthophoto quadrangle series, 1:24,000. The following Oregon map sheets:

   a. Ragsdale
   b. Butler Butte
   c. Richter
   d. Sugarpine
   e. Deadman
   f. Tiller
   g. Pickett Butte
   h. Dumont Creek
   i. Acker Rock
   j. Buckeye Lake

2) United States Forest Service, USDA, Umpqua National Forest special edition, 1:126,720, visitors edition.

3) United States Forest Service, Portland Regional Office, Tiller Ranger District, Umpqua National Forest special edition, 1:63,360.

4) United States Geological Survey, State of Oregon, 1:500,000, 1982.

Appendix 1 (Trees of the South Umpqua Basin)

OREGON WHITE OAK (Quercus garryana) - A deciduous tree growing to heights of 50 to 70 feet. Found in California, Oregon, and Washington, this tree is the predominant oak species of the area. It is found in lower elevations and requires the least amount of moisture of those trees identified here. Within the study area, the Oregon White Oak is common in the project classes, of "Mixed Oak/Conifer, Rock/Shrub, and Natural Grass/Other". On aerial photographs, oak crowns have distinctive shapes much different than conifer crowns. Color differences are also obvious, especially during early fall after leaves have changed colors.

PONDEROSA PINE (Pinus Ponderosa) - A conifer tree growing 150 to 180 feet tall. Of the conifers, the Ponderosa is the most drought resistant, thus it can survive at lower elevations and on southern facing slopes somewhat better than other pines. Ponderosa Pine is common throughout the Western United States and is an important source of lumber. This conifer is found throughout the study area. From overhead its crown appears broad and open.

PACIFIC MADRONE (Arbutus mensiesii) - The madrone is a member of the heath family (Ericaseae) and is found all along the west coast of the United States. Trees grow to heights of 100 feet, and exceed four feet in diameter. Pacific Madrones are fairly easy to spot in aerial photographs, appearing lighter in color than conifers and having a smooth texture to the crown. Madrones are found in lower elevations and southern slopes of the South Umpqua basin.

INCENSE CEDAR (Calocedrus decurrens) - Incense cedars are found in small clumps within the study area. Its bright green appearance and dense conical crowns make it identifiable on aerial photographs, especially at scales under 1:10,000. These trees grow 100 to 150 tall and are found mainly in Oregon and California.

DOUGLAS FIR (Pseudotsuga mensiesii) - Douglas Fir is the climax vegetative cover for most of the study area. Its value as a source of high grade lumber makes it a prime target for commercial logging interests. The Douglas Fir has a dense, compact conical crown, and drooping side branches. Trees can grow to heights in excess of 250 feet. Using shadow as a recognition element, the long bare trunk and distinctive crown make it identifiable. Most regenerating stands have been planted with Douglas Fir.

SUGAR PINE (Pinus lambertiana) - Sugar Pines are the tallest American pine, growing over 200 feet tall. Its cones are also the longest of any American conifer with lengths of 10 to 26 inches. The crown is pyramidal in shape, and not easily identified unless large scale photography is available. Within the study area, Sugar Pines are prevalent in small clumps at most elevations.

WESTERN WHITE PINE (Pinus monticola) - A close relative to the Sugar Pine, the Western White Pine crown closely resembles that of its cousin, being pyramidal in shape. The tree grows 100 to 175 feet high in cooler, moister locations.

WHITE FIR (Abies concolor) - The White Fir has a bluish-green tint and a dome-shaped crown. Though not as prevalent as the Douglas Fir, the White Fir is common throughout the South Umpqua Basin. It is found at most elevations and is usually able to handle the drier soil conditions of southern facing slopes. White Firs grow 125 to 150 feet in height and are found throughout the Western United States.

WESTERN HEMLOCK (Tsuga heterophylla) - These trees grow from Northern California on up into Canada and even Alaska. It likes locations providing adequate moisture, preferring the cooler temperatures of the higher elevations. The Western Hemlock grows 125 to 175 feet tall with a diameter of up to 5 feet.

MOUNTAIN HEMLOCK (Tsuga mertensiana) - Mountain Hemlocks are shorter than its cousin, the Western Hemlock. It grows only 75 to 100 feet tall when in protected locations. At higher exposed locations, it can appear stunted and more shrub-like. The Mountain Hemlock has a dense, green, rough appearance to its crown. Within the study area, Mountain Hemlocks are normally found only on north facing slopes and at high elevations.

APPENDIX 2

INTERPRETATION GUIDES

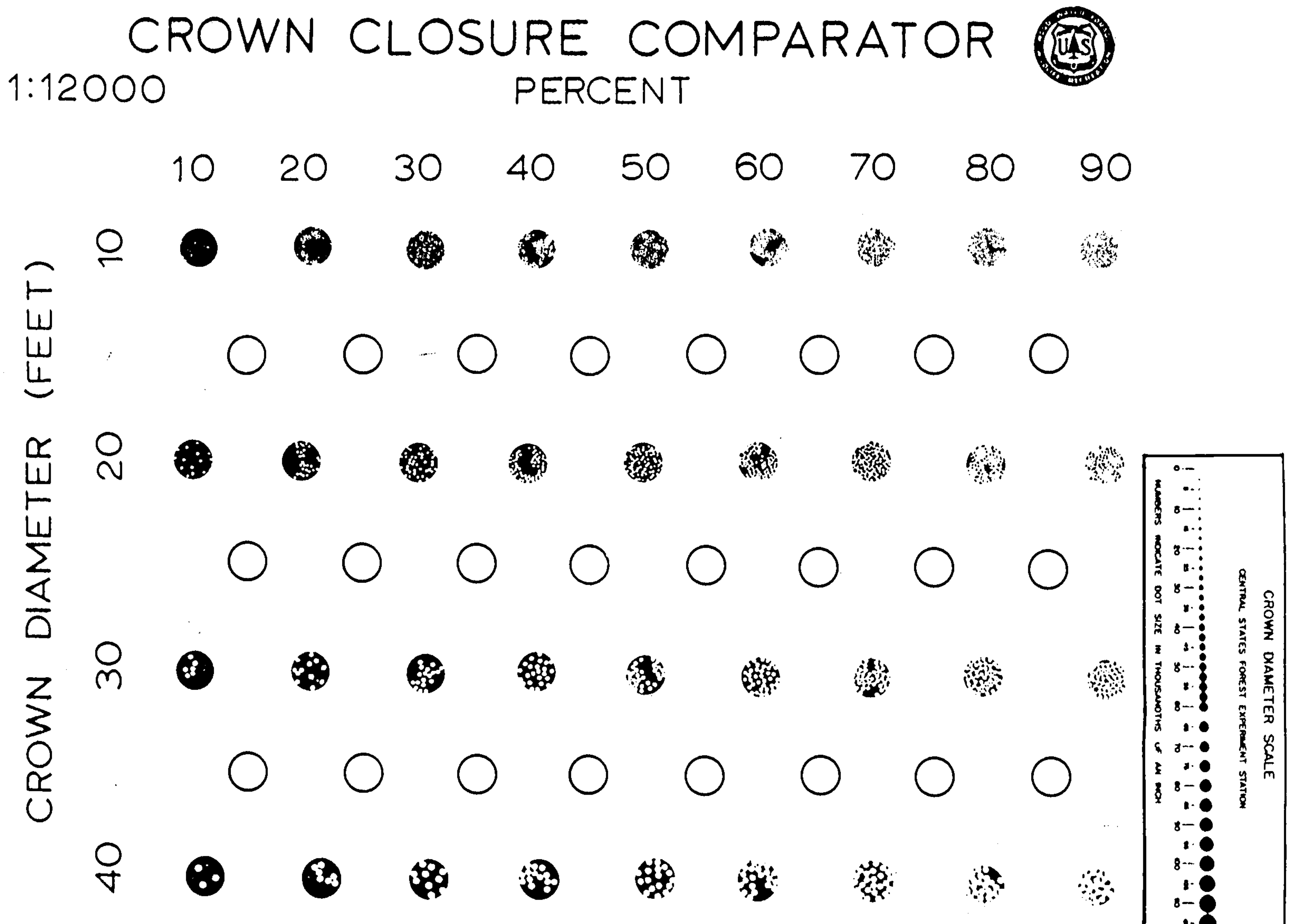


Figure 7-3.— Forest survey crown diameter scale.

