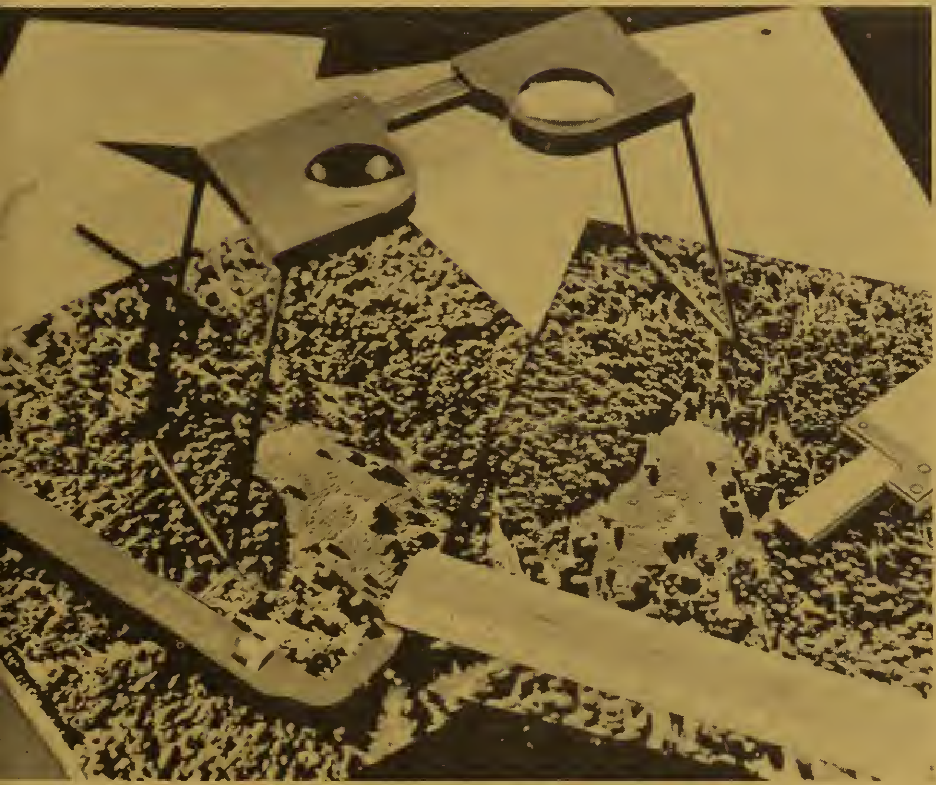
TRAINING HANDBOOK

Basic Techniques in Forest Photo Interpretation

BY

KARL E. MOESSNER



Intermountain Forest & Range Experiment Station
Forest Service
U. S. Department of Agriculture
Ogden, Utah
Reed W. Bailey, Director

In preparing this training handbook, photographs, photo interpretation devices, tables, and ground measurements have been assembled from many sources.

In particular, we wish to recognize the cooperation of the following:

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INTRODUCTION

This training handbook presents a series of practical problems in the use of aerial photos for persons who learn best by doing.

Foresters, engineers, and many other land use scientists are fast recognizing the value of aerial photos in their work. Photogrammetry initially gained status through use in mapping, but it can help greatly in solving the everyday problems of timber estimating, range and watershed reconnaissance, and road or trail location.

Recent graduates and many experienced foresters have studied existing textbooks and manuals in the hope of learning how to use aerial photos effectively. These foresters may have varying amounts of working knowledge and experience with photogrammetry, but they have one thing in common--lack of success in learning techniques or skills by merely reading about them. Effective use of aerial photos is a skill that can be acquired only by practice.

Two general types of information can be extracted from aerial photos:

Objective.--Essentially the various kinds of spatial measurements, such as location, direction, length, size, area, and volume.

Subjective.--The personal conclusions and interpretations reached by specialists as they evaluate these measurements and other information of a qualitative nature for their various fields.

The successful interpreter first learns to make the simple yet precise measurements, which his knowledge and experience will translate into reliable interpretations that will have value in his work.

In the Forest Service, training in the use of aerial photos is a never-ending responsibility. College students employed seasonally in the Forest Survey field organization are one group that must be trained every spring. Research personnel, rangers, staff assistants, and others of the permanent organization form a second group, with somewhat advanced needs. Cooperators,

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1/ This training handbook has been prepared primarily for use by instructors in photo interpretation. For purposes of illustration only it includes text and photos for a series of 13 instructional problems. These problems and the necessary photos, photo interpretation aids and devices may be purchased as a kit by ordering from Engineering Division, Region 4, U.S. Forest Service, Ogden, Utah.

visitors from other nations, and management specialists--all would like to be able to use available aerial photos effectively. Even colleges and forestry schools are eager for assistance, particularly in connection with short courses. Although these various groups present a diversity of requirements, all have one common requirement--to learn the techniques of elementary photogrammetry. These techniques are not too difficult to learn and mastery does not depend upon years of experience or proficiency in specialized work.

OBJECTIVES

This training handbook presents a series of laboratory exercises designed to carry the trainee from procedure in elementary stereovision through basic photo measurements to the practical application of these skills in problems of photo sampling, aerial estimating of timber volumes, and preliminary location of forest roads and trails.

The exercises, accepted answers, and a brief discussion of training methods are presented to help instructors prepare photo training programs to fit their particular needs.

These exercises, together with necessary photos, aids, and devices, are available in looseleaf form for classroom use or for use by individuals who wish to learn the elementary skills of photo interpretation by directed practice.

BASIC PRINCIPLES

Any training school is held for the sole purpose of enabling the student to do his job better. A photo training school should improve the student's skill in his everyday use of aerial photos. The chief value of a lecture on the many uses for aerial photos is that it acquaints the student with many opportunities for using this skill. Such a lecture should create in the student a desire to get the most possible out of the training course. The lecture itself adds little to his skill in using photos.

The laboratory method, i.e. learning by doing, is the oldest and probably the best method of learning techniques and skills. Since effective use of aerial photos involves a high degree of skill in the use of several aids and devices, laboratory methods that include little lecturing and much practice give best results.

A training school should be planned in terms of what the instructor wants the student to learn to do, not what material he wants to "cover."

Students learn not because of what the instructor does but because of what he gets them to do. Having decided what specific skills are to be taught, the instructor concentrates on what the students need to do to learn these operations. In this course, training is limited to practice of specific elementary skills used in operations performed on aerial photos.

The instructor's job is to create interest on the part of the student, guide him through certain procedures, and give him opportunity to spend most of his time in practicing techniques and in correcting mistakes. The instructor's work does not end with the lecture or presentation of the problem: it is completed only when he is sure the student understands and can apply the techniques taught.

ANALYZING TRAINING NEEDS

Since this kind of photo training course is to be planned in terms of what the student will learn to do, it is necessary to analyze his job and find out what parts of it require use of aerial photos. Learning is an active process. Time is limited in any training school, and most of it should be used for exercises that will help the student learn the skill he needs. Exploration of all parts of the subject is seldom possible. Instead, the instructor must be selective. He must confine his course to those techniques actually needed by the student in his work.

For example, if we study the work of a seasonal Forest Survey field man to determine his photo training requirements, we find that certain phases of his work require him to use aerial photos (see column I of the tabulation in figure 1). These parts of his job impose requirements of specific skills in photo interpretation; and these, in turn, dictate desirable learning outcomes from a course such as this.

After determining what he must be able to do and what we can reasonably expect him to learn within the allotted training time, we build detailed laboratory exercises and problems designed to fit his needs.

Analysis of the photo training requirements of many different forestry jobs indicates that certain basic photogrammetric techniques are needed on all. For example, almost all jobs require the individual to identify objects and recognize terrain on the photos. To do this he must learn to view the photos stereoscopically. Many jobs require the location of points from the photos; therefore he must be able to measure lines and angles on the photos. To convert these measurements to distances on the ground, the trainee must first be able to determine the scale of his photos. The same photogrammetric principles used by the engineer to determine elevation difference and slope percent are needed by the watershed manager and the soil scientist in their terrain studies, and are the basis for the techniques developed by the forester to measure tree height and stand volume. However, not all trainees require the same skill in every phase, and not all training schools are the same length. The instructor in his individual analyses must determine what kind and how many exercises he can use.

The basic techniques--stereoscopy, identification of photo images, measurement of distance, angles, elevation differences, areas, and volumes--together with some examples of application to the problems of the forester, form the basis for the exercises in this training handbook.

I. HIS JOB.--What he does that requires a knowledge of aerial photos.

A. Travels to the vicinity of a selected field plot which has been pinpointed on his aerial photos.

B. Locates on the ground the precise field plot center pinpointed on his aerial photos.

C. Checks photo classification and typing in vicinity of the field plot.

II. PHOTO REQUIREMENTS.--What he must be able to do on or with photos.

1. View aerial photos stereoscopically through lens stereo.
2. Recognize terrain features on his photos.
3. Identify landmarks.
4. Visualize slopes and grades.
5. Recognize difficult and dangerous field conditions.
6. Select the best travel routes to plot areas.
7. Pinpoint on his photos trees or other landmarks defining his base line.
8. Measure on photos the precise length of a line.
9. Determine the scale of his photos at plot location.
10. Measure bearing and distance on photo and record.
11. Recognize species classes.
12. Visualize minimum areas and width of strips.
13. Recognize stand size classes.
14. Recognize stand density classes.

III. LEARNING OUTCOME.--What we can expect him to learn during this specific photo course.

a. To align photos for best stereo vision using principal and conjugate principal points. To transfer points stereoscopically between overlapping photos. To learn basic photo nomenclature.
b. To study and identify terrain conditions and specific points or landmarks.
c. To measure distances and angles and to convert these to ground distance and bearing using the photo scale protractor and other photo aids.
d. To determine the local scale of his photos by base line and to visualize and compute scale differences due to topographic changes of the ground. To recognize photo displacement due to topography.
e. To recognize species and stand size classes, height changes and possible site differences visible on the photos and to recognize and locate type lines between them.
f. To recognize crown cover classifications.

Figure 1.--Analysis of photo training requirements for a Forest Survey field man. Analysis of specific training requirements along these general lines should aid instructors in selecting those photo training problems needed for their particular training school.

THE TRAINING PROBLEMS

The training problems in this handbook are designed to lead the student through a series of motions, measurements, and thoughts to assure that he is doing instead of merely sitting and listening. The first few problems present basic ideas with requirements that illustrate the technique, formula, or photogrammetric aid being studied. These exercises can be completed in a 1- or 2-hour period, including the time spent in explanation, demonstration, and checking or discussing results.

Later exercises allow the student to use one or several of the aids and techniques in solving practical problems related to his job. In these he not only finds it necessary to think how he will apply what he learned in earlier exercises but also improves his skill by using several aids and techniques in one problem. These more complicated problems may require 4 to 6 hours for complete solution.

The Problem Format

The standard format used for each problem is outlined below:

Title and number.--A short title indicates the main point of the problem. A number is added for reference but does not necessarily indicate the order in which these problems are to be used in any one training session.

Objective.--A brief statement of objectives lists what the student is to learn from working this problem.

Tools and materials.--A list of the photo interpretation tools, aids, and tables necessary to work the problem, together with the reference number of the annotated photos used, shows what the trainee must have at hand to prepare each assignment.

Explanation.--This section explains all formulas, theories, and background information necessary to work this problem. Essentially the same material is discussed by the instructor at the start of the period, but this pointed statement allows the student to refer to the necessary information without the need of writing detailed notes on the preceding lecture.

Requirements.--This section enumerates exactly what the student must do to complete this problem. Usually this section contains blanks for entering measurements, computations, or other answers to questions. Having the solution in this form rather than on assorted scrap paper is advantageous to the instructor when he checks results, and to the student when he reviews techniques.

The Problem Photos

Stereo coverage is required for each problem. Annotations consisting of numbered or lettered arrows and circles must be entered on one photo of the stereo pair to indicate precisely the distances, angles, trees, plots, or objects to be measured or identified while solving the problem. All students must be given identical photos.

Normally a pair of 9- x 9-inch contact prints would be needed for each problem, and these would have to be annotated by hand since no entries can be made on the original aerial film. Photographic materials for a training course of this type are admittedly expensive, and can seldom be re-used by consecutive training classes. In order to reduce this excessive cost, stereo half-photos are used in most problems where individual photos are required, and stereograms are used in those problems where previously mounted photos are acceptable; wherever possible, photos used in one problem are used for different purposes in later problems.

Since stereo coverage is obtained from the overlapping 60 percent of two consecutive aerial photos, stereo half-photos (fig. 2) are prepared by mounting two overlapping contact prints end to end in line of flight, and copying the center portion on a single 8- x 10-inch negative. Annotations, including principal points, are entered on prints before copying or on copy negatives. The resulting 8- x 10-inch prints are cut in half for class use.

Stereograms (fig. 3) are prepared by mounting photos in line of flight, properly separated for viewing with a lens stereoscope, and with principal and conjugate points in a single straight line. Copies are made on 5- x 7-inch or 8- x 10-inch film with annotations as described. Stereograms are used as a single print.

Occasionally, where terrain features needed for the problem do not occur on a single contact print, several stereograms are mounted together and printed as a single problem photo. Copy work is usually at 1:1 scale since any change in scale must be accounted for in problem formula. Frequently, the problem photos are printed on glossy paper for added detail, though semi-matte or aerial paper can be used if desired. The copy method may result in a slight loss of photo detail, but it assures identical annotated prints for each student, and a saving of at least half the cost in photographic materials.

Interpretation Aids and Tables

Interpretation aids needed in working the problems are included with the training kit. Alignment guides, photo scale protractors, parallax wedges, crown diameter wedges, and other measuring devices included as film transparencies are shown in figure 4.

Crown coverage charts are printed on photo paper, and the various parallax tables, flying-height photo-scale conversion tables, and aerial volume tables included in printed form are shown in figure 5.

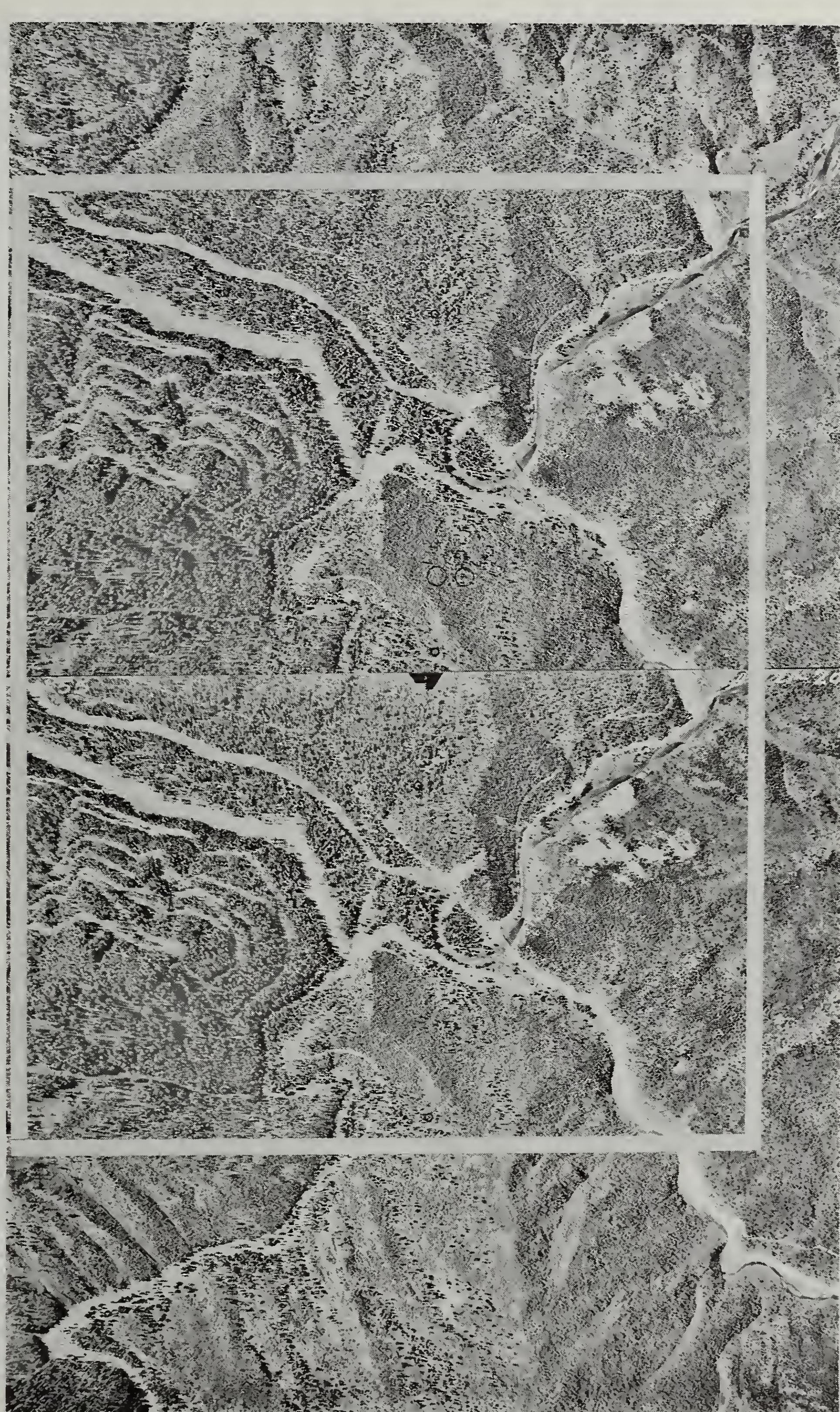


Figure 2.--Stereo half-photos are prepared by mounting two overlapping prints as shown, and copying the center 8- x 10-inch area as indicated by the taped line. They are later cut apart for class use. Principal and conjugate principal points, together with other annotations, may be entered on the photo before copying or on the copy negative.

Figure 3.--Stereograms are prepared as shown. Photos are set up for parallax measurement. The area within the taped line is copied and used as a single print. Annotations may be entered either on the original photo or the copy negative.

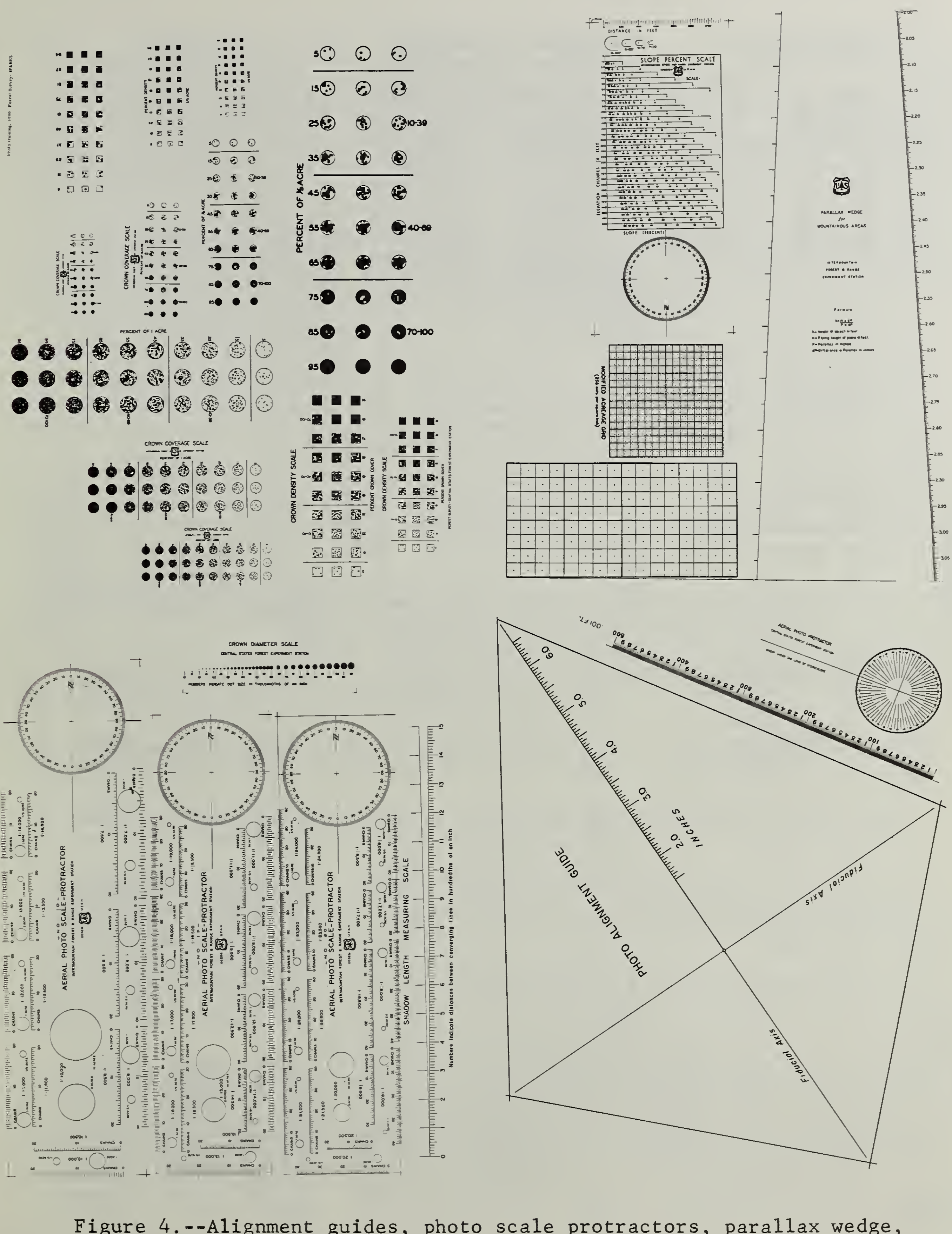


Figure 4.--Alignment guides, photo scale protractors, parallax wedge, crown diameter wedge, slope percent scale, and other measuring devices are illustrated here at reduced scale. All except crown coverage scale are used as film transparencies. See appendix.

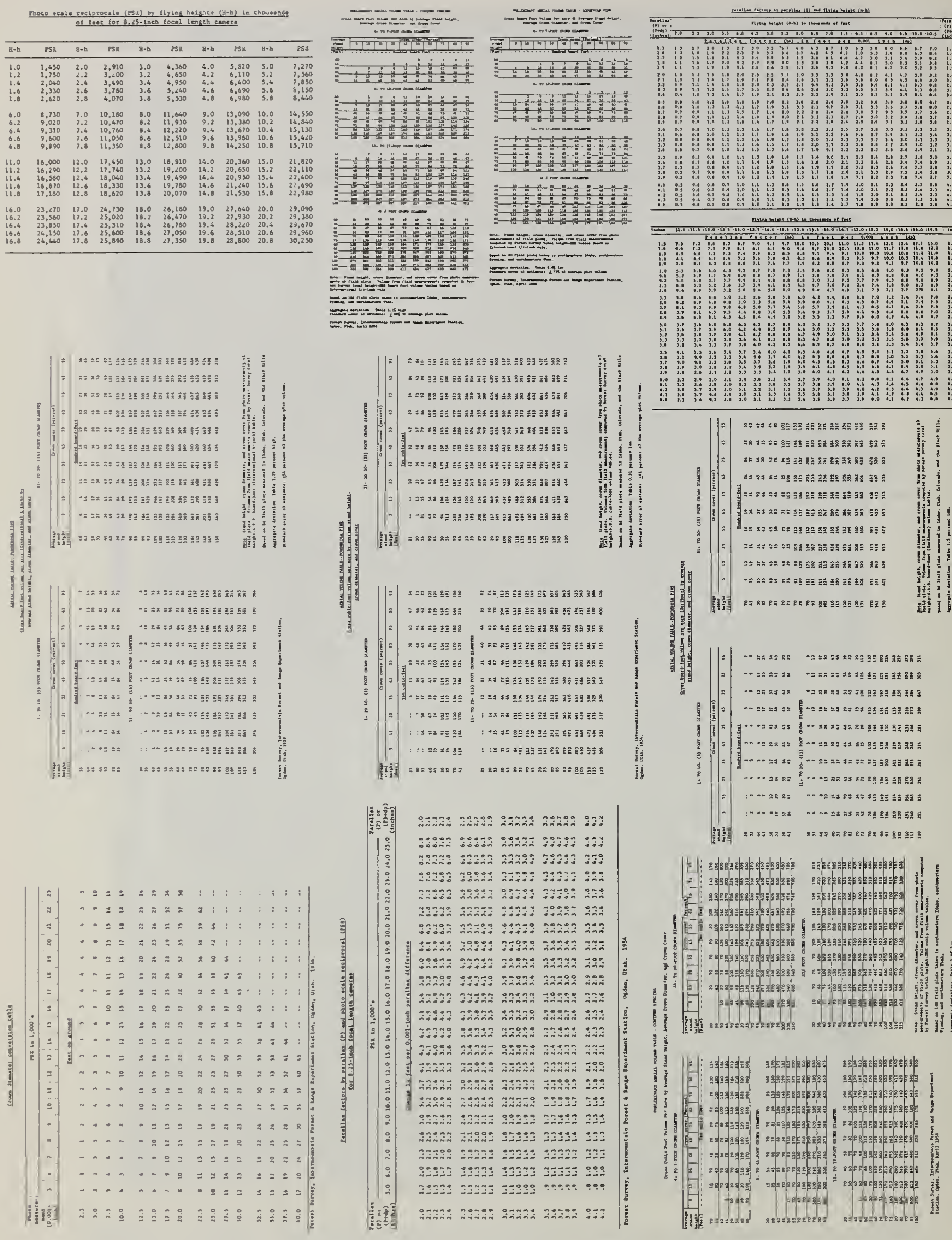


Photo scale reciprocals (PSR) by flying heights (H-h) in thousands of feet for 8.25-inch focal length camera

H-h	PSR	H-h	PSR	H-h	PSR	H-h	PSR	H-h	PSR
1.0	1,450	2.0	2,910	3.0	4,360	4.0	5,820	5.0	7,270
1.2	1,750	2.2	3,200	3.2	4,650	4.2	6,110	5.2	7,560
1.4	2,040	2.4	3,490	3.4	4,950	4.4	6,400	5.4	7,850
1.6	2,330	2.6	3,780	3.6	5,240	4.6	6,690	5.6	8,150
1.8	2,620	2.8	4,070	3.8	5,530	4.8	6,980	5.8	8,440
6.0	8,730	7.0	10,180	8.0	11,640	9.0	13,090	10.0	14,550
6.2	9,020	7.2	10,470	8.2	11,930	9.2	13,380	10.2	14,840
6.4	9,310	7.4	10,760	8.4	12,220	9.4	13,670	10.4	15,130
6.6	9,600	7.6	11,050	8.6	12,510	9.6	13,980	10.6	15,420
6.8	9,890	7.8	11,350	8.8	12,800	9.8	14,250	10.8	15,710
11.0	16,000	12.0	17,450	13.0	18,910	14.0	20,360	15.0	21,820
11.2	16,290	12.2	17,740	13.2	19,200	14.2	20,650	15.2	22,110
11.4	16,580	12.4	18,040	13.4	19,490	14.4	20,950	15.4	22,400
11.6	16,870	12.6	18,330	13.6	19,780	14.6	21,240	15.6	22,690
11.8	17,180	12.8	18,620	13.8	20,070	14.8	21,530	15.8	22,980
16.0	23,270	17.0	24,730	18.0	26,180	19.0	27,640	20.0	29,090
16.2	23,560	17.2	25,020	18.2	26,470	19.2	27,930	20.2	29,380
16.4	23,850	17.4	25,310	18.4	26,780	19.4	28,220	20.4	29,670
16.6	24,150	17.6	25,600	18.6	27,050	19.6	28,510	20.6	29,960
16.8	24,440	17.8	25,890	18.8	27,350	19.8	28,800	20.8	30,250

Figure 5.--Parallax tables, conversion tables, and aerial volume tables as shown at reduced scale. These are used in printed form. See appendix.

THE LESSON PLAN

Most persons are unable to absorb more than three to five new ideas during a short lecture and cannot retain even these unless they are given a chance to use them, think about them, and perhaps ask a few questions. Rapid presentation of 15 or 20 facts just to cover the subject may reduce rather than increase learning.

The photo training course presented here is built around a series of exercises many of which can be completed in 2 hours. When using the laboratory method, the instructor should confine his presentation to those few ideas or formulae needed to work the given problem and the limited information required to integrate this problem into the whole course. Any qualified instructor familiar with his subject will have more facts and data available than he can possibly present in this manner. But since the laboratory method assumes students learn by doing, it is most important that the instructor know when to stop talking and let the students start learning.

This cannot be left to chance; it requires careful study. The instructor not only has to plan what he will do and what he hopes the student will do, but he must also estimate how long it will take to do it. This can best be done by using a lesson plan that will show for each period of instruction:

Objective or learning outcome.--Precisely what the instructor expects the student to learn as a result of the period of instruction.