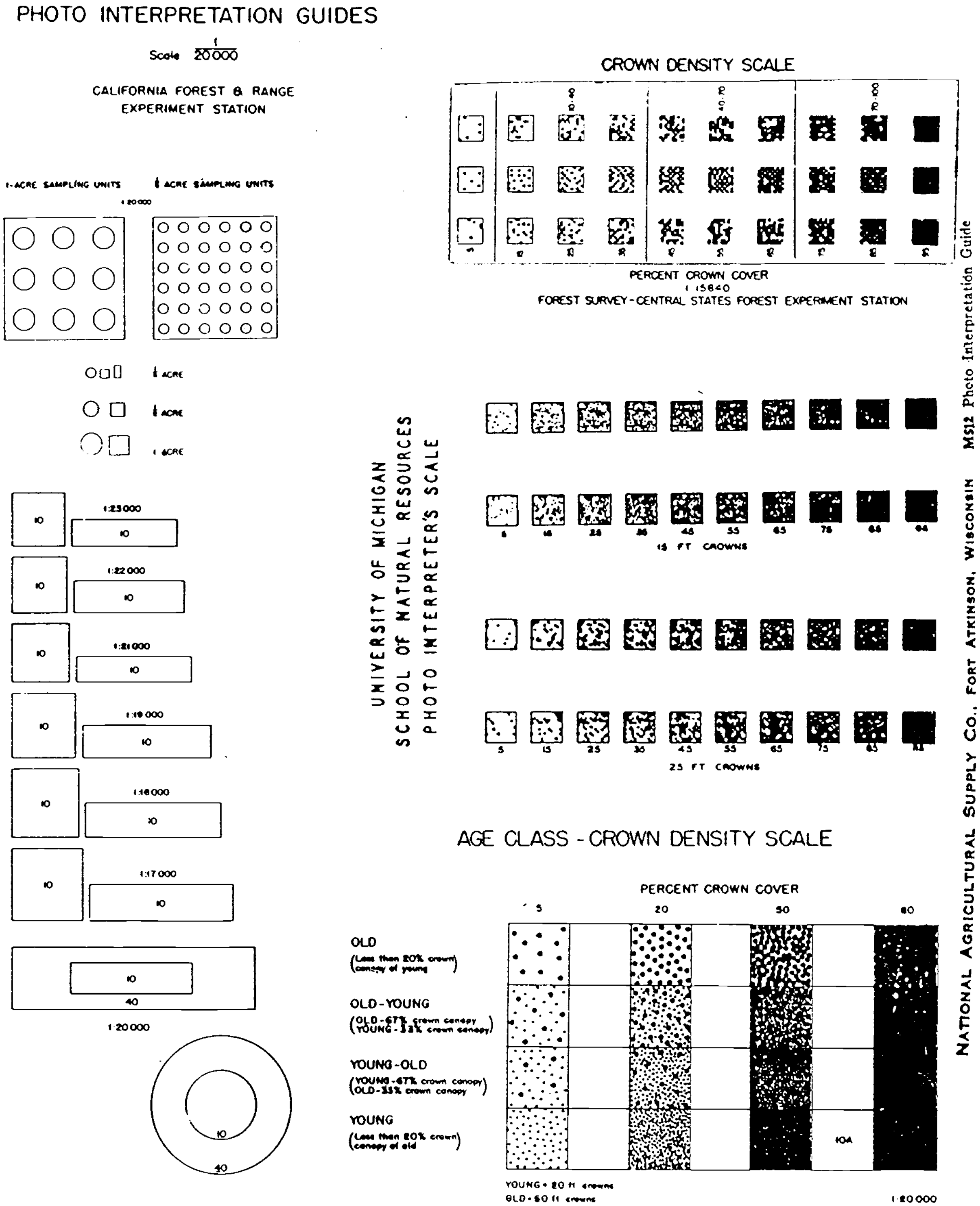
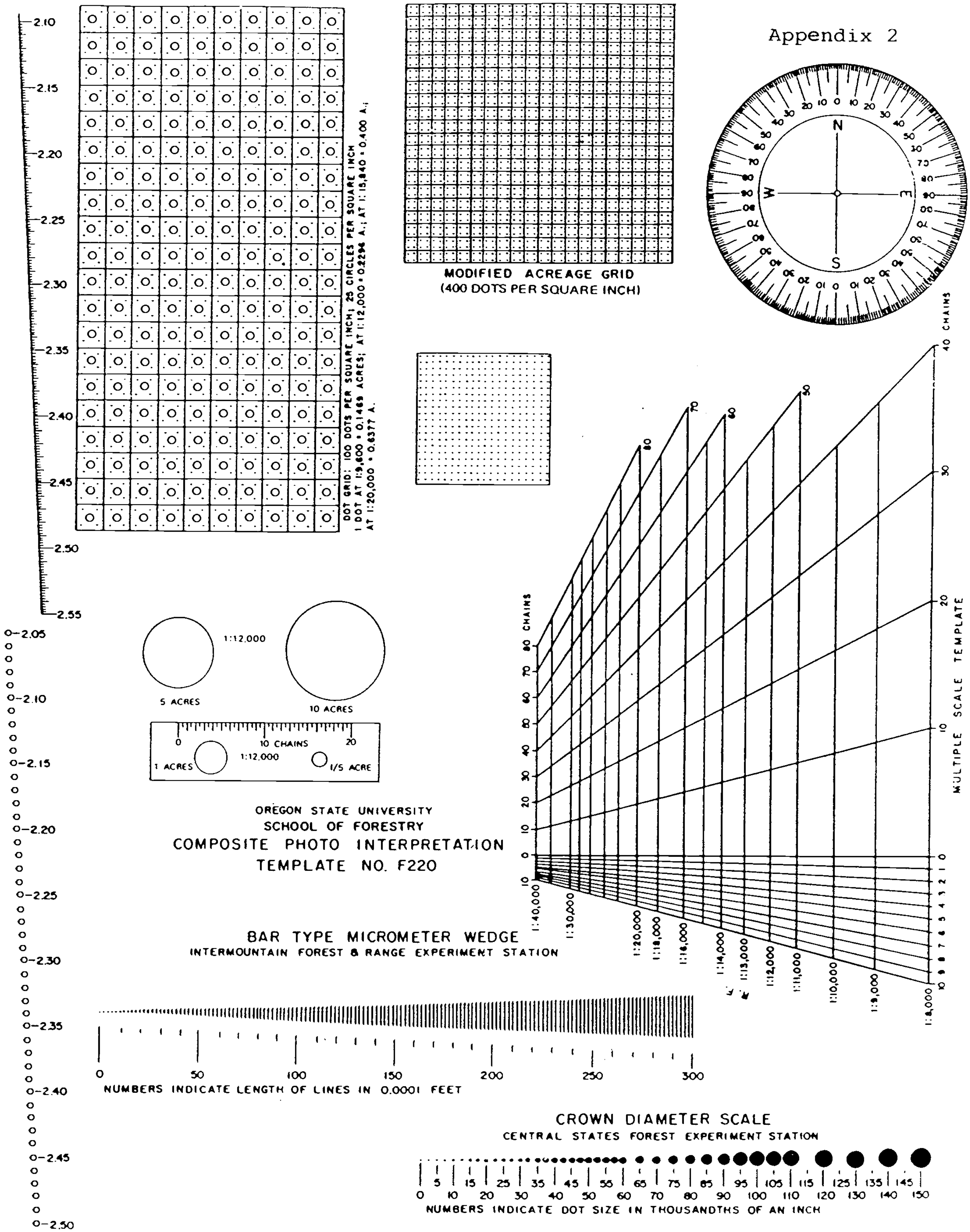


Figure 7-2.— Forest survey crown density scale.

Appendix 2


DOT GRID: 100 DOTS PER SQUARE INCH; 25 CIRCLES PER SQUARE INCH
1 DOT AT 1:9,600 = 0.1469 ACRES; AT 1:12,000 = 0.2296 A.; AT 1:15,840 = 0.400 A.;
AT 1:20,000 = 0.6377 A.
MODIFIED ACREAGE GRID
(400 DOTS PER SQUARE INCH)
N
S
E
W
1:12,000
5 ACRES
10 ACRES
10 CHAINS
1 ACRES
1/5 ACRE
OREGON STATE UNIVERSITY
SCHOOL OF FORESTRY
COMPOSITE PHOTO INTERPRETATION
TEMPLATE NO. F220
BAR TYPE MICROMETER WEDGE
INTERMOUNTAIN FOREST & RANGE EXPERIMENT STATION
MULTIPLE SCALE TEMPLATE
40 CHAINS
80 CHAINS
1:40,000
1:30,000
1:20,000
1:18,000
1:16,000
1:14,000
1:13,000
1:12,000
1:11,000
1:10,000
1:9,000
1:8,000
0 50 100 150 200 250 300
NUMBERS INDICATE LENGTH OF LINES IN 0.0001 FEET
CROWN DIAMETER SCALE
CENTRAL STATES FOREST EXPERIMENT STATION
5 15 25 35 45 55 65 75 85 95 105 115 125 135 145
0 10 20 30 40 50 60 70 80 90 100 110 120 130 140 150
NUMBERS INDICATE DOT SIZE IN THOUSANDTHS OF AN INCH

Appendix 3 (Delineation of the Effective Area)

This process is taken from the guide for Forest Resource Inventories (pp. 3.18-21). The basic steps used in this procedure were used in the delineation of effective areas on project aerial photographs.

The effective area of a vertical photograph is the area closer to its PP than to the PP of any other photograph. The shape of the camera lens and variations of topography make only a portion of the aerial photograph suitable for mapping within reasonable accuracy limits. The true effective area is circular as is the camera lens; but to simplify the procedure, a rectangular area is generally used. The procedures for mountainous country, where elevation differences exceed 152m (500 ft), are given in the following steps:

Step 1: Select from the indexed photographs the flight strip on the east edge of the photocoverage.

Step 2: Starting from the south end of this flight strip, begin with the first two photographs that give stereocoverage of a given ownership.

Step 3: By inspection, place the south boundary of the area on photograph 1 or the southernmost photograph (line A>B on fig. 10).

Step 4: Since it is easier for a right-handed person to transfer a line from the north to the south, move to photograph 2 or the next photograph north. To delineate the south boundary of the effective area on this photograph, construct a line approximately bisecting the overlap. Extend this line to both edges of the photograph (line C>D on fig. 10).

Step 5: Place photographs 1 and 2 in stereoposition and transfer the line drawn on photograph 2 to photograph 1. This is most easily done by drawing dashes where the line appears to cross ridges and valleys and then connecting then under stereovision. Depending on the variation in the topography, this line many be undulating rather than straight (line C'>D' on fig. 10).

Step 6: The northern and southern effective area boundaries are now on photograph 1. Follow this same procedure northward up the flight strip until it is completed. The northern effective area boundary on the northernmost photograph will be the area boundary.

Step 7: After working two adjoining flight strips as above, begin delineating the east and west boundaries of the effective area.

Step 8: Beginning at the south end again, select adjacent photographs from the two easternmost flights and place them in the stereoposition to view the sidelap. (The stereocoverage may be poorly defined because of the interval between photoexposures in these two flights and the aggravated distortion on the edges

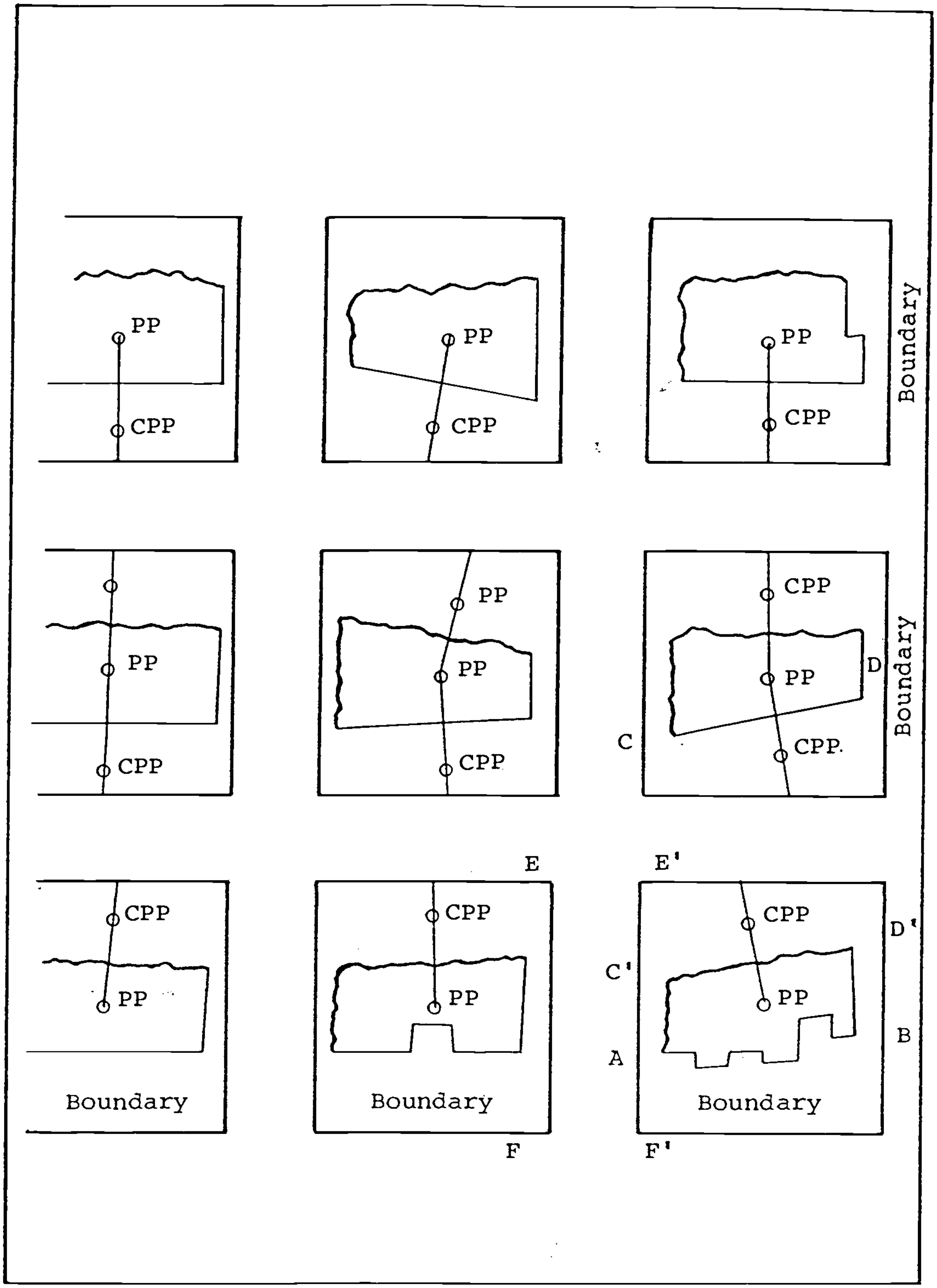


Figure 10.— Effective area delineation for mountainous areas.

of the photographs.) Draw the matching line under the stereoscope whenever possible, using the same situations, stereomodels will be impossible to achieve between the flight lines. When this situation occurs, dot the corresponding images in the center area of the sidelap and connect them with straight lines. In many cases one picture covers only a portion of the sidelap match line; therefore, the picture immediately above or below must be used to complete the boundary (line E>F on fig. 10).

Step 9: Transfer the line drawn on the left-hand photograph to the right-hand photograph, completing the outlining of the effective area (lines E' and F' on fig. 10)

Step 10: Continue in this manner until all photographs are completed. The result is an effective area in the center of each, which covers all areas in the project without duplication. Figure 10 shows the appearance of the completed photographs.

For areas of low topographic relief (elevation differences less than 152m or 500 feet), the procedure can be changed slightly.

The effective areas can be delineated on alternate photographs. In step 4 above, using photographs 1 and 3, instead of bisecting the flight line, the line should be drawn near the CCP (approximately one-half the overlap) and perpendicular to the flight line. Sidelap should be divided in the same manner as for mountainous areas. Figure 11 shows the completed appearance of the completed photographs.

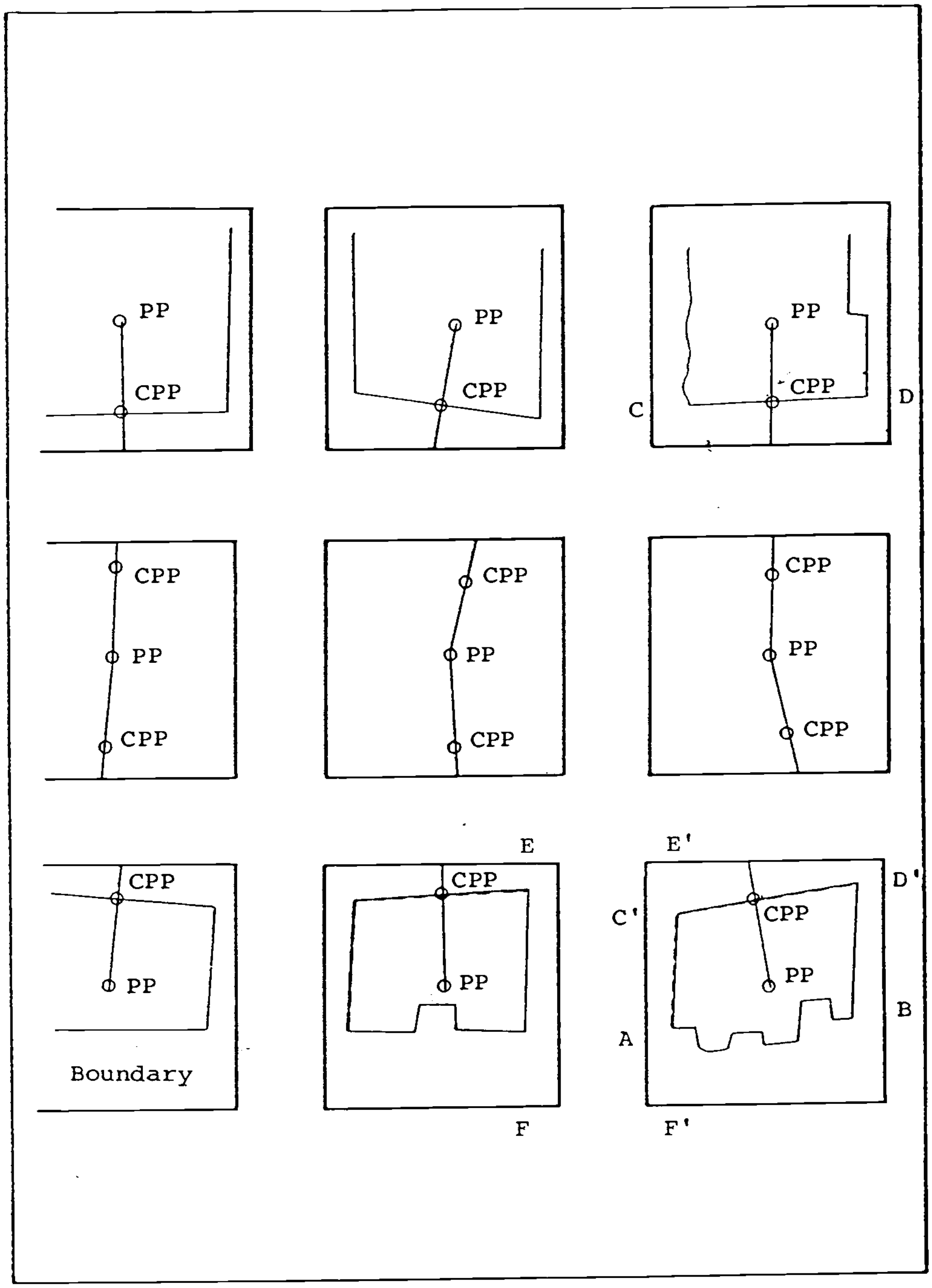


Figure 11.– Photopreparation for flatwoods.