Instructor activity.--What the instructor is going to do, or say, to help the student reach this learning outcome.

Student activity.--What the student is expected to do during the period in order to achieve the learning outcome.

Problems and materials.--The problem sheet, aerial photos, tools, and interpretation aids needed by the student in reaching this learning outcome.

Time.--The total time required for the period--the amount to be used by the instructor in presentation, demonstration, and checking; and the amount needed by the student to work the problem, ask questions, and discuss results.

An example of a lesson plan for the exercises included in the training kit is shown in figure 6.

The instructor will gain much from using such a lesson plan, even if he is unable to follow it precisely. At least he will have limited his material so that the students will have opportunity to absorb it, he will have the necessary work materials available when needed, and he will have organized the period so that most of the time is devoted to practical student learning.

Photo training, 1960. Forest Survey - IF&RES.

Training Plan
Basic Techniques in Forest Photo Interpretation

Estimated time	Problem No.	Problem name	Learning outcome	Instructor activity	Student activity	Tools and materials
10 min.--lecture 30 min.--tests 20 min.--grades 1 hour total	--	Stereoperception Test	An understanding of stereoperception. A measure of the student's stereoperception and ocular ability.	Discusses stereovision and its relationship to normal binocular vision, goes over instructions for the test. Grades tests as they are completed.	Takes stereoperception test, after learning to orient stereoscope, by checking each floating circle. Waits for grade. Repeats test if required.	Lens stereoscope, floating circles test sheet, pencil.
10 min.--lecture 30 min.--problem 20 min.--checking 1 hour total	1	Positioning Photos for Best Stereovision	Ability to align photos for best stereovision and for parallax measurements. Understanding of basic photo nomenclature.	Discusses photo nomenclature and explains why photos should be correctly lined up for measurement and for best stereo viewing. Demonstrates use of alignment guide. Checks individual photo setups and corrects those in error.	Locates principal points by use of alignment guide. Orients photos under stereo, and transfers points to overlapping photo. Aligns photos by means of guide and fastens to table by hinge tape. Checks alignment and measures distance between PP's.	Stereoscope, alignment guide, red and black pencils, needle point, problem sheet and stereo pair of photos, and two strips of masking tape.
10 min.--lecture 50 min.--problem 30 min.--check and discuss results 1.5 hours total	2	Recognition of Ground and Cover Conditions	Recognition of small details, differences in tone, texture, size, form, and shadow. Understanding of the relation of these to final photo interpretation.	Discusses the importance of studying small details in photo interpretation. Briefly indicates importance of tone, texture, size, shape, and shadow in arriving at interpretations. Indicates importance of logical reasoning. Reads and checks answers and discusses results.	Interprets 50 points and objects enumerated on his problem photos by checking one of four multiple choice answers. Studies each point in detail and checks its relation to surrounding terrain. Arrives at conclusions by logical reasoning. Checks paper as answers are read, studies incorrect points, and questions instructor where reasoning is obscure or not understood.	Stereoscope, problem sheet, stereogram, and pencil.
15 min.--lecture 90 min.--problem 15 min.--check and discussion 2 hours total	3	Determining Photo Scale	Ability to determine photo scale by photo-map or photo-ground relationship. Use of a base line and photo scale protractor to determine scale in the field. Understanding of scale differences due to elevation changes.	Points out importance of accurate scale determination in all interpretation. Lists scale formula and where used. Demonstrates use of photo scale and other scales. Illustrates use of base line on map or ground and photos. Emphasizes importance of level base line, length of base line, and base line close to point of use. Checks and discusses answers.	Measures several scale lines on problem photos and on map, using 0.001-foot rule. Computes scale of photo at each line. Uses stereoscope as magnifier during measurement, and slide rule during computation. Determines scale by photo scale protractor using base lines indicated on photos and premeasured distances. Compares scales at higher and lower elevations and discusses reasons for scale changes.	Stereoscope, map, problem sheet and photos, 0.001-foot rule, photo scale protractor, needle point, pencils, slide rule, and masking tape.
10 min.--lecture 90 min.--problem 20 min.--discussion 2 hours total	4	Determining Project Scale and Flying Height	Ability to determine project scale and flying height from a series of random base lines.	Discusses importance of determining mean flying height for a given project, and corresponding flying height and scale for various ground elevations. Points out that sampling and averaging simplify this determination. Checks average flying heights and computed errors.	Computes scale on 12 base lines previously measured on ground. Computes flying height above ground and sea level, and average height above sea level. Determines error of that average. Compares average with accepted answers and prepares table of scale and flying height for project. Uses table of scale flying height relationships.	Stereoscope, problem sheet and stereogram photos, needle point, pencils, slide rule, and flying height scale tables.
10 min.--lecture 40 min.--problem 10 min.--check and discussion 1 hour total	5	Determining Bearing and Distance on Aerial Photos	Ability to use scale protractor and measured base line to determine bearing and distance to plot center or other point located on photos.	Discusses use of scale protractor on Forest Survey. How to determine bearing and distance from base line. Stresses importance of base lines 10 to 15 chains long. Checks answers and discusses possible errors.	Determines scale from base line using scale protractor. Determines distance and bearing with scale protractors. Records on problem form for checking.	Stereoscope, problem sheet and photos, needle point, pencils, and photo scale protractor.
15 min.--lecture 5 min.--demonstration 130 min.--problem 30 min.--check 3 hours total	6	Determining Relative Elevation by Parallax Wedge	Ability to see the floating wedge line, and to measure ground line. Ability to compute absolute parallax and to use parallax formulae in computing height.	Discusses use of parallax measurements in forest jobs, and theory and formula used in parallax measurements. Refers to publication. Demonstrates principle of parallax wedge and how used by means of training stereogram. Gives personal assistance during problem; checks results.	Studies the parallax training stereogram until wedge lines and readings are visualized. Orients wedge over problem photos. Reads and records parallax wedge readings for points. Determines absolute parallax and substitutes data in formula to compute elevation differences.	Stereoscope, problem sheet and photos, training stereogram, parallax wedge, needle point, alignment guide, pencils, and slide rule. Pub. "Parallax Wedge Procedures."
15 min.--lecture 200 min.--problem 25 min.--check 4 hours total	7	Measurement of Tree and Stand Heights by Parallax Wedge	Ability to see and measure parallax at treetops. How to determine parallax difference for tree. Ability to compute tree height by formula and to use parallax factor and slide rule.	Discusses reasons for low measurements of tree heights. Points out that treetops and ground level are completely independent measurements. Stresses that parallax difference should be read direct for speed. Value of tree height measurements in aerial volume estimates. Use of parallax factor and parallax table. Computations in rough topography. Use of slide rule and parallax factor. Demonstrates procedure to those students requiring help. Checks answers and results and compares with established learning curve.	Studies parallax training stereogram with special attention to treetops. Orients wedge over photos and records ground and treetop readings for annotated trees. Tries reading parallax difference direct without recording top and bottom readings. Uses parallax factor and slide rule in computing tree height. Computes height by formula for comparison. Discusses procedure and compares results with accepted answers and with results obtained by other members of class.	Stereoscope, problem sheet and photos, training stereogram, parallax wedge, needle point, pencils, slide rule, and parallax and flying height tables.
10 min.--lecture 50 min.--problem 30 min.--check and discussion 1.5 hours total	8	Estimating Crown Diameter and Crown Coverage	Ability to measure tree crowns with dot type crown wedge. Ability to measure average crown diameter and crown coverage of plots.	Discusses value of tree and stand measurements in describing and classifying stands. Compares dot type and line type crown wedges. Discusses crown coverage measurements and means of making them. Why crown coverage scales rather than line sample. Demonstrates how wedges and scales are used under scope. Checks answers and compares results.	Visualizes reasons for measurements. Measures crown diameter on selected trees. Measures average crown diameter and crown coverage on selected plots. Measures both dominant and younger age classes on plots where they are obvious.	Stereoscope, problem sheet, stereograms, crown diameter scale, crown coverage scales, conversion tables.
15 min.--lecture 30 min.--problem 15 min.--discussion 1 hour total	9	Estimating Board-foot and Cubic-foot Volume on Sample Plots	Familiarization with aerial photo stand volume tables and methods of using these tables.	Discusses stand and tree aerial volume tables and their use. Briefly tells how made. Demonstrates use. What measurements are needed. Checks answers and compares results.	Visualizes what the volumes in aerial table mean, and how this table is used in stand estimating. Reads and records volume for plots measured in previous problem, after checking those measurements. Averages total volumes for comparison.	Stereoscope, problem sheet, stereograms, parallax wedge, crown diameter and crown coverage scales, conversion tables, composite aerial volume tables.
10 min.--lecture 30 min.--problem 20 min.--discussion 1 hour total	10	Dot Sampling for Areas	Understanding of principles and application of dot sampling on aerial photos.	Discusses use of dot sampling in stratification of forest areas. Emphasizes value when areas are small, involved, and difficult to show on map. Points out this method more objective than type map and far cheaper. Demonstrates use of dot shield and checks answers and compares results.	Visualizes dot sampling as tool useful in many ways. Recognizes sampling always faster and less costly than 100 percent coverage. Uses dot shield and classifies areas. Computes percentage and compares results.	Stereoscope, problem sheet, stereograms, 16 dots per square inch dot grid, grease pencil.
15 min.--lecture 240 min.--problem 45 min.- discussion 5 hours total	11	Direct Volume Estimates from Aerial Photos	Understanding of one method of direct photo estimating by dot sampling and plot measurement.	Discusses direct photo estimating by means of sample plots. Briefly explains how such estimates can be adjusted to net volume by species from measurements of field plots. Shows method of computation. Checks answers and compares results.	Visualizes uses of direct estimating on forest. Measures indicated sample plots and classifies all sample plots. Computes mean volumes for strata and for stand. Compares computed volumes with accepted solution.	Stereoscope, problem sheet, map, stereogram; parallax wedge, crown diameter and crown coverage scales; crown conversion tables and ponderosa pine aerial volume tables.
10 min.--lecture 40 min.--problem 10 min.--discussion 1 hour total	12	Measuring Slope Percents	Ability to measure slope percent on aerial photos.	Discusses use of slope percent in various surveys. Explains how slope percent is computed from photo measurements. Demonstrates use of slope percent scale. Checks answers and compares results.	Visualizes how the reading of slope percent might help him in various resource surveys. Measures elevation differences and computes slope percent. Uses slope percent scale. Compares results.	Stereoscope, problem sheet, stereogram, parallax wedge, 0.001-foot scale, slope percent scale, parallax tables.
20 min.--lecture 5 hrs.--problem 40 min.--discussion 6 hours total	13	Road Planning on Photos	Understanding of method useful in planning short access roads on photos.	Discusses method of road location useful on contact prints. Points out limitations in accuracy, particularly when more than one stereo pair is needed. Stresses advantages on timber sales. Demonstrates method of laying out 500-foot tangents by bow compass to obtain preliminary grade. Checks answers and compares results.	Visualizes how planned layout might save time on timber sales. Locates preliminary line by 500-foot arcs and relocates as needed to meet specifications. Measures slope percents and records. Measures side slopes as required. Compares results.	Stereoscope, problem sheet, stereogram, parallax wedge, 0.001-foot rule, slope scale, and tables.

Figure 6.--Lesson plan for photo training exercises included in this training kit.

CLASSROOM AND CLASS PROCEDURE

Since this course assumes that most student learning results from what the student does, the size and arrangement of the classroom are important. Cramped space, poor lighting, and noise or other distractions can reduce the effectiveness of any training procedure, no matter how well conceived. Although photo training schools are often held in less desirable quarters, it seems well here to list ideal conditions.

When actually working on photos the student should have desk or table space of at least 2 by 3 feet on which to spread photos, problem sheets, stereoscope, slide rule, and necessary interpretation aids. He needs a good light source: it should come from in front of him and should be adjustable. Early stereo training is aided by having the shadows on the photos agree with the light source. This can be accomplished through the use of adjustable 2-bulb fluorescent desk lights. Where natural lighting must be used, students should face the source of light. Nonfluorescent overhead lighting is not desirable since it forces the student to work in his own shadow when using the stereoscope.

The short lecture preceding each work period requires the use of a blackboard. Time seldom permits the instructor to delve very deeply into the geometry of the photo or the derivations of the photogrammetric formulae used. But a very brief explanation if accompanied by a simple drawing will usually satisfy the needs of any student who is primarily interested in practical application. A blackboard will also be advantageous in recording results of some problems to illustrate the range of answers given by the class.

Space between tables is of considerable importance because the instructor will have to move about the room to give individual demonstration and aid to students requesting it. Best results are obtained with classes of fewer than 20 students, but classes of 30 can be handled where one or more assistant instructors are available.

Each training period is programmed in the following manner:

1. The instructor presents the necessary background information, stating what the student should learn during this period and how this objective fits into the over-all course. Any theories or formulae needed in working the problem are included in this discussion.

2. The instructor issues the problem together with necessary photos, interpretation aids, and tables. If a new tool or aid is included, the instructor will demonstrate its use.

3. The students read the problem and then work on its solution, asking questions if the procedure to be followed is not clear. Supervision and demonstration may be given some individuals where this is needed during the class period.

4. Work is checked against accepted answers, and opportunity is given for some class discussion or clarification of techniques. In checking students' work, the instructor should use control charts or curves from previous class records wherever possible. For example, when learning to use the parallax wedge, an extended period of practice is needed to acquire the necessary skill. And yet, a student's work may improve considerably during the few hours devoted to its use in this short training course. Progress curves from past training periods aid the instructor in evaluating the learning of the individuals and in helping retain class enthusiasm by showing comparative progress.

No student can reasonably expect to become highly skilled during a short course in use of aerial photos. Learning photo techniques is like learning other skills: proficiency can be developed only by directed practice over an extended period of time. Therefore, a certain amount of practice or drill is included in each problem. Successive problems tend to use techniques learned earlier in the course; this helps the learning process and gives the student a certain elementary skill. As he acquires such skill, he feels accomplishment and gains enthusiasm that will aid him during the long period of practice necessary to become an expert.

THE TRAINING PROBLEM SECTION

This section includes a brief discussion of each training problem and its importance, which may aid the instructor in his presentation. Accompanying this discussion are illustrations of the problem sheet and problem photos as prepared for the Training Kit. Since the stereo test is given at the first session of each training school, it is included in this problem section.

Stereoperception Test

A stereoperception test is a necessary preliminary to any organized photo interpretation training. Many persons lack depth perception or have other ocular defects that handicap them in using aerial photos stereoscopically. Since very few reliable data can be obtained from a single photo and since most photo measurements are made under stereo, it is important that the instructor know the limitations of his students early in the course.

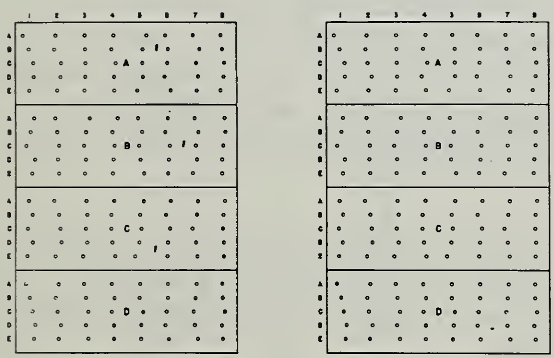
The test shown in figure 7 was designed for classroom use and requires no equipment other than the simple lens stereoscope. Its use enables the instructor to rate, in less than an hour, the stereoperception of each student. Comparison of these ratings with the normal rating scale indicates which student will find it difficult or impossible to use aerial photos stereoscopically.

The testing procedure is simple. Each student is given a lens stereoscope and a test sheet. If inexperienced, he is shown how to determine the correct lens separation for his eyes and how to orient the stereoscope over the stereogram. He then examines the blocks systematically, scanning each row from left to right and moving through the blocks from top to bottom. He indicates the position of each floating circle by marking with an "X" the appropriate number on the answer sheet.

FLOATING-CIRCLES STEREOGRAM TEST SHEET

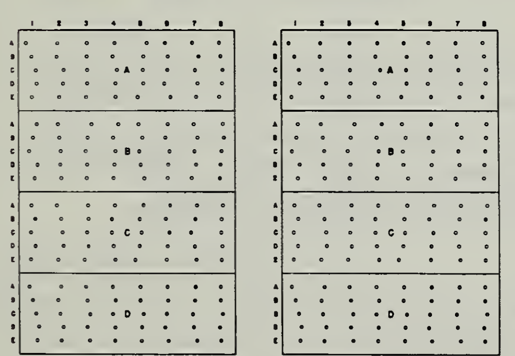
Stereogram I

(Lens separation - 2.25 inches)



Stereogram II

(Lens separation - 1.9 inches)



Name ______________________________

Date ______________________________

____

____

Mark the number of each circle in each row and block that appears to float above the datum plane formed by the paper.

A	1	2	3	4	5	6	7	8	
B	1	2	3	4	5	6	7	8	
C	1	2	3	4	5	6	7	8	Block A
D	1	2	3	4	5	6	7	8	
E	1	2	3	4	5	6	7	8	
A	1	2	3	4	5	6	7	8	
B	1	2	3	4	5	6	7	8	
C	1	2	3	4	5	6	7	8	Block B
D	1	2	3	4	5	6	7	8	
E	1	2	3	4	5	6	7	8	
A	1	2	3	4	5	6	7	8	
B	1	2	3	4	5	6	7	8	
C	1	2	3	4	5	6	7	8	Block C
D	1	2	3	4	5	6	7	8	
E	1	2	3	4	5	6	7	8	
A	1	2	3	4	5	6	7	8	
B	1	2	3	4	5	6	7	8	
C	1	2	3	4	5	6	7	8	Block D
D	1	2	3	4	5	6	7	8	
E	1	2	3	4	5	6	7	8	

Figure 7.--A stereoperception test is given each student at the beginning of the training course.

Each floating circle correctly identified is counted as +4. Omissions and incorrect identifications are counted as -4. Thus, a test with one floating circle omitted is scored as 96. If, in addition, another circle was incorrectly marked as floating, the score would be 92.

When grading, the instructor should check the result of each test against the normal pattern. A "normal" test usually has the floating circles correctly identified in the easier blocks (A and B), and the errors, if any, in the more difficult blocks (C and D) at the end of the test. Major variations from this normal pattern and their probable causes are:

1. Errors concentrated early in test, with most circles in the last two blocks correctly identified. This indicates that the student was not seeing stereo at the beginning of the test, probably because of poor orientation.

2. Clusters of circles in the outer banks incorrectly identified as floating. This indicates that the student was looking out of the corner of his eye instead of shifting his stereoscope from left to right and viewing the circles from directly above. The curved datum plane created by looking through the lenses at an angle may cause the other circles to appear above those in the center of the stereogram, and inexperienced students frequently list these as floating.

3. Many circles or clusters of circles incorrectly identified as floating. This indicates that the student did not have the stereogram properly oriented. In some tests this may indicate that the student was guessing; his grade will be far below his actual stereo ability.

4. Several floating circles throughout the test not identified. This indicates haste or some other fault usually not connected with poor stereovision.

For most students, the solution to this problem of abnormal patterns is merely to rerun the test. Occasionally, if time is limited the instructor may choose to ignore one or two errors occurring early in the test if correct answers are given later. Probably the best approach is to grade each test as it is completed. Rechecks can then be made immediately where needed.

The "normal" rating scale shown in figure 8 was prepared as a guide for instructors in interpreting the results of their students' tests. This rating scale shows graphically the mean, median, and distribution of grades on more than 500 recorded test sheets. By plotting a test grade on the scale, the instructor can see the comparative rating of the individual. Average grades for small groups can be expected to vary somewhat from the normal averages shown here. Usually, instructors can assume that students having grades of 80 or better have no ocular deficiency that will prevent them from mastering photo techniques. But students having grades below 60 can be expected to have trouble in learning and using any technique that must be accomplished stereoscopically.

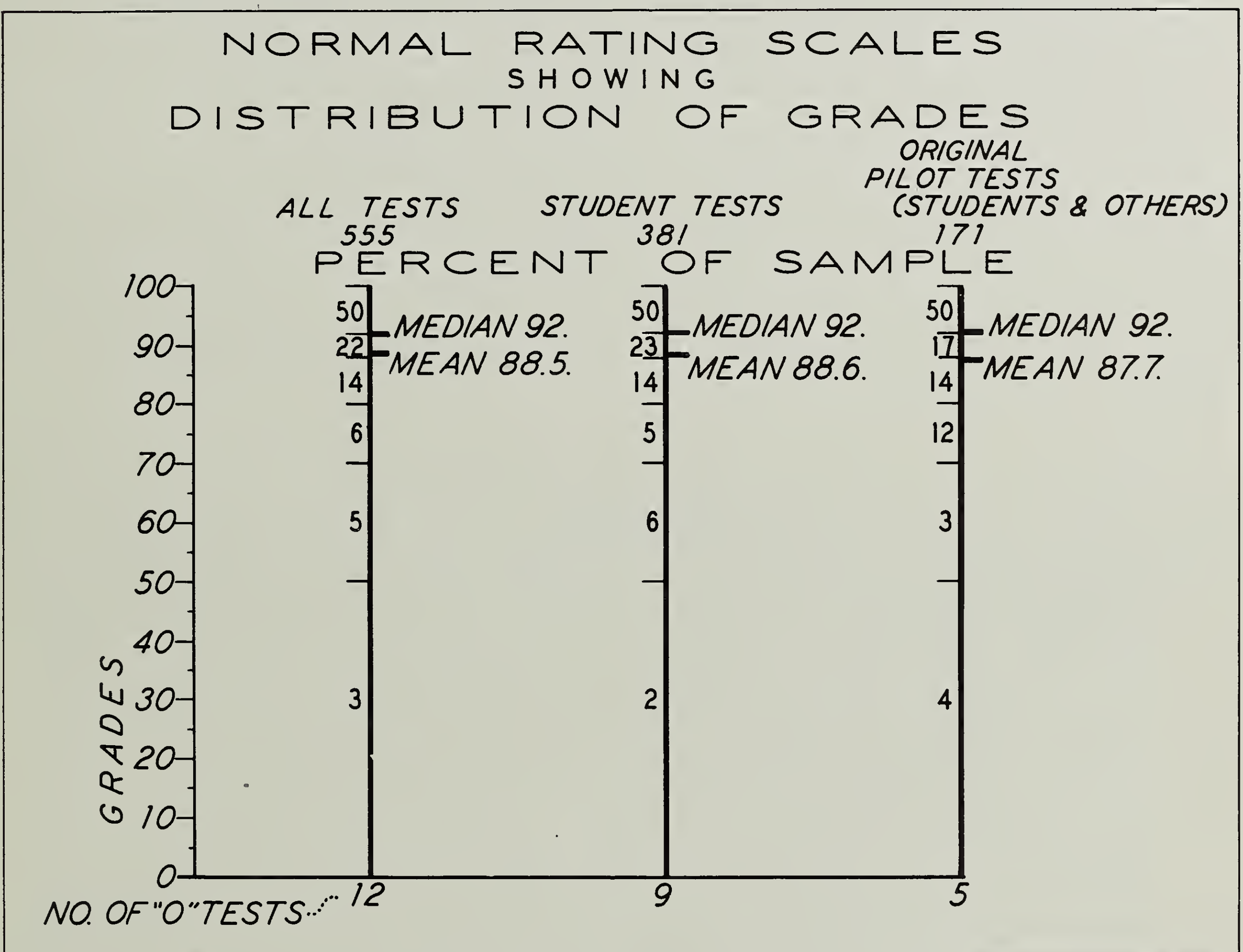


Figure 8.--Normal rating scale is used by the instructor in evaluating the test grades and class average.

NOTES

PROBLEMS

Problem 1--Positioning Photos for Best Stereovision

In working problem 1 the student learns to orient photos for stereovision and measurement by means of the principal and conjugate principal points. He learns to use the alignment guide in locating the principal points, to transfer those points from one photo to another while viewing the photos in stereo, and to align the photos at the correct viewing distance by using the guide. He also learns to tape photos at the outer edge by means of a hinge tape so that the photos can be viewed with either the right-hand or left-hand photo on top without the need of realigning.

For background material on this problem, the instructor gives a brief description of the title data found on photos, the amount of overlap specified between and within strips, and the nomenclature, such as "fiducial marks" and "principal points" and their meaning. He also explains that correct stereo is obtainable only within flight lines and only when photos are aligned in the same order as they were flown. He may, during this period, point out that when photos are taped down, y-parallax must be removed by twisting the stereoscope. He should explain that much practical photo interpretation is done without taping photos, but that precise methods should be learned before shortcuts are attempted.

Experienced instructors realize that some students in every group will say they are seeing the photos in stereo, and may actually believe it, when they are not. By insisting that the student perform this problem and tape down the photo, the instructor can quickly detect photos that are out of line or too far apart for stereovision. He can then correct that particular student's technique.

The orientation taught in this first problem is also correct for parallax measurements taught later in the course. By familiarizing the student with this method in the first problem, the instructor can reduce the number of techniques that the student must learn in the complex problems on parallax measurements that follow.

Photos properly oriented and taped are shown in figure 9. The stereo pair used in this problem should be complete contact prints. No special annotations are needed, but prints should be clean and unmarked. Photos used by all students need not be identical, and can be returned to files after use.

PROBLEM 1

TITLE.--POSITIONING PHOTOS FOR BEST STEREOVISION

OBJECTIVES.--To aid you in orienting the photos for best stereovision by means of principal and conjugate principal points. To familiarize you with the nomenclature and characteristics of the photos.

TOOLS AND MATERIALS.--Stereoscope, selected photos, photo alignment guide, pencil, needles, and problem sheet.

EXPLANATION.--

1. Title data.--Usually on north edge of photos flown north and south or on west edge of photos flown east and west. Key data consist of:

   a. Upper left, date of photography.
   b. Upper right, county or contract symbol, roll number, print number. Example, (AA 1 - 12K - 184).
   c. Upper center at ends of flight, time of day.

2. Fiducial marks.--Arrows or other marks printed at edge of photo which define the principal point.

3. Principal point.--The exact center of the photo obtained by joining opposite fiducial marks. The foot of a perpendicular whose base is the focal plane of the camera. On vertical photos this point is considered to be the point directly below the camera at time of exposure.

4. Conjugate principal point.--The image of the principal point of one photo on the adjoining photo. Images of any object shown on two adjoining photos are said to be conjugate.

   When the principal and conjugate principal points of two consecutive photos in the same flight are placed in a straight line, the line approximates the path of the camera. Photos thus oriented and separated at a usable distance are said to be set up for best stereovision.

REQUIREMENTS.--Alignment of photos with alignment guide.

1. Place the guide over your first photo so that the intersecting axes fall exactly on the fiducial marks. Pinprick the principal point through the hole at the intersection of the axes. Repeat on second photo of the stereo pair. Mark point with red crayon for visibility.

2. Place the photos on your desk with the titles to the left and the right-hand photo on top and with identical areas superimposed. Separate the photos in line of flight, until the conjugate images are about 2.3 inches apart.

3. Place your stereoscope on the photos with the center over the edge of the top photo, and the lenses centered over conjugate points. Look straight down through the lens and see the stereo model in third dimension.

4. Having seen the stereo model, shift your stereoscope until you see the principal point of the left photo in stereo. Using your needle between the right-hand legs of your stereoscope, place the point directly over the conjugate image of the principal point and pinprick on the right-hand photo. Mark this point with red crayon.

5. Reverse the pictures placing titles to the right. The former left-hand photo is now the right-hand photo and should be on top. Adjust stereo, and pinprick the second conjugate point in the same manner.

6. Place photos in line of flight, headings to the left, and tape outer (left) edge of the left photo to your desk with a 6-inch strip of masking tape.

7. Place the alignment guide over this photo and orient with zero over principal point and the graduated axis cutting the conjugate principal point.

8. Hold the guide firmly with your left hand and slip the second photo beneath it from the right. Orient this photo so that the conjugate principal point is directly beneath the 2.3-inch mark, and the principal point is beneath the graduated axis. By pressure on the guide, hold the right-hand photo firmly and tape its outer, or right-hand, edge.

9. Your photos are now correctly oriented for best stereovision and for parallax measurements with a 2.3-inch parallax wedge.

When viewing photos taped down in this manner you must orient the stereoscope parallel to the line of flight. Slight disorientation will probably prevent you from seeing the stereo model.