Appendix 4 (Work and Cost Estimate)

Work Estimate:

Photographs to interpret (approximately)	=	250
Time to prepare and interpret one photo (avg)	=	25 min.
Time to transfer one photo to overlay	=	15 min.
Time per photo for prep/interpret/transfer	=	40 min.
250 X 40 min.	=	**166.7 hours**
Administrative Time	=	10 hours
Final Map Preparation (ink)	=	20 hours (2x10)
Field Time	=	24 hours (3x10)
Total Estimated Time for Project	=	**220.7 hours**

Hours Available:

December	=	30
January	=	80
February	=	70
March	=	60

Total Hours Avail. = 240

(19.3 hours excess)

Cost Estimate:

Drafting Supplies	=	$100.00
Miscellaneous	=	$50.00
Field Expenses / Gas	=	$150.00 (3 trips)
Hours (240 X $15.00)	=	$3600.00
Reprographics Cost	=	$300.00

Total Project Estimated Cost = $4200

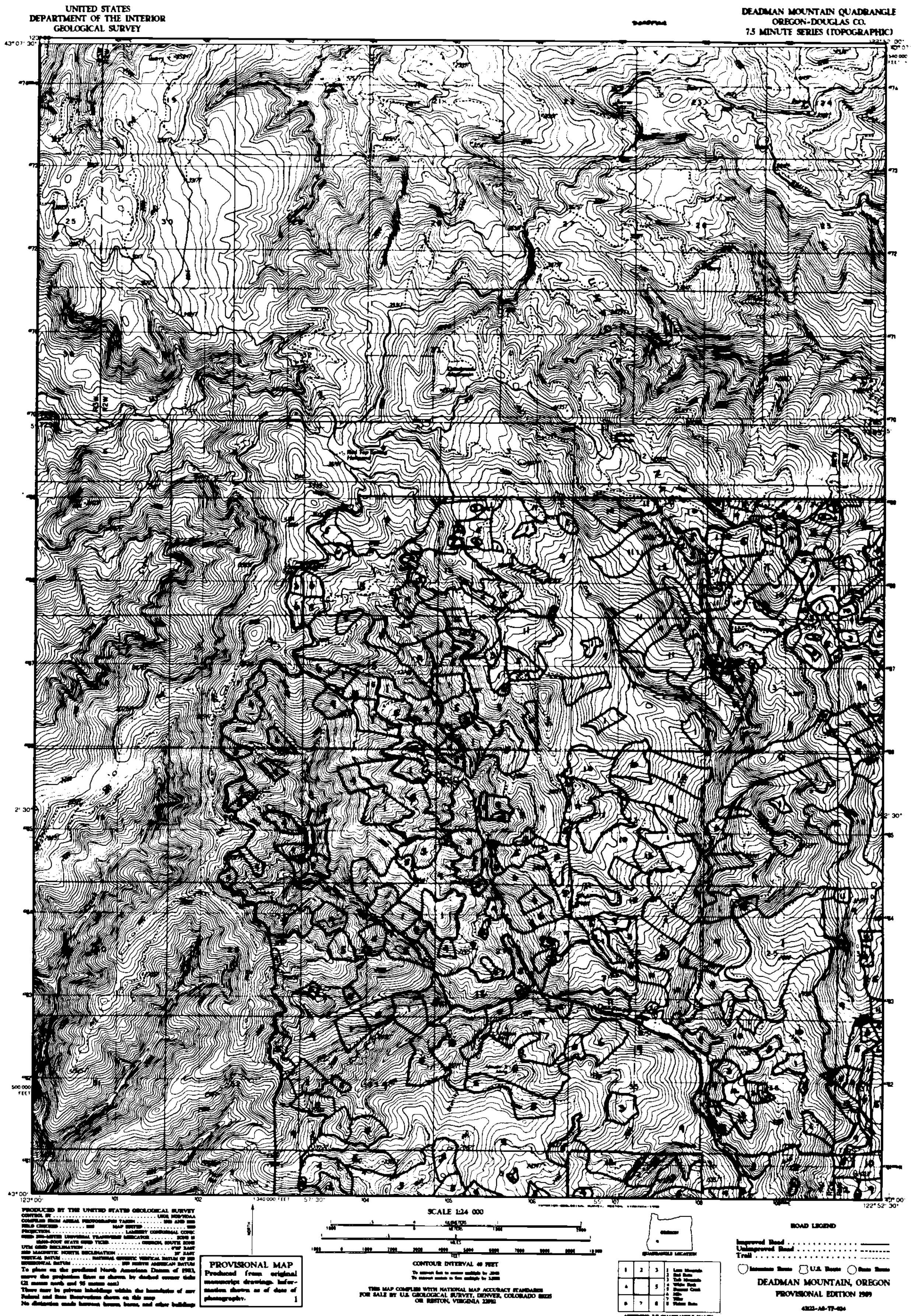
South Umpqua Turkey Project

7.5 Min. Topographic Quadrangle Key

DEADMAN	DUMONT	ACKER ROCK	BUCKEYE LAKE
TILLER	PICKETT BUTTE	BUTLER BUTTE	
RICHTER	RAGSDALE	SUGARPINE CREEK	

TN ↑

(See References for Specific Map Information)



UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
DEADMAN MOUNTAIN QUADRANGLE
OREGON-DOUGLAS CO.
7.5 MINUTE SERIES (TOPOGRAPHIC)
PRODUCED BY THE UNITED STATES GEOLOGICAL SURVEY
PROVISIONAL MAP
Produced from original manuscript drawings. Information shown as of date of photography.
SCALE 1:24 000
CONTOUR INTERVAL 40 FEET
THIS MAP COMPLIES WITH NATIONAL MAP ACCURACY STANDARDS
FOR SALE BY U.S. GEOLOGICAL SURVEY, DENVER, COLORADO
OR RESTON, VIRGINIA
ROAD LEGEND
U.S. Route
DEADMAN MOUNTAIN, OREGON
PROVISIONAL EDITION

Bottom

UNITED STATES
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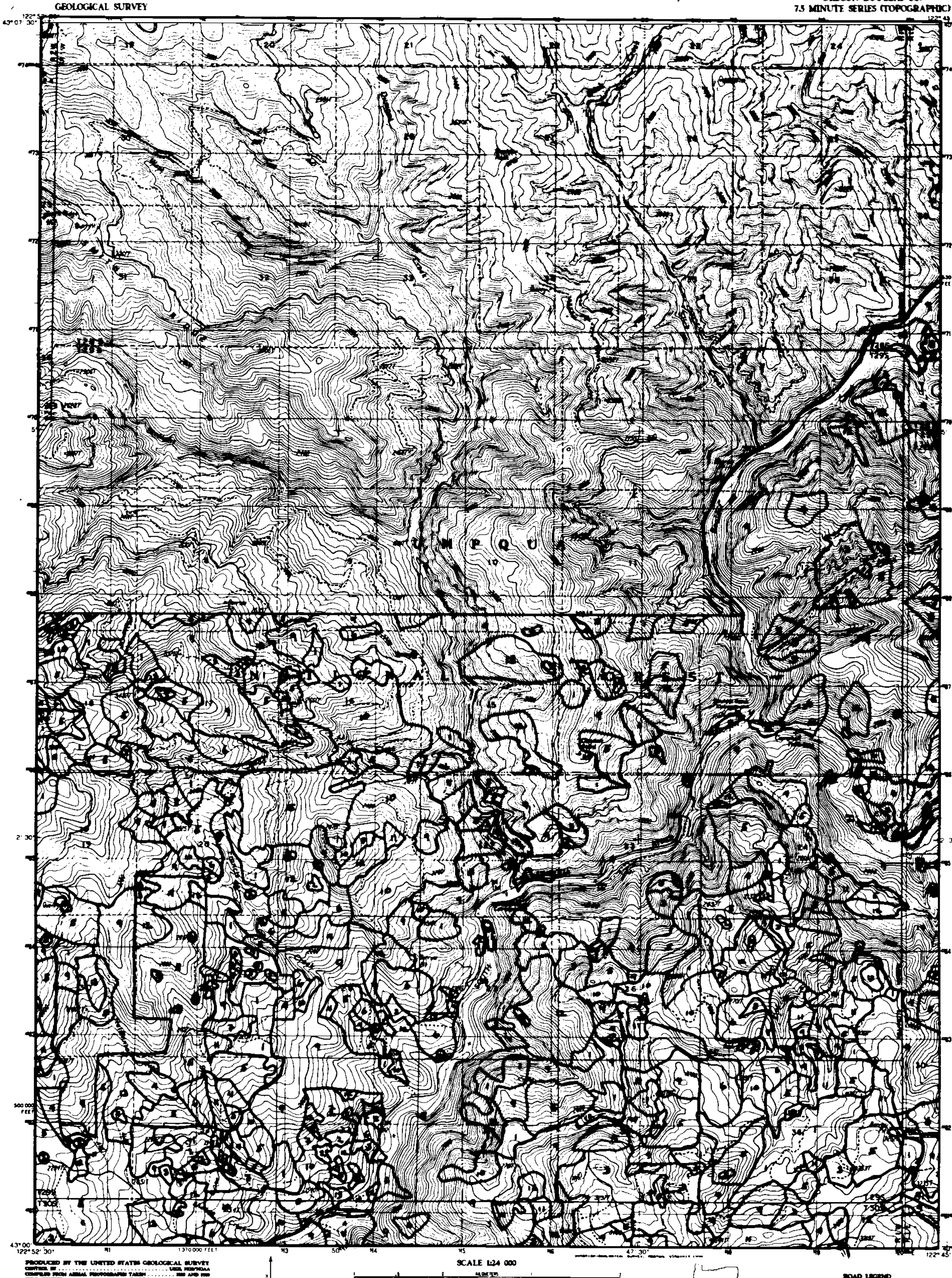
GEOLOGICAL SURVEY