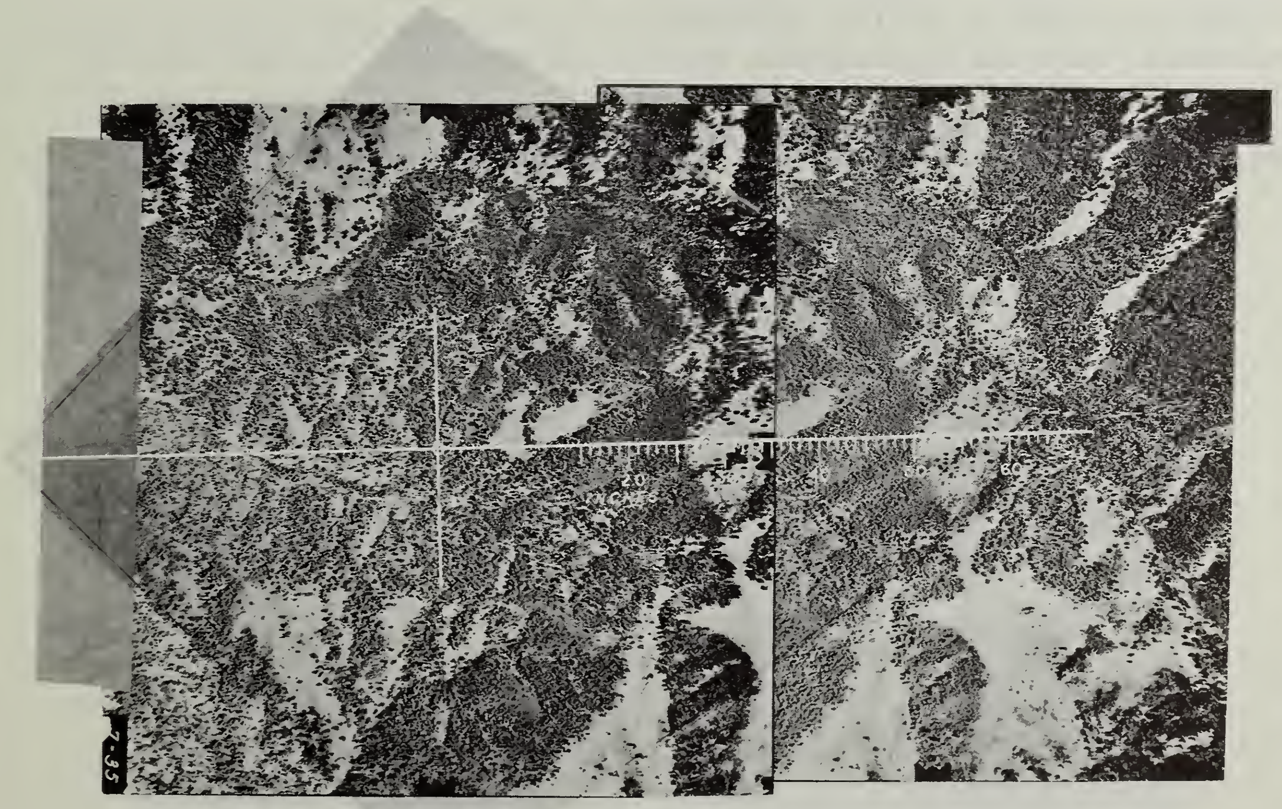


Figure 9.--The transparent alignment guide is shown over a pair of aerial photos properly lined up and taped for stereovision. The guide is a usable aid in this alignment. (Greatly reduced.)

Problem 2--Recognition of Ground and Cover Conditions

In this problem the student learns some of the indicators that help him recognize objects, cover, and ground conditions. Through experience, he learns that he must study these minute images, then make his interpretations of them by reasoning from surrounding objects and from past experience. Quick guesses based on mere appearance and tone often result in incorrect interpretations.

For explanation and background information, the instructor should briefly discuss the value of tone, texture, shape, and shadow in interpretation of images on photos. He should point out the value of recognition of height differences, landforms, drainage patterns, and tonal differences due to water and shadow. He should avoid long discussion of interpretation methods, since this subject is adequately treated in numerous texts, but he may well introduce examples into class discussion.

Probably the greatest value of this type of problem is achieved when the student learns that he cannot interpret photos correctly unless he first studies precise images intently. He then draws logical conclusions based not only on that image but also on its relation to surrounding images.

The instructor will find that multiple choice problems, like the one shown below, will add considerable zest to the students' approach to the rather tedious techniques of photo measurement. He will probably want to liven up his class from time to time with the change of pace that such problems provide.

Stereograms used in this problem are shown in figure 10.

PROBLEM 2

TITLE.--RECOGNITION OF GROUND AND COVER CONDITIONS

OBJECTIVES.--To familiarize you with some indicators used in recognizing cultural objects, cover, ground conditions, and relative elevation on photos. To give you practice in stereovision.

TOOLS AND MATERIALS.--Stereoscope, problem stereogram, and problem sheet.

EXPLANATION.--Both natural and cultural objects are recognized on aerial photos by differences in tone, texture, shape, shadow, and relative height. For example, bare soil or rock usually photographs light, grass somewhat darker, brush or forest still darker. Water and shadows normally appear darkest of all. Grass shows very fine texture, stands of trees range from fine to coarse, depending on species, size, and density. Ledge rock is indicated by straight lines and vertical cliffs, talus slopes are light and usually show rough texture. Shadows often indicate the number and size of trees in clumps.

REQUIREMENTS.--From your present knowledge of aerial photos, interpret each of the 50 points numbered on these 1:20,000-scale stereograms. Indicate your interpretation by placing an "X" before one of the four possible answers.

	a	b	c	d
1.	__plantation	__piles of rock	__orchard	__vineyard
2.	__bridge	__dam	__siphon	__ford
3.	__drain ditch	__fence line	__irrigation canal	__highway
4.	__borrow pit	__farm pond	__basement hole	__sludge pit
5.	__farm building	__mine building	__lumber pile	__haystack
6.	__dry ditch	__railroad grade	__pack trail	__road
7.	__small town	__construction camp	__mine building	__ranch building
8.	__aspen	__cottonwood	__pine	__spruce
9.	__irrigated field	__plowed field	__swamp	__tall grass
10.	__farm buildings	__lumber piles	__baled hay piles	__corral
11.	__bare ground	__grass-sagebrush	__rock slope	__sand slope
12.	__irrigation ditch	__fence line	__hedgerow	__windbreak
13.	__clay bank	__lava rock ledge	__sandstone ledge	__boulder rocks
14.	__hardwoods	__conifers	__juniper	__white pine
15.	__hard rock cliff	__tilted rock	__clay bank	__retaining wall
16.	__sand bar	__dry bed	__dam	__rapids
17.	__fence line	__irrigation ditch	__road	__tillage pattern
18.	__fence line	__soil change	__tillage pattern	__irrigation ditch
19.	__hayfield	__grass-sagebrush	__sand dunes	__chaparral
20.	__irrigation canal	__stream	__drainage canal	__highway ditch
21.	__marsh pattern	__beaver ponds	__muskeg swamp	__salt flats
22.	__clay piles	__rock piles	__dry grass	__brush piles
23.	__standard gage	__narrow gage	__old road grade	__water ditch
24.	__gravel pit	__sawmill	__mine buildings	__cabins
25.	__abandoned mine	__old rock slide	__old sawmill	__gravel pit
26.	__standard gage RR	__improved road	__paved highway	__haul road
27.	__water ditch	__drain ditch	__fence line	__road
28.	__pine trees	__cottonwood	__oak trees	__spruce trees
29.	__pinyon pine	__pine saplings	__juniper	__sagebrush
30.	__rock pile	__tree stump	__water hole	__exploration pit
31.	__cutting line	__fireline road	__sale boundary	__mining road
32.	__aspen poles	__cottonwood poles	__oakbrush	__pine poles
33.	__hayfield	__sagebrush	__old lakebed	__mountain meadow
34.	__aspen poles	__pine saplings	__tall grass	__hardwood brush
35.	__ledge rock	__rock dike	__line fence	__tilted sandstone
36.	__main haul road	__unimproved road	__old RR grade	__paved road
37.	__clearcut	__selective cut	__dead spruce	__fire-kill trees
38.	__gravel pit	__sand and rock	__fire pattern	__beaver meadows
39.	__cutting line	__type line	__section line	__fireline
40.	__spruce	__lodgepole	__aspen	__oak
41.	__mud flat	__irrigated area	__beaver pond	__ice
42.	__main haul road	__skidroad	__jammer road	__mine road
43.	__main haul road	__skidroads	__fire trails	__jammer roads
44.	__landing	__yard	__skidding setup	__road junction
45.	__clay bank	__toe slope	__cirque wall	__talus slope
46.	__toe slope	__talus slope	__gravel slope	__snowslide
47.	__cirque wall	__cirque floor	__sand	__talus slope
48.	__blue spruce	__lodgepole pine	__spruce, fir	__pinyon juniper
49.	__timberline fir	__sagebrush	__chaparral	__pinyon juniper
50.	__bare rock	__sand	__short grass	__snow

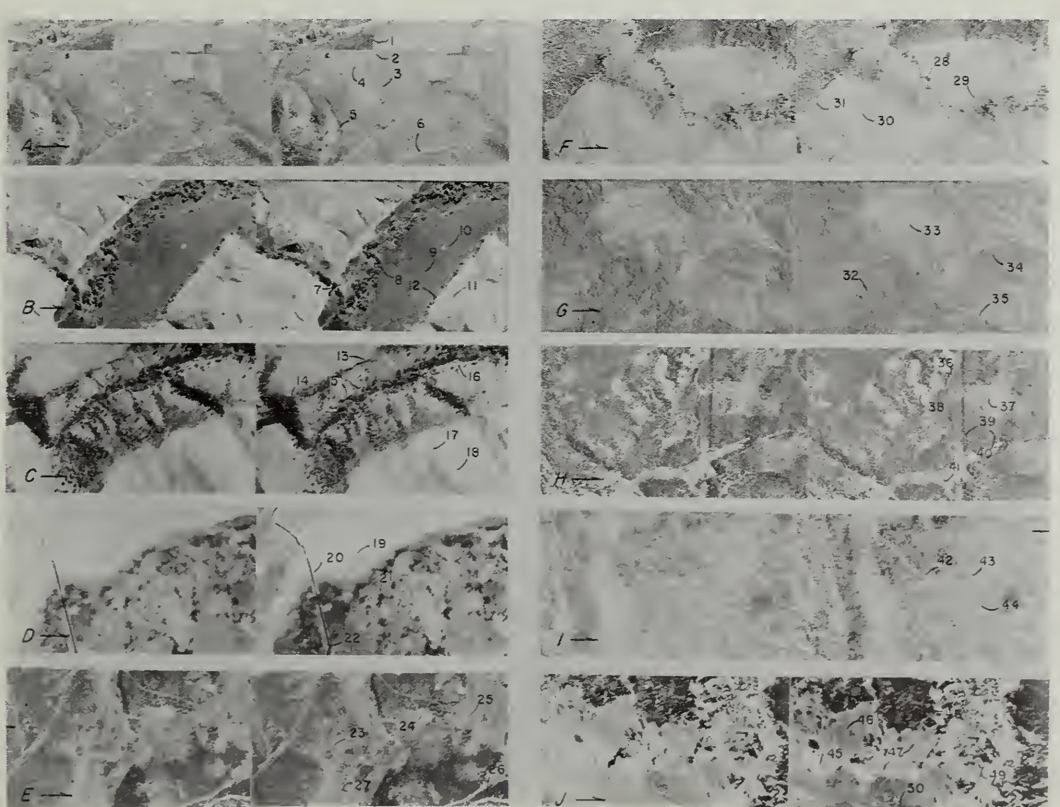


Figure 10.--A multiple stereogram is used for problems on point or object identification. Each point to be identified is indicated by arrow and number. (Greatly reduced.)

Problem 3--Determining Photo Scales

In this problem the student learns to determine the scale of aerial photos by using the relation between the photos and the ground and between the photos and available maps. He uses the basic photogrammetric formulae and is introduced to such terms as "representative fraction," "scale," and "photo scale reciprocal." He learns the technique used in measuring distances and the need of pinpointing landmarks and using one lens of his stereoscope as a magnifier when making measurements. He also determines scale by using a measured base line and the graduated scales printed on the photo scale protractor.

The background material should explain that aerial photos are perspectives and that difference in scale results from elevation differences. It should also include the basic formulae and an explanation of the photo scale protractor and the 0.001-foot rules with a demonstration of their use.

Since this is the student's introduction to scale, it is extremely important that he understand how to determine scale, how to use it, and how elevation differences change scale. Explanations will be helped by simplified drawings and a brief discussion of the geometry of the aerial photo.

The stereo half-photos used in this problem are shown in figure 11.

PROBLEM 3

TITLE.--DETERMINING PHOTO SCALES

OBJECTIVES.--To give you practice in determining scale (representative fraction) of aerial photos by simple photo-map, photo-ground relations. To acquaint you with scale problems caused by topographic differences, and to illustrate some uses of photo scale protractor.

TOOLS AND MATERIALS.--Photos, stereoscope, 0.001-foot rule, photo scale protractor, needle, pencil, problem sheet, and tables.

EXPLANATION.--Three basic formulae used in determining the scale (R/F) of aerial photos are:

1. $\frac{\text{Photo distance}}{\text{Ground distance}} = \frac{1}{X}$ = (The R/F of the photo).

2. $\frac{\text{Focal length of camera}}{\text{Height of plane above datum}} = \frac{1}{X}$ = (The R/F of the photo).

3. $\frac{\text{Photo distance}}{\text{Map distance}} = \frac{1/X}{1/Y} = \frac{\text{R/F of photo}}{\text{R/F of map}}$

Since we are interested only in the denominator or photo scale reciprocal,

1. may be written $PSR = \frac{GD}{PD}$ and

3. may be written $PSR = \frac{MSR \times MD}{PD}$.

From these simple relationships the approximate scale of photos is readily determined. However, this scale applies only to the datum plane (elevation) for which it is calculated. In level terrain this creates no problem and the average scale may apply to most of the photo; but in mountains, many different scales will be found on a single photo. This occurs because photos are in perspective. High peaks are closer to the camera and photograph at larger scale, while low areas, since they are farther away, photograph at smaller scale. This means that scale calculated from a base line in the valley will increase as we climb the mountain.

Good topographic maps, required for accurate scale determinations, are not always available. One practical field method of determining scale is:

1. Select two intervisible landmarks at approximately the same elevation which can be readily identified on your photos.

2. Chain or pace the distance between them.

3. Scale the distance on your photo.

4. Substitute in formula number 1 above and solve.

With the photo scale protractor such calculations are unnecessary. Simply select the chain scale that fits your measured ground line and record its R/F. This procedure will be most precise when the scale line is selected close to and at the same elevation as the point where it is to be used. For field use PSR's are usually rounded to the nearest 500 units on medium scale photography.

Scale determined from a base line applies to the mean elevation of the ends of the line. When the map method is used, select landmarks you can identify on your map as well as on your photos, and estimate the mean elevation of each line from the map. Measure both photo and map distance with the same 0.001-foot rule.

REQUIREMENTS.--

1. Locate points 1, 2, 3, 6, 7, 9, and 11 on the attached portion of a U.S.G.S. 1:24,000-scale map, and measure the distances between them with your 0.001-foot rule. Estimate elevations from your map.

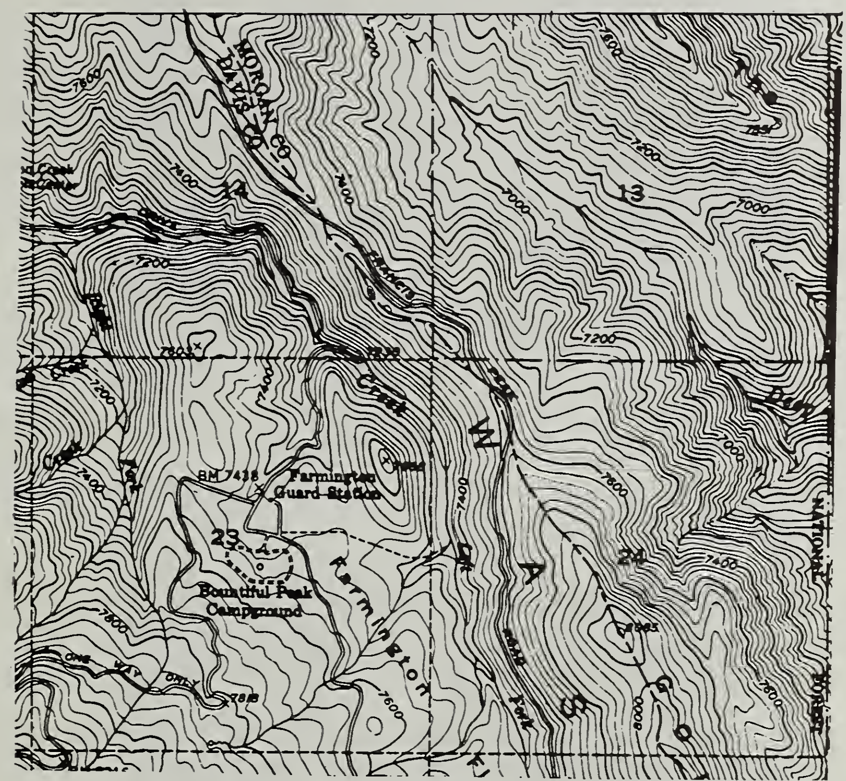
2. Record distances, mean elevations, and computed PSR's in the following table:

Line	Photo distance	Map distance	Mean elevation	PSR
1 - 2				
2 - 3				
6 - 7				
6 - 9				
7 - 11				

3. The following lines have been chained on the ground. Select the chain scale you would use in this vicinity and record R/F.

Line	Ground chainage	R/F
1 - 14	17.80	
5 - 6	15.25	
7 - 8	23.50	
10 - 11	16.20	
12 - 13	13.90	

PROBLEM NO. 3



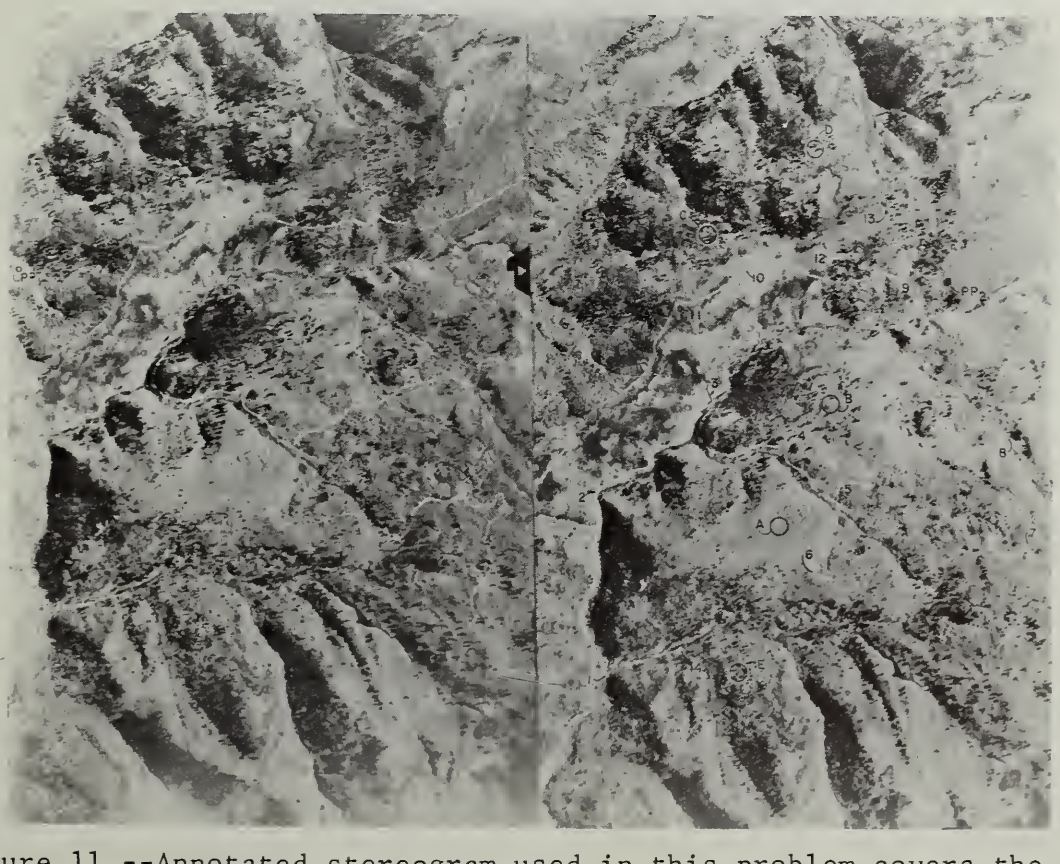


Figure 11.--Annotated stereogram used in this problem covers the area shown on the accompanying USGS map section. (Greatly reduced.)

Problem 4--Determining Project Scale and Flying Height

In this problem the student learns to determine the average flying height and photo scale over an entire photo project, using a series of scale lines and the photo-ground relationship. He learns that mean flying height can be readily determined for a given project and used in determining photo scale at various ground elevations. He learns to determine flying height from scale using focal length relationship and to test his mean scale by use of its standard error. While solving this problem he gains familiarity with the flying height-photo scale relationship.

Background material should include a brief discussion of the advantages of taking two scale lines at right angles to each other over the principal point of the photo, and the reasons why this is usually impossible on photos taken in mountainous country. Emphases should be placed on (1) the use of averages in the problem as a means of keeping the error to a minimum in the determination of mean flying height, and (2) the advantages of recorded base or scale lines throughout the ranger district or forest.

This problem increases the student's knowledge of scale and flying height by repeating many of the procedures of problem 3. It also gives him a practical solution for scale differences within a photo project.

The type of composite stereogram used in this and in later problems is shown in figure 12. This type of problem requires a number of scale or base lines scattered throughout an area and cannot be shown on a single stereo pair.

PROBLEM 4

TITLE.--DETERMINING PROJECT SCALE AND FLYING HEIGHT

OBJECTIVES.--To give you practice in determining photo scale and flying height from a series of base lines measured on the ground. To acquaint you with short-cut methods usable over entire photo project.

TOOLS AND MATERIALS.--Photo stereograms A through L, stereoscope, 0.001-foot scale, needle, pencil, problem sheet, and tables.

EXPLANATION.--It is usually advantageous to determine mean flying height above sea level for a given photo project from a series of randomly selected base lines. From these base lines both mean flying height and its standard error are computed. If this error is less than ±2 percent of mean H-h at one standard deviation, the computed flying height is well within contract specifications.

Two basic formulae are used in this problem:

1. $PSR = \frac{GD}{PD}$ where

   $\text{Photo Scale Reciprocal} = \frac{\text{Ground distance}}{\text{Photo distance}}$

2. $H\text{-}h = PSR \times FL$ where

   Flying height (above ground) = Photo Scale Reciprocal x Focal Length (in feet). FL for this project is 8¼ inches or 0.6875 foot.

Procedure consists of measuring a series of base lines on the ground and on the photos, then determining PSR and flying height (H-h). Flying height above sea level will then equal (H-h) + h where h = mean elevation of the base line.

After determining mean flying height above sea level (H) a table should be prepared listing flying height and PSR for 200-foot elevation changes within the elevation range of the project.

REQUIREMENTS.--

1. Measure the precise photo distance between the points circled on the left-hand photo of each of the 12 stereograms A through L and record below, in table 1.
2. Determine PSR and flying height (H-h) and H, and record in table 1.
3. Determine mean flying height above sea level ($\bar{H}$) and determine its standard error.
4. Determine PSR and H-h for the elevations listed and record in table 2.

Table 1.

Base line	Measured distance		Mean elev. above sea level (h)	Computed PSR	Flying height above	
	Ground	Photo			Ground (H-h)	Sea level H
	Feet		Feet		Feet	
A	936		8,600			
B	533		8,490			
C	948		8,695			
D	842		8,635			
E	842		8,635			
F	776		8,375			
G	752		8,690			
H	467		8,230			
I	785		8,490			
J	739		8,030			
K	631		8,400			
L	741		8,510			

Table 2.--PSR and (H-h) for ground elevations

Elevation	PSR	H-h	Elevation	PSR	H-h
Feet			Feet		
7,000			8,000		
7,200			8,200		
7,400			8,400		
7,600			8,600		
7,800			8,800		

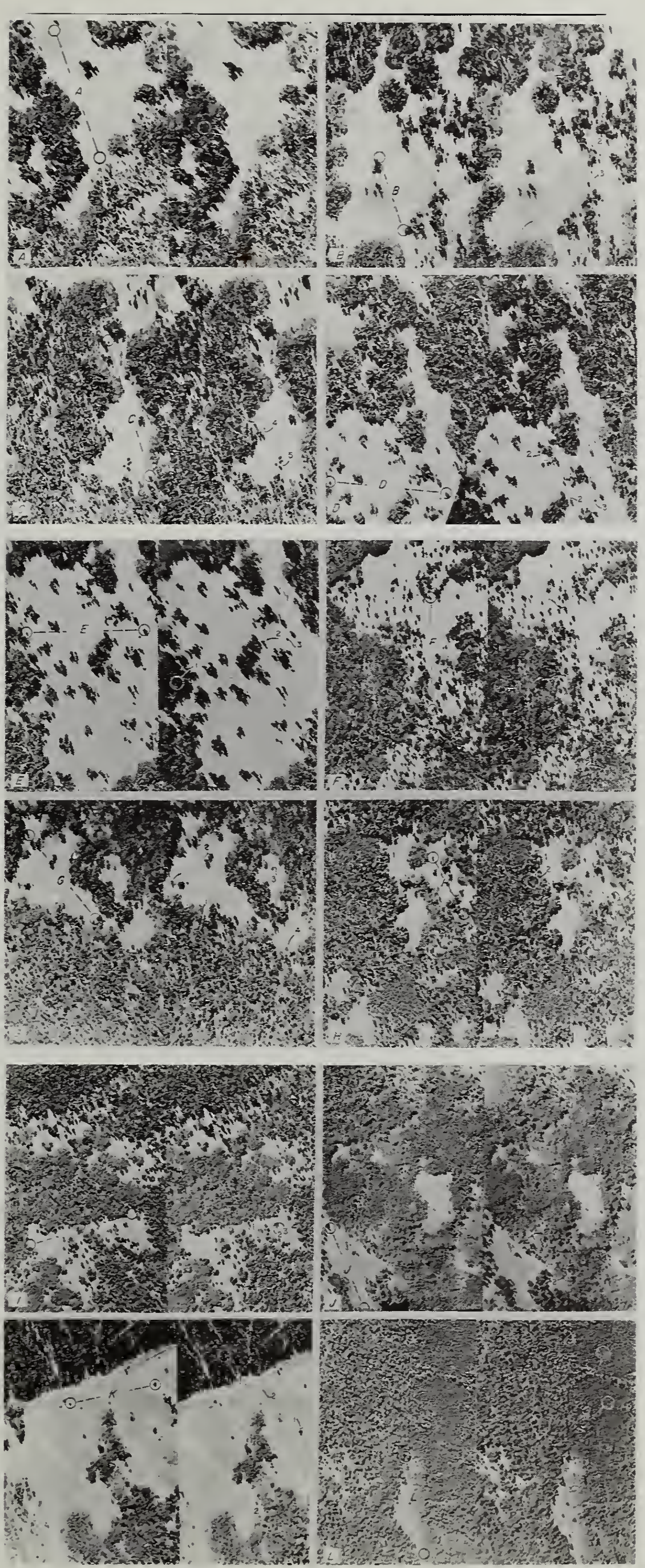


Figure 12.--Multiple stereograms are needed for this problem since several scale lines are required. This illustrates one of the three photos used. Trees marking ends of base lines are circled on left-hand side of each stereogram. (Greatly reduced.)

Problem 5--Determining Bearing and Distance on Aerial Photos

In this problem the student reviews his use of the photo scale protractor in determining photo scale from a base line measured on the ground and learns to determine bearing by means of this same base line. This technique may be used in locating any point previously marked on the photo. It has particular application in timber estimating and in preliminary road location.

The instructor should stress the need of laying out base lines not less than 10 chains long, close to and at the same elevation as the point to be located. Effect of displacement upon angles should again be mentioned. However, this technique should be taught as a practical and usable field expedient for determining bearings from photos.

The stereo half-photos used in this problem are those used in problem 3, but the position of the scale protractor in reading bearings is illustrated in figure 13.

PROBLEM 5

TITLE.--MEASURING DISTANCE AND BEARING

OBJECTIVES.--To give you practice in determining distance and bearing directly on your photos. To illustrate how the photo scale protractor is used to locate field plots.

TOOLS AND MATERIALS.--Stereoscope, photos, scale protractor, needle, and problem sheet.

EXPLANATION.--You can measure ground distance in chains directly from your photo by means of the correct photo scale. Use the scale which best fits the line you measure on the ground. When land lines are visible on the photos, scale may be determined by fitting 20 chains between 40 lines.