DUMONT CREEK QUADRANGLE
OREGON-DOUGLAS CO.
7.5 MINUTE SERIES (TOPOGRAPHIC)

DUMONT CREEK



PRODUCED BY THE UNITED STATES GEOLOGICAL SURVEY

To place on the predicted North American Datum of 1983, move the projection lines as shown by dashed corner ticks

There may be private inholdings within the boundaries of any Federal and State Reservations shown on this map

No distinction made between houses, barns, and other buildings

PROVISIONAL MAP
Produced from original manuscript drawings. Information shown as of date of photography.

SCALE 1:24 000

CONTOUR INTERVAL 40 FEET

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OR RESTON, VIRGINIA 22092

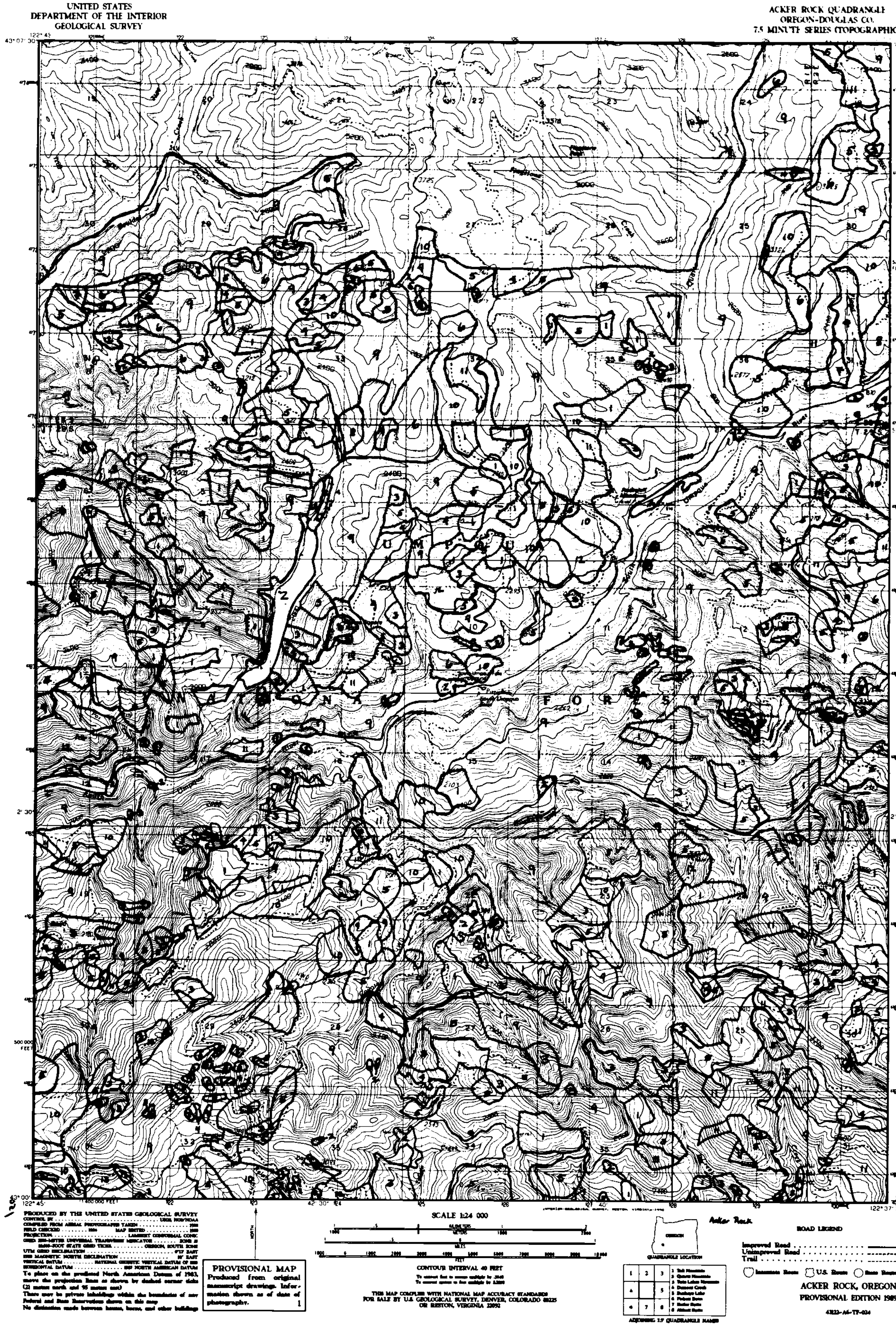
QUADRANGLE LOCATION

ADJOINING 7.5' QUADRANGLE NAMES

ROAD LEGEND
Improved Road
Unimproved Road
Trail

Interstate Route · U.S. Route · State Route

DUMONT CREEK, OREGON
PROVISIONAL EDITION 1989


UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
ACKER ROCK QUADRANGLE
OREGON-DOUGLAS CO.
7.5 MINUTE SERIES (TOPOGRAPHIC)
PRODUCED BY THE UNITED STATES GEOLOGICAL SURVEY
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SCALE 1:24 000
CONTOUR INTERVAL 40 FEET
FOR SALE BY U.S. GEOLOGICAL SURVEY, DENVER, COLORADO
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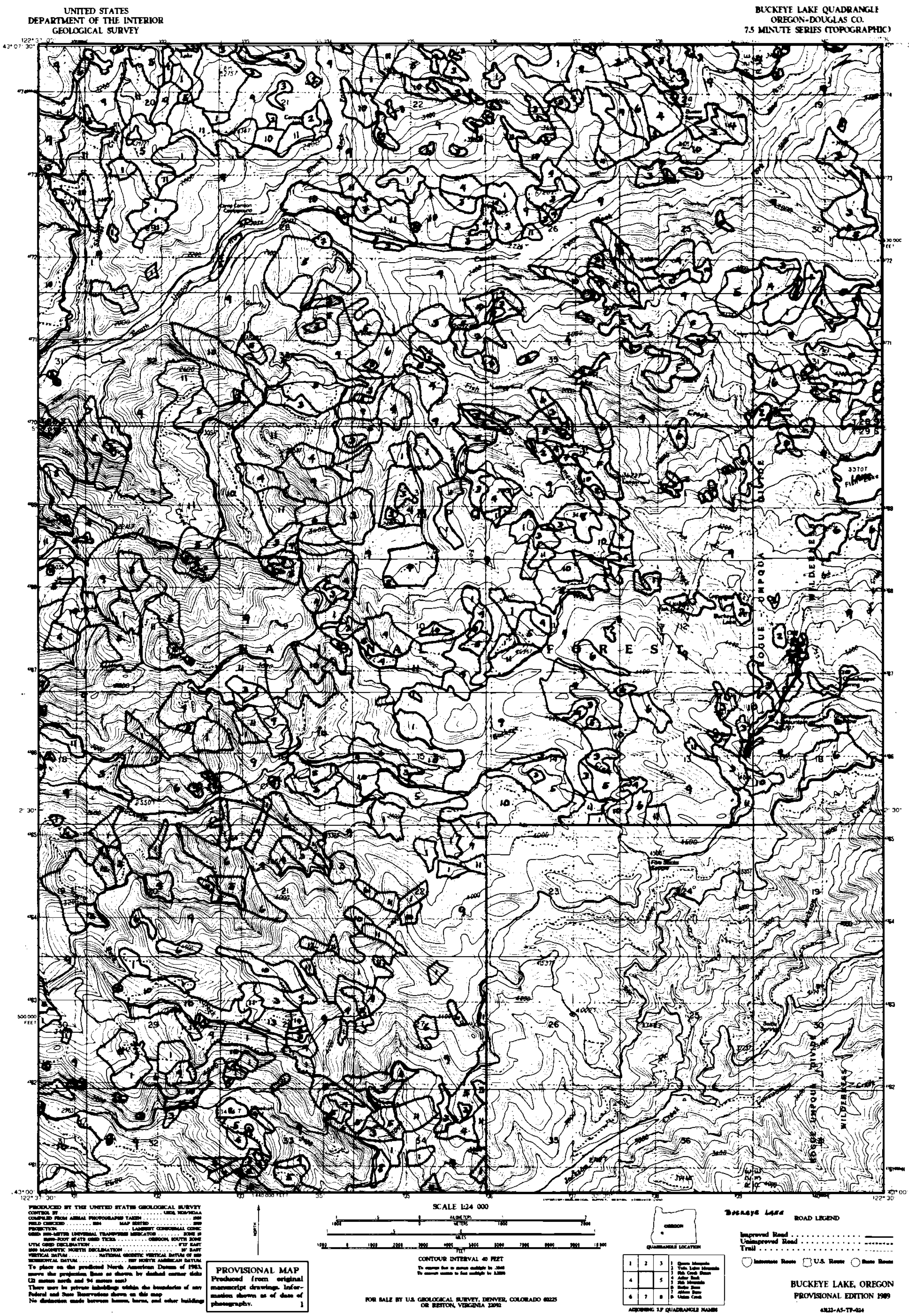
QUADRANGLE LOCATION
ROAD LEGEND
Improved Road
Unimproved Road
Trail
U.S. Route
ACKER ROCK, OREGON
PROVISIONAL EDITION 1989


UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
BUCKEYE LAKE QUADRANGLE
OREGON-DOUGLAS CO.
7.5 MINUTE SERIES (TOPOGRAPHIC)
SCALE 1:24 000
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PROVISIONAL MAP
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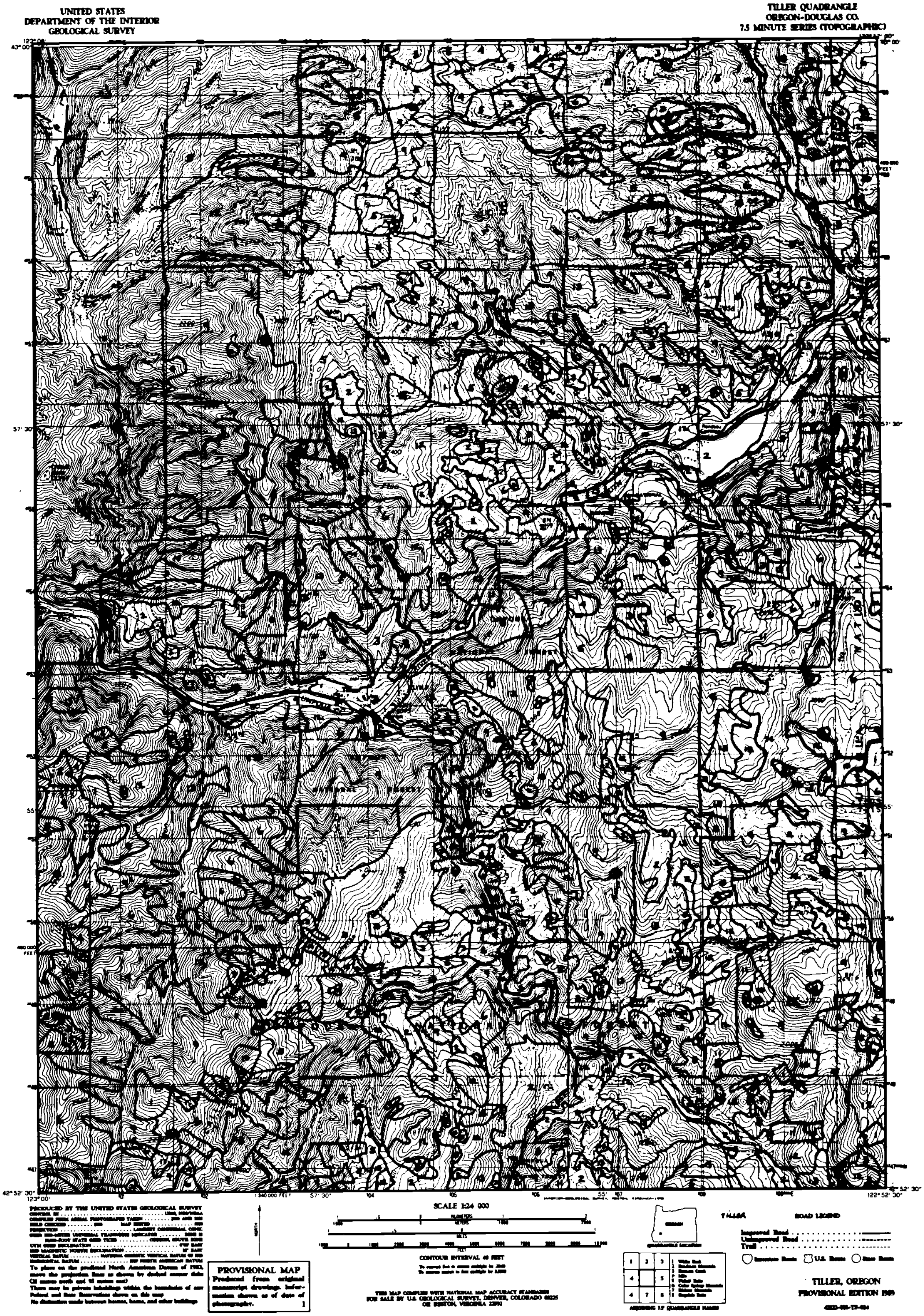
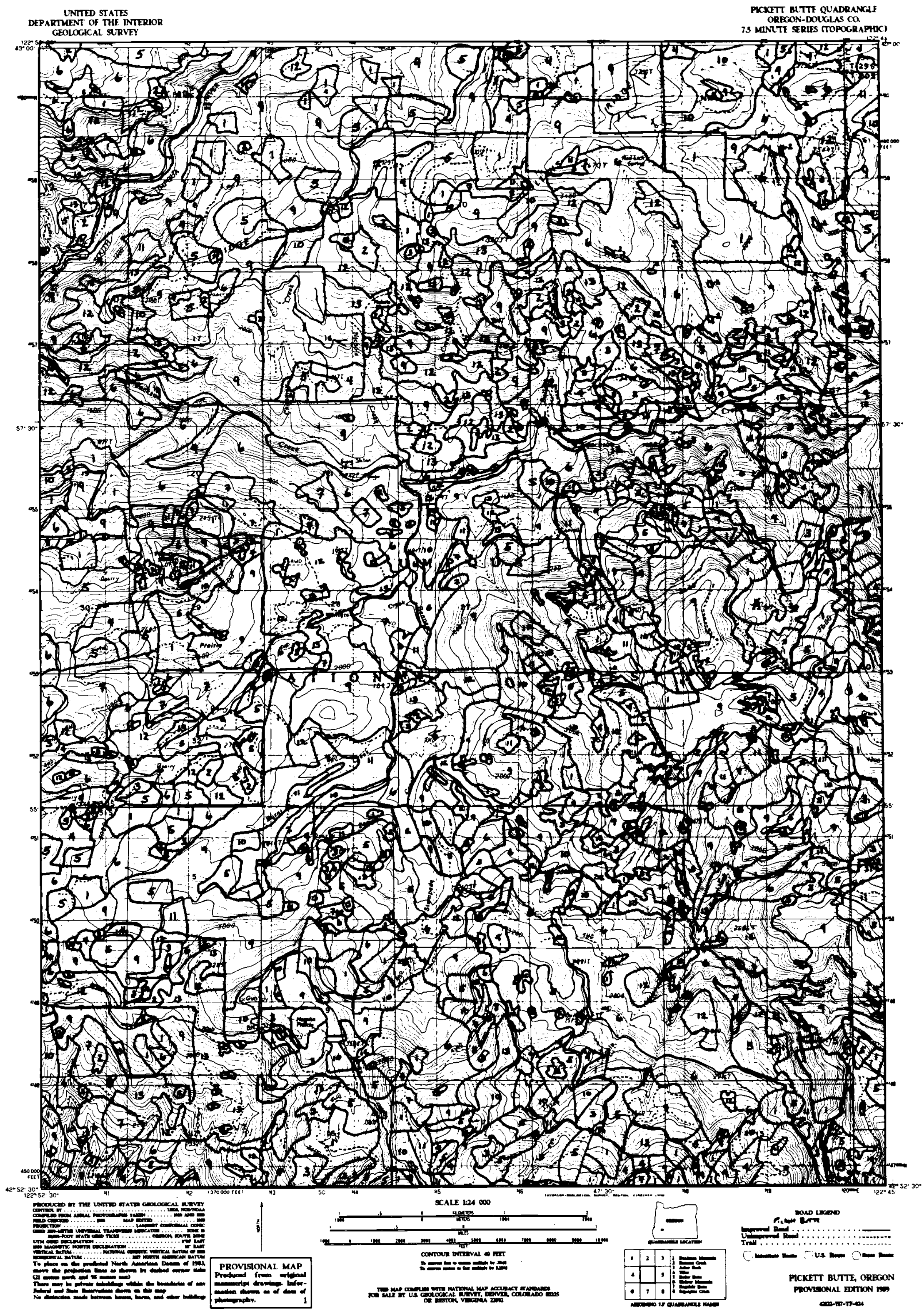
ROAD LEGEND
BUCKEYE LAKE, OREGON
PROVISIONAL EDITION 1989


UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
TILLER QUADRANGLE
OREGON-DOUGLAS CO.
7.5 MINUTE SERIES (TOPOGRAPHIC)
43° 00'
57' 30"
55'
42° 52' 30"
123° 00'
122° 52' 30"
SCALE 1:24 000
CONTOUR INTERVAL 40 FEET
PROVISIONAL MAP
Produced from original manuscript drawings. Information shown as of date of photography.
ROAD LEGEND
Trail
U.S. Route
TILLER, OREGON
PROVISIONAL EDITION 1989


UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
PICKETT BUTTE QUADRANGLE
OREGON-DOUGLAS CO.
7.5 MINUTE SERIES (TOPOGRAPHIC)
PRODUCED BY THE UNITED STATES GEOLOGICAL SURVEY
SCALE 1:24 000
CONTOUR INTERVAL 40 FEET
PROVISIONAL MAP
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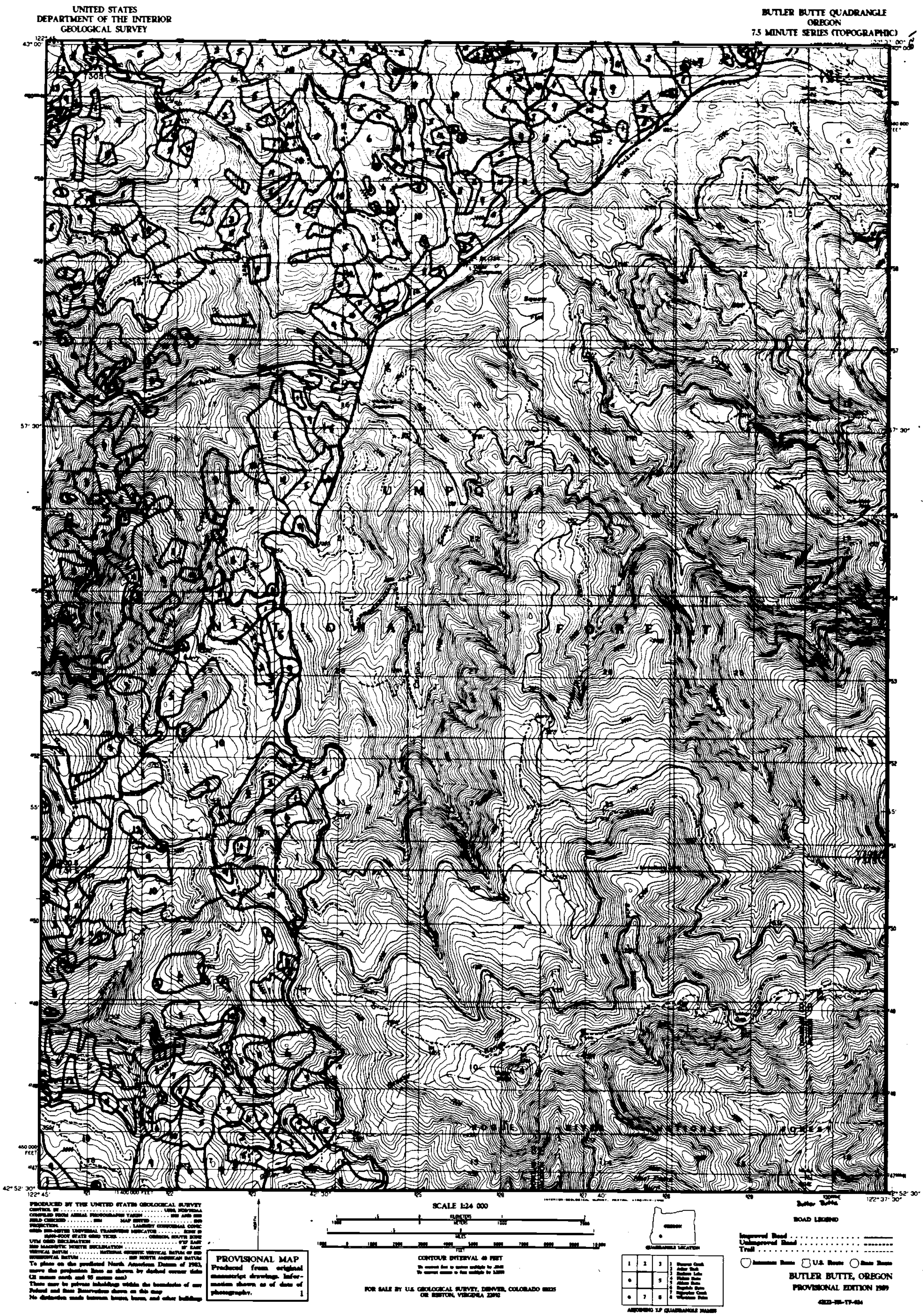
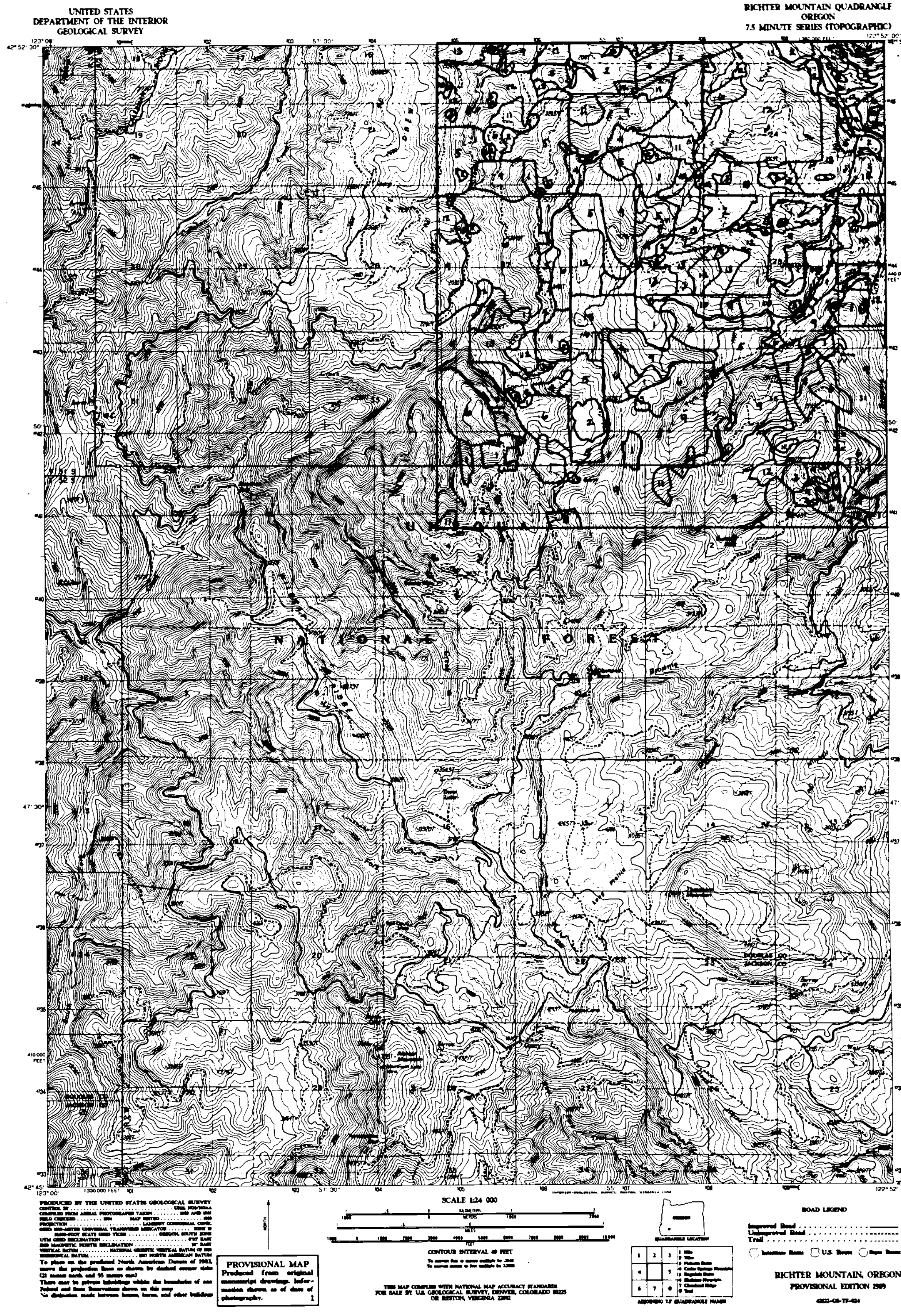
ROAD LEGEND
PICKETT BUTTE, OREGON
PROVISIONAL EDITION 1989