The scale protractor is designed to allow the field man to read the compass bearing of lines directly from his photos, by reference to a base line of known bearing. To do this:

1. Select a base line that can be identified both on photos and on the ground.
2. Read the compass bearing of this line.
3. Orient the protractor over the scale line by means of this bearing and read the bearing to your plot direct.
4. Use a needle or very sharp pencil to scribe both base line and line to plot center on your photo before measuring angle. Lines may be extended as needed, but should be broken at the circle marking the plot to preserve photo detail.

REQUIREMENTS.--The length and bearing of each base line measured on the ground is recorded below. Measure and record the chainage and bearing to the indicated field plot locations.

Base line	Length	Bearing	PSR	Line	Length	Bearing
5 - 6	15.25	N. 70° W.	________	5 - A	________	________
--	--	--	________	4 - B	________	________
10 - 11	16.20	N. 28° W.	________	10 - C	________	________
12 - 13	13.90	S. 28° E.	________	13 - D	________	________
1 - 14	17.80	S. 20° E.	________	14 - E	________	________
				Field Corner - D	________	________

In practice, experienced field men would probably chain in from the east corner of the nearby clearing. Record this bearing and distance.

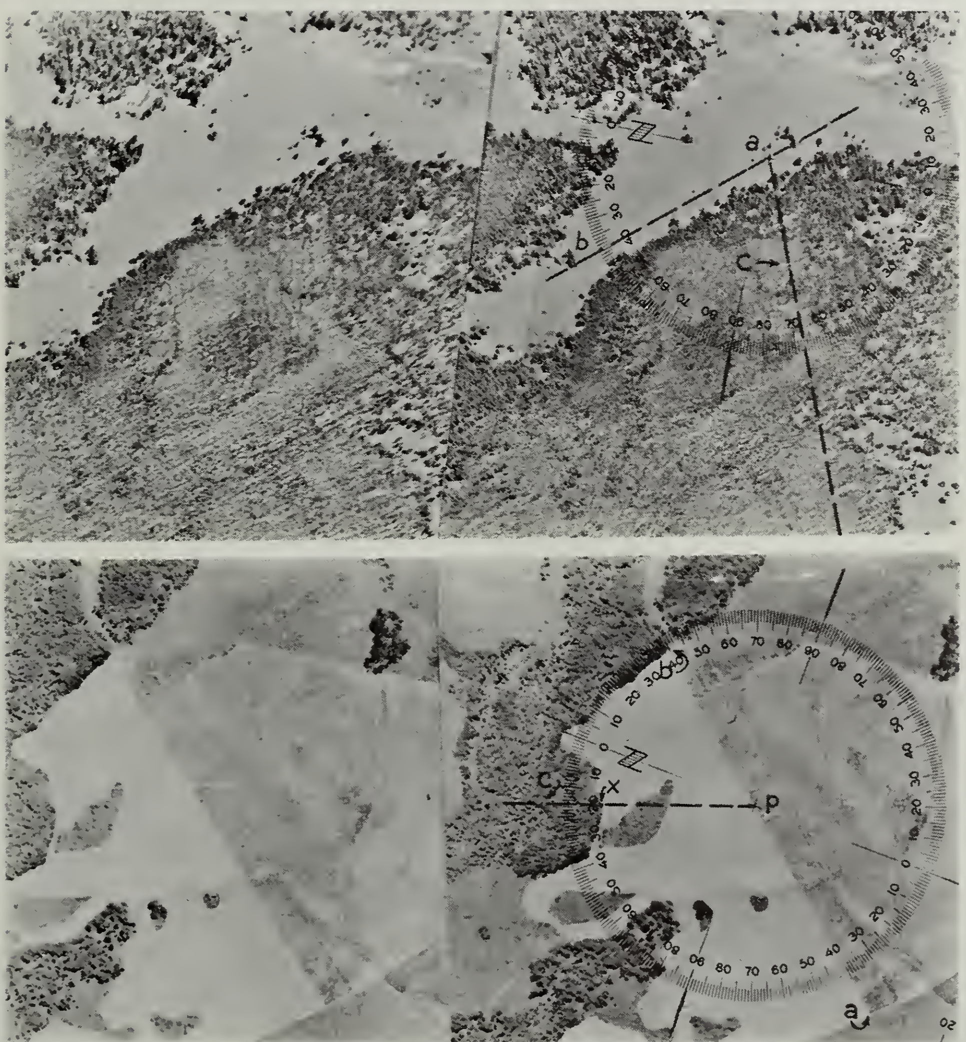


Figure 13.--Position of scale protractor in measuring bearing. (Greatly reduced.)

Problem 6--Determining Relative Elevation by Parallax Wedge

This problem introduces the student to parallax measurements and to the parallax wedge as a device for making them. He learns how to view the wedge stereoscopically and how to make parallax measurements of the ground level. He learns to use simple parallax formulae and to determine absolute stereoscopic parallax when using photos of mountainous areas. In solving this problem he is primarily interested in learning to read the parallax wedge.

Background material emphasizes the value to both forester and engineer of making height readings by parallax; it describes the wedge and explains the meaning of parallax formulae and illustrates by simple drawing how height is measured. The instructor should point out that this particular technique requires considerable skill and that intensive practice over a long period is needed, but that much can be gained during a short 2- or 3-day training period under supervision of a skilled instructor.

The instructor should spend most of his effort in making certain that each student actually is viewing and reading the wedge properly. Training in this technique can best be started by having each student view a training stereogram with a properly oriented parallax wedge overprinted on it.

While computations should be discussed and the use of formulae explained, the technique of using the wedge is by far the most important part of this problem.

The stereo triplet used in this problem and in road location problem 13 is illustrated in figure 14. Point 1 on the parallax wedge stereogram, figure 15, illustrates the method of reading ground level. Photos for this beginning problem in parallax measurements should be large scale with solid ground images.

PROBLEM 6

TITLE.--DETERMINING RELATIVE ELEVATION BY PARALLAX WEDGE

OBJECTIVES.--To familiarize you with the parallax wedge and method of reading parallax at the ground level. To give you practice in computing relative elevations from parallax readings.

TOOLS AND MATERIALS.--Stereoscope, parallax wedge, parallax tables or alignment chart, slide rule, parallax stereogram, problem stereogram, and problem sheet.

EXPLANATION.--Perhaps the most difficult part of learning to make parallax measurements is visualizing the floating line of the wedge. The accompanying "Parallax Wedge Stereogram" illustrates the correct position of the parallax wedge for both ground and treetop readings. To produce this stereogram, parallax wedges were oriented over duplicate stereo pairs and photographed. When you see the timber background in stereo, the floating lines of these wedges will also be visible.

You are interested in position 1. Note how the converging lines blend into one for a portion of their length. By looking intently at this line and ignoring the background, you can follow it up into space. See how this single graduated line appears to bend and separate at 1 (the ground level). Note also that the long ticks on the two lines of the wedge are exactly opposite each other. This assures the shortest measurement between conjugate images on the photo.

The computations necessary to convert parallax readings to elevation differences are relatively simple. Either of the two following formulae may be used to obtain elevation difference or height of object although (1) is usually preferred in mountainous areas.

1. $ho = \frac{H\text{-}h \times dp}{P + dp}$ where

   ho = height of object (feet)
   H-h = height of camera above object (feet)
   dp = parallax difference (inches)
   P = stereoscopic parallax (inches)

2. $ho = \frac{f \times dp}{R/F\ (P + dp)}$ where

   f = focal length of camera (feet)
   R/F = representative fraction (scale) of photos

To solve formula (1) for (ho) you need to know (P) and (H-h), as well as (dp). To determine (P) for point 30:

a. Measure the distance between PP_1 and PP_2 to nearest 0.05 inch.

b. Using your parallax wedge, measure the distance between conjugate images at point 30 (the ground reading at 30). Subtract (b) from (a).

Flying height (H) has been computed as 9,760 feet above sea level. Elevations (h) of the following control points have been established as: A--6,030; B--6,300; 29--5,960 feet; and 30--5,B70 feet.

For small elevation differences such as tree heights on medium scale photography, formula 1 is normally solved for a (dp) of 0.001 inch. (See table of parallax factors.) Measured parallax difference is then multiplied by this factor toobtain height of object. However, when the (dp) term reaches an appreciable proportion of (P) this shortcut method is not advised.

Your problem stereogram consisting of two stereo models has been set up for correct stereo viewing and reduced to approximately 2.3 inches' separation.

REQUIREMENTS.--Your first job is to become familiar with the parallax wedge.

1. Place your parallax wedge on the problem stereogram with lines converging away from you and cutting conjugate images in circle 30.

2. View the wedge and photo in stereo and adjust slightly until tick marks are opposite one another. Your wedge should look like those on the training stereogram.

3. While viewing the wedge in stereo, move it around over the stereogram and see the changes in location of the point where the lines appear to converge and bend.

4. After you have become familisr with the appearance of the wedge, record below the ground reading for the following points to the nearest 0.001 inch; e.g., 2.216, and the parallax difference (dp) from the control point.

Left Stereo Model

No.	Ground reading	Parallax difference (dp) From 30
30	________	
31	________	________
41	________	________
43	________	________
1	________	________
2	________	________
PP_2	________	________

Right Stereo Model

No.	Ground reading	Parsllax difference (dp) From 29
29	________	
41	________	________
43	________	________
51	________	________
53	________	________
3	________	________
B	________	________
PP_2	________	________

NOTE: (dp) determined from wedge readings will have a (-) sign for higher elevations. Stereoscopic parallsx increases with higher elevstions. When using the wedge, the student should remember that (-dp) represents an increase in elevation.

5. After completing these readings and (dp)'s, compute the elevation difference between 30 and points 1, 2, and PP_2 and between 29 and points B, 3, and PP_2.

	Inches		Inches
PP_1 to PP_2	________	PP_2 to PP_3	________
Reading 30	________	Reading 29	________
P for 30	________	P for 29	________
H-h for 30	________	H-h for 29	________

Solve for (ho) in formula (1) $ho = \frac{(H-h)\ dp}{P + dp}$ to determine difference in elevation.

For example, assuming a dp of 0.100 above 29

$$ho = \frac{(9,760 - 5,960)\ 0.100}{0.994 + 0.100} = 347'$$

Enter your computed elevation differences below.

No.	dp	Elevation difference	Elevation above sea level	No.	dp	Elevation difference	Elevation above sea level
30			5,870	29			5,960
1	______	______	______	3	______	______	______
2	______	______	______	B	______	______	______
PP_2	______	______	______	PP_2	______	______	______

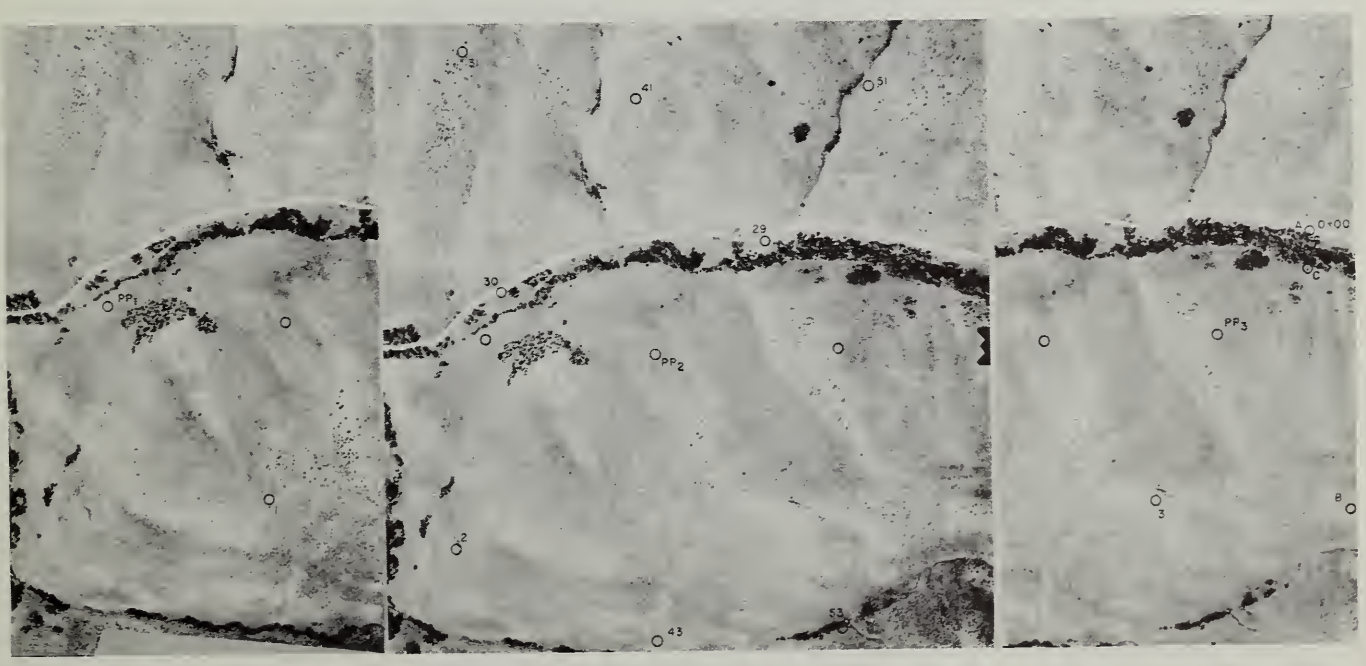


Figure 14.--Stereo triplet consisting of three annotated photos properly aligned and reduced to one-half original scale to accommodate stereovision. This same photo is also used in slope and road problems. (Greatly reduced.)

Problem 7--Measurement of Tree and Stand Heights by Parallax Wedge

In this problem the student learns to measure parallax at the treetop and continues his practice of measurements at the base or ground level. He learns to compute a parallax factor and to use it on his slide rule to simplify and speed up computation of tree height. He becomes familiar with the parallax factor table, which lists factors by parallax and flying height. He learns to read parallax difference directly from his parallax wedge without the necessity of recording the readings at top and base of the tree, and gains a measure of proficiency in this by measuring a number of trees and stands.

The instructor should start this class by having each student study his parallax training stereogram and pay particular attention to the position of the sloping line of the wedge when the reading is made at treetop (position 2 on figure 15). In the previous problem the student learned that the wedge line separates and bends at the ground level; in this problem, the instructor should point out that treetop images are too nebulous to produce this effect. Instead, the line cuts down through the tree crowns; therefore, the treetop readings must be made where the floating line of the wedge and the tip of the tree meet.

To be sure that the student sees the wedge line correctly, the instructor may have him orient the wedge over the stereoperception test chart so that the lines cut the images of one floating circle on the two halves of the stereogram. When viewed stereoscopically, the sloping line appears to float through the circle and the student can make a reading at circle height.