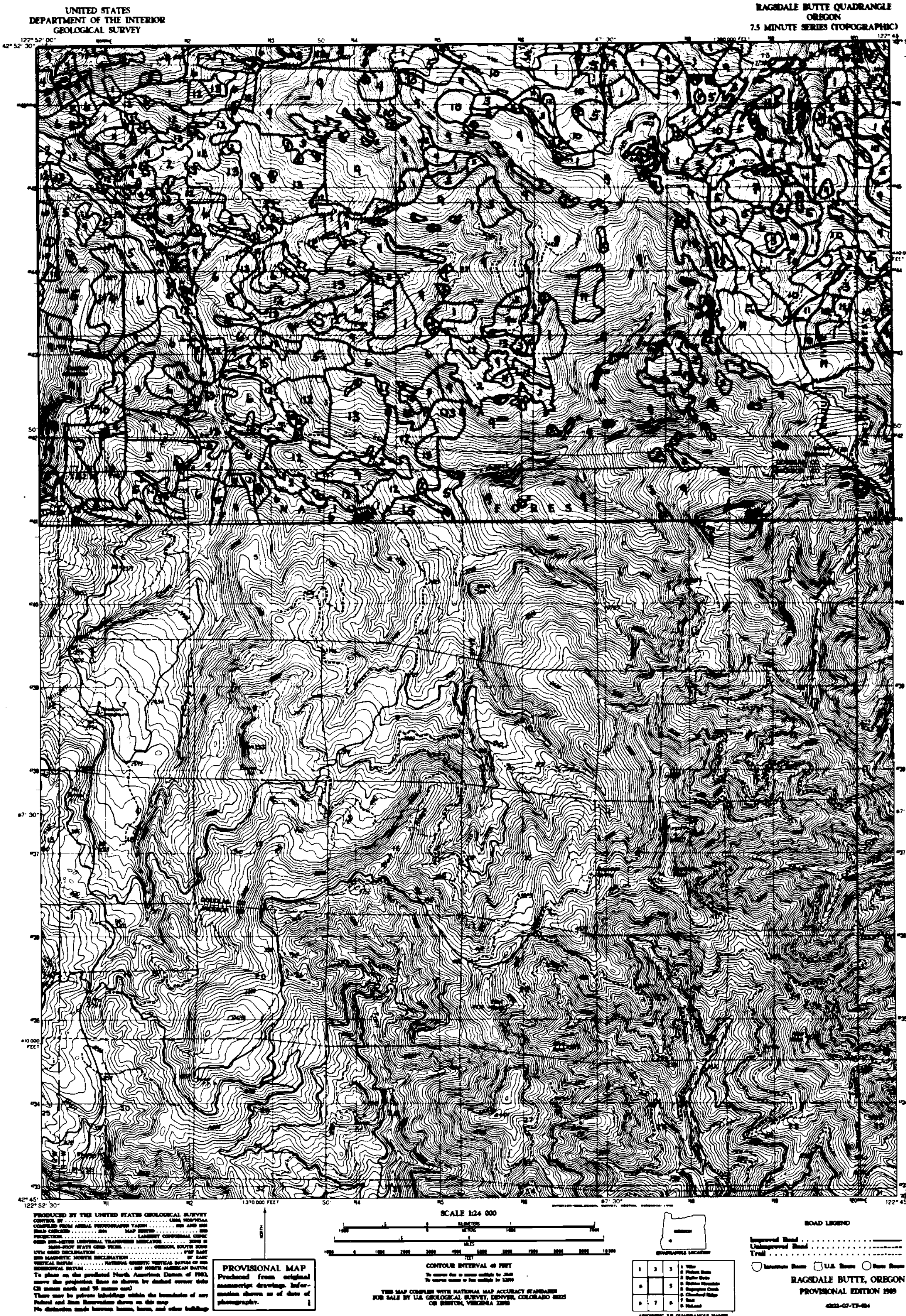
Pickett



UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
BUTLER BUTTE QUADRANGLE
OREGON
7.5 MINUTE SERIES (TOPOGRAPHIC)
43° 00'
57' 30"
55'
42° 52' 30"
122° 45'
42' 30"
40'
122° 37' 30"
U M P Q U A
N A T I O N A L
F O R E S T
PRODUCED BY THE UNITED STATES GEOLOGICAL SURVEY
To place on the predicted North American Datum of 1983, move the projection lines as shown by dashed corner ticks (21 meters north and 95 meters east)
PROVISIONAL MAP
Produced from original manuscript drawings. Information shown as of date of photography.
SCALE 1:24 000
CONTOUR INTERVAL 40 FEET
FOR SALE BY U.S. GEOLOGICAL SURVEY, DENVER, COLORADO 80225
OR RESTON, VIRGINIA 22092
QUADRANGLE LOCATION
ADJOINING 7.5' QUADRANGLE NAMES
ROAD LEGEND
Improved Road
Unimproved Road
Trail
BUTLER BUTTE, OREGON
PROVISIONAL EDITION 1989


UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
RICHTER MOUNTAIN QUADRANGLE
OREGON
7.5 MINUTE SERIES (TOPOGRAPHIC)
NATIONAL
FOREST
SCALE 1:24 000
CONTOUR INTERVAL 40 FEET
PROVISIONAL MAP
Produced from original manuscript drawings. Information shown as of date of photography.
ROAD LEGEND
RICHTER MOUNTAIN, OREGON
PROVISIONAL EDITION 1989

Top Right



UNITED STATES
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RAGSDALE BUTTE QUADRANGLE
OREGON
7.5 MINUTE SERIES (TOPOGRAPHIC)
PRODUCED BY THE UNITED STATES GEOLOGICAL SURVEY
PROVISIONAL MAP
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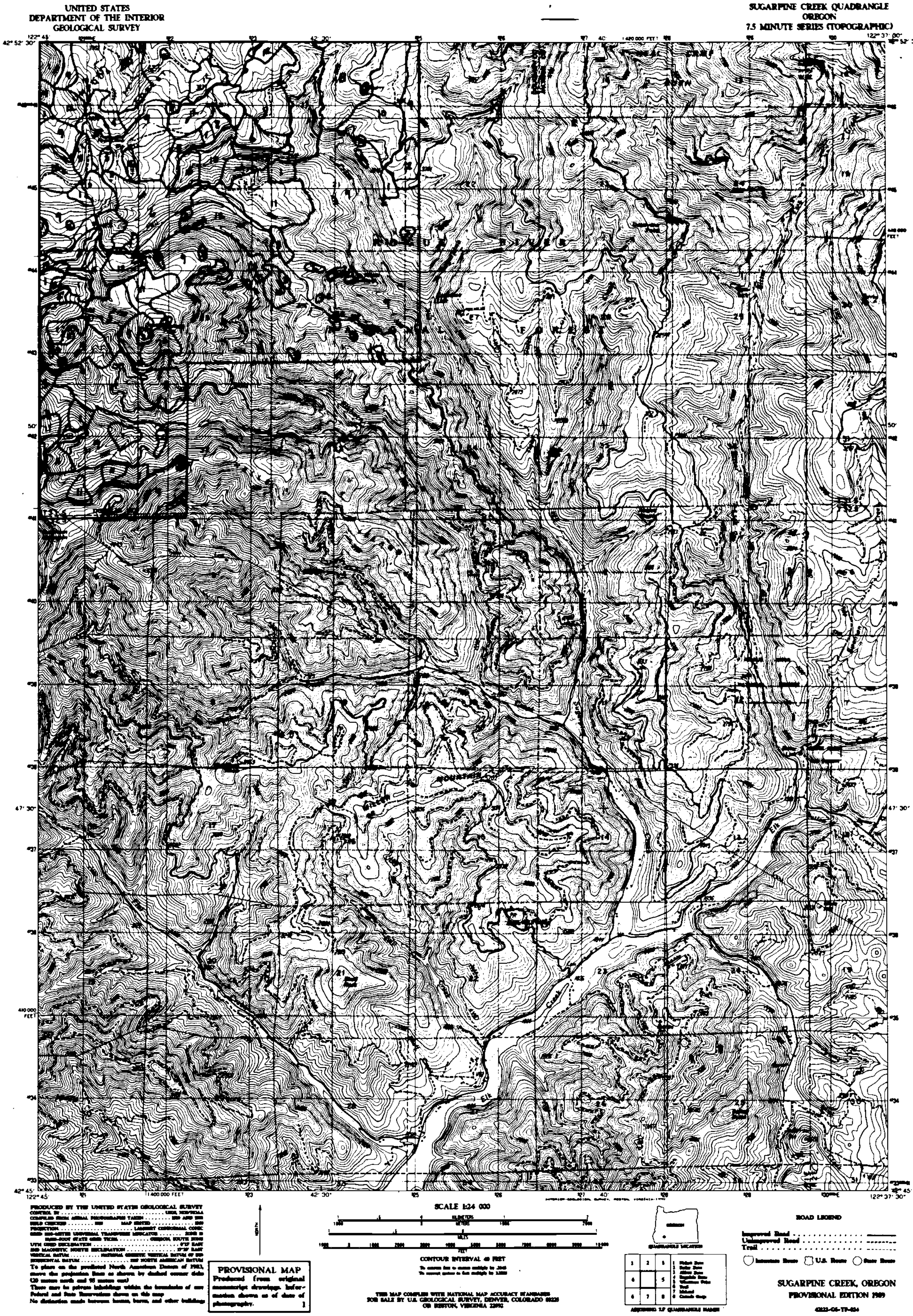
SCALE 1:24 000
CONTOUR INTERVAL 40 FEET
ROAD LEGEND
Improved Road
Unimproved Road
Trail
U.S. Route
RAGSDALE BUTTE, OREGON
PROVISIONAL EDITION 1989


UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
SUGARPINE CREEK QUADRANGLE
OREGON
7.5 MINUTE SERIES (TOPOGRAPHIC)
SCALE 1:24 000
CONTOUR INTERVAL 40 FEET
PROVISIONAL MAP
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ROAD LEGEND
Improved Road
Unimproved Road
Trail
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SUGARPINE CREEK, OREGON
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