In spite of such preliminary practice the instructor will find that most students make low readings at the start. Experience indicates that very few untrained persons actually can focus their eyes on treetops when viewing aerial photos in stereo. Instead, they look past the trees to the most solid image of the ground. They are unable to select a point on a graduated floating line equal in height to the top of a tree because they do not see this treetop in stereo. The need for practice to develop this accommodation should be emphasized repeatedly during the problem. Most students improve considerably in the first three or four periods of practice, but skill requires much longer training.

Background material for this problem can be obtained from "Parallax Wedge Procedures" and other publications that explain the wedge and the techniques of using it. The instructor should again stress that skill in using the wedge is the key to many usable forest and engineering measurements.

The student should be advised to read parallax difference directly rather than record top and base readings and obtain difference by subtracting. This slower method should be used only in the earliest training steps and should not be allowed to become habitual. The use of parallax factors and the slide rule in computations should be stressed, because speed and accuracy are usually most important in this technique. Few photo interpreters can justify the time required to compute measurements by hand.

The stereograms used in this problem were also used in problem 4 and are illustrated in figure 12.

PROBLEM 7

TITLE.--MEASUREMENT OF TREE AND STAND HEIGHTS BY PARALLAX WEDGE

OBJECTIVES.--To familiarize you with the method of reading parallax at the treetops, and parallax difference for the tree or stand being measured. To give you practice in computing tree heights from parallax difference.

TOOLS AND MATERIALS.--Stereoscope, parallax wedge, training stereogram, parallax table, problem stereograms, slide rule, and problem sheet.

EXPLANATION.--Study your parallax stereogram under stereo. Note the reading at treetop (2)--the point where the floating line of the wedge appears level with the tip of the tree crown. The ground reading (1) is made exactly as you made it in determining relative elevation in problem 6. However, these two readings are rarely made with one setting of the wedge. Instead, the wedge is shifted so that the ground reading may be made close to, and at the same elevation as, the base of the tree. The experienced interpreter makes no effort to record the parallax at these two points, but merely reads and records the parallax difference. On large scale photos of tall trees you will find it impossible to see tree crowns and ground line in sharp focus at the same time. The eyes should be focused on each as it is measured. Necessary photo data--average scale, flying height, parallax, and parallax factor--are given below for each stereogram. Focal length of camera is 8¼ inches in each case.

Do not make repeated measurements or spend a long period studying each tree. You will learn most by making at least one measurement of all trees.

After you have completed 8 or 10 measurements, read and record (dp) only.

Stereogram	PSR	H-h	Par.	Par. fac.
A	5,670	3,900	2.45	1.6
B	5,820	4,000	2.20	1.8
C	5,530	3,800	2.60	1.5
D	5,670	3,900	2.65	1.5
E	5,670	3,900	2.65	1.5
F	5,960	4,100	2.40	1.7
G	5,530	3,800	2.60	1.5
H	6,110	4,300	2.50	1.7
I	5,820	4,000	2.55	1.6
J	6,550	4,500	2.30	2.0
K	5,960	4,100	2.70	1.5
L	5,820	4,000	2.50	1.6

REQUIREMENTS.--Measure and record parallax readings for numbered trees on each stereogram. The numbered circles are not included in this problem.

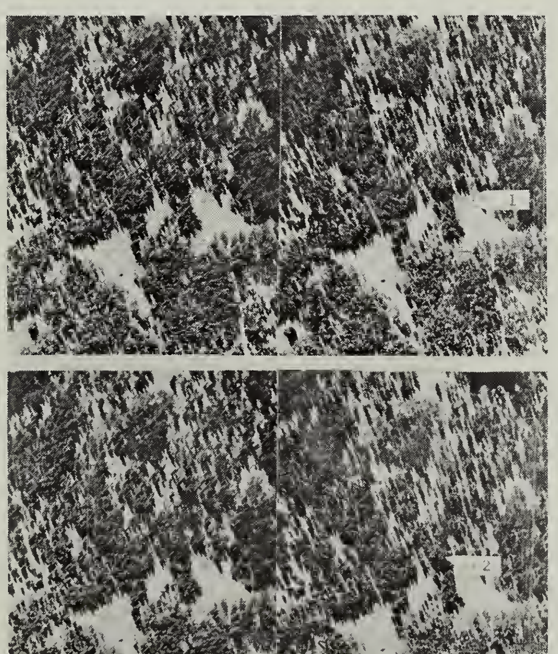
Stereogram	Tree No.	Wedge readings: Ground	Wedge readings: Tree top	dp	Tree ht.	Stereogram	Tree No.	Ground	Tree top	dp	Tree ht.
		- - 0.001 inch - -			Feet			- - 0.001 inch - -			Feet
A	1	___	___	___	___	C	1	___	___	___	___
	2	___	___	___	___		2	___	___	___	___
B	1	___	___	___	___		3	___	___	___	___
	2	___	___	___	___		4	___	___	___	___
	3	___	___	___	___		5	___	___	___	___

Set the appropriate parallax factor on your slide rule and record (dp) and computed height only, for the remainder.

Stereogram	Tree No.	dp	Tree ht.
D	1	___	___
	2	___	___
	3	___	___
E	1	___	___
	2	___	___
	3	___	___
F	1	___	___
	2	___	___
	3	___	___

Stereogram	Tree No.	dp	Tree ht.
G	1	___	___
	2	___	___
	3	___	___
	4	___	___
H	2	___	___
I	1	___	___
	2	___	___
	3	___	___
	4	___	___

Stereogram	Tree No.	dp	Tree ht.
J	1	___	___
	2	___	___
K	1	___	___
	2	___	___
L	3	___	___
	4	___	___



PARALLAX WEDGE STEREOGRAM

H-h = 3900' P = 2.45"

Wedge Readings - Ground 1 = 2.300"

Tree Top 2 = 2.242"

Par Diff = 0.058"

Tree Height = 90'

Figure 15.--Training stereogram with overprinted parallax wedges illustrates correct position of wedge in reading treetop and ground lines. (Greatly reduced.)

Problem 8--Estimating Crown Diameter and Crown Coverage

In solving this problem the student learns four things: (1) how to use the dot-type crown diameter wedge in measuring tree crowns; (2) how to use the crown coverage scale in estimating percent of area covered by tree crowns; (3) the procedure used in determining the average crown size for a plot and the crown coverage on a plot; and (4) how to convert crown diameter measurements to ground scale.

The instructor should explain that crown diameter is used as an indicator of d.b.h. Although it cannot be measured with as much precision as tree height, it can help considerably in estimating average tree size and is a guide in estimating age. Crown coverage is related to basal area and can be used as an indicator of number of stems and of stocking. In stand measurements, crown coverage is substituted for stem counts, which are seldom reliable even on large-scale photos.

In making these measurements, the student should always view the photos in stereo. This is necessary to separate crowns from shadows and to separate the various age classes or crown levels in the stand.

Problem photos are stereograms used in problems 4 and 7 and are illustrated in figure 12.

PROBLEM 8

TITLE.--ESTIMATING CROWN DIAMETER AND CROWN COVERAGE

OBJECTIVES.--To give you practice in estimating crown diameter and crown coverage. To familiarize you with the dot type crown diameter scale and the crown density scale used as aids in this classification.

TOOLS AND MATERIALS.--Stereoscope, problem stereograms, crown diameter scale, 1/5-acre crown density scale, parallax wedge conversion table, and problem sheet.

EXPLANATION.--The size of tree crowns--particularly the total height-crown diameter relationship--is a good indicator of stand size and age. The measurement of crown diameter is one of the simplest measurements possible on photos.

Crown size can be classified most consistently with the aid of the dot type crown diameter scale. This scale consists of a series of dots graduated from 0.0025 inch to 0.115 inch in diameter, printed on transparent film. Under stereo, select a dot size equal to the tree crown you are measuring.

In most problems you are interested in stands of 1/5-acre or larger and must select a dot size typical of the stand. The selected measurement is then converted to feet on the ground. On 1:5,000-scale photos, the measurement of conifer crowns is usually limited to dots smaller than 0.070 inch in diameter and to 1-foot classes.

Crown coverage or crown density, as it is often called, is used as a substitute for number of trees. It measures the proportion of an area covered by tree crowns, and is made by comparison with the crown density scale.

This scale consists of three columns of 1-acre circles or squares containing dots that cover from 5 to 95 percent of the area. The two outer columns are randomly spaced, and the center one is mechanically spaced to offer a variety of conditions typical of the forest. This scale is usually printed on paper so that the crown density pattern of the photo does not show through and confuse the interpreter. For large scale photos, 1/5-acre scales are often used.

As before, place your photos in stereo and view the photos and the scale under the stereoscope at the same time. To read density, match the pattern on the photos with the pattern on the scale. These two scales allow the reading of a variety of conditions. You can, for example, read the overstory and understory in stands where two distinct size or age classes exist. Even though individual readings may be confined to 1 acre, you can read a much larger stand by averaging two or three sample locations. These aids are standards designed to produce more consistent classifications on photos.

Crown diameters can be converted from inches on the photo to feet on the ground through use of a simple conversion table.

Training in measurement of crown diameters may be started with the measurement of open grown trees, but these crowns are usually much larger than the visible crowns found in stands; therefore most of your time should be spent on measurements of the average visible crown on plots.

REQUIREMENTS.--

1. Measure crown diameter of the following numbered trees on stereograms A through D. Record photo and ground measurements.

	Readings: Photo Inches	Readings: Ground Feet		Readings: Photo Inches	Readings: Ground Feet
A 1.	______	______	C 3.	______	______
B 1.	______	______	5.	______	______
3.	______	______	D 2.	______	______

2. Next, measure and record the average total height, crown diameter, and crown cover of the dominant stand on each of the numbered 1/5-acre plots on stereograms A through L. Two-storied stands may be recorded on A-2, F-1, and L-1.

Readings

Stereogram	Total height (Feet)	Crown diameter (Feet)	Crown cover (Percent)	Stereogram	Total height (Feet)	Crown diameter (Feet)	Crown cover (Percent)
A 1.	______	______	______	H 1.	______	______	______
2.	______	______	______	2.	______	______	______
B 1.	______	______	______	3.	______	______	______
2.	______	______	______	I 1.	______	______	______
C 1.	______	______	______	2.	______	______	______
2.	______	______	______	J 1.	______	______	______
D 1.	______	______	______	2.	______	______	______
2.	______	______	______	K 1.	______	______	______
E 1.	______	______	______	2.	______	______	______
F 1.	______	______	______	L 1.	______	______	______
2.	______	______	______	2.	______	______	______
G 1.	______	______	______	3.	______	______	______
2.	______	______	______				

Problem 9--Estimating Board-Foot and Cubic-Foot Volume on Sample Plots

In this problem, the student learns to estimate timber volumes by means of an aerial volume table. He continues his practice on height measurements and the measurement of crown diameter and crown coverage. He learns to make all the measurements consecutively on a single acre plot, record them on a plot card,2/ and record plot volumes from the aerial tables. He also learns that overstory measurements are used to enter the table but that the understory may also be read and the data entered on the card as descriptive information. He is given a chance to visualize the photo measurements in terms of average-per-acre volume.

Background material should include some discussion of the evolution of aerial volume tables, comparison of the stand versus the tree type tables; how the tables are prepared; why total height, crown diameter, and crown cover are used as photo measurements; and why tables are not prepared for individual species.

This problem sums up the stand measurements usually made on sample plots. It continues the student's practice in measurements and introduces him to aerial volume tables before he tries aerial estimating.

Stereograms used in this problem are those introduced in problem 4 and illustrated in figure 12.

2/ A typical plot card is shown in figure 16.

PROBLEM 9

TITLE.--ESTIMATING BOARD-FOOT AND CUBIC-FOOT VOLUME FOR ACRE PLOTS

OBJECTIVES.--To give you practice in estimating board- and cubic-foot volume on acre plots from measurements made on aerial photos. To familiarize you with the aerial stand volume tables, and the technique of using them.

TOOLS AND MATERIALS.--Stereoscope, stereograms, parallax wedge, crown diameter scale, crown density scale, parallax tables, composite aerial volume tables, and slide rule.

EXPLANATION.--Aerial stand volume tables relate the board- or cubic-foot volume per acre from ground plots with photo measurements of one total height, crown diameter, and crown coverage of the same plots. Good estimates by means of these tables must be considered an art to be learned only through long practice, but the procedure is relatively simple. Since it is impossible to enter the table with more than one reading for each of the three photo factors listed, you must first estimate the height and crown diameter of the average dominant on the acre; then you must decide the percent of the acre covered by crowns of this stand size or age class.

In two-storied stands, the table is usually entered with measurements of the oldest or dominant stand. However, where this stand occupies 10 percent or less of the acre, the tables may be entered with measurements of the younger stand for cubic feet and older stand for board feet. In no case should you attempt to strike an average for the measurements of both stands or use height and crowns from one stand with crown coverage for all trees on the acre.

REQUIREMENTS.--The readings made in problems 7 and 8 may be used to enter the aerial volume tables. However, you should examine each plot in stereo and, if necessary, remeasure or reinterpret these factors before using them.

Record measurements and volumes for the following plots:

		Average Measurements of Dominant Stand			Per Acre Volumes	
		Total height	Crown diameter	Crown cover	Cubic feet	Board feet
A	1.					
B	2.					
C	1.					
D	1.					
E	1.					
F	1.					
G	1.					
H	1.					
I	2.					
J	1.					
K	1.					
L	1.					
		Total volume recorded				
		Av. per acre volume				

RE-INT Form PHOTO INTERPRETATION RECORD Dec. 1958

Photo		Plot	Co.	State	F. Plot	
Forest-Nonfor.		Conifer Types		Hardwood Types		
Com. forest		White pine type		Cot.	Alder-Wil.	
Noncom. for.		W. pine		Asp.	Other	
Nonforest		W. hemlock		Other Cover Type		
Stand-Size		W. redcedar		Crop	Grass	Rock
Deforested		Grand fir		Water	Other	
Seed-Saplg.		Pond. pine type		Stand Measurements		
Poles		LP & WLP type		Av.dom.tree	O'Sty	U'Sty
Sawtimber		LP pine		Tot.ht.(ft)		
Topographic Site		WL pine		Cr.dia.(ft)		
Ridge top		Larch, D.-fir		Cr.cov.(%)		
Dry slope		W. larch		Per Acre Volume		
Moist slope		D.-fir			Photo	Field
Canyon bottom		Spruce-fir type		Cubic		
Alluv. bottom		Spruce		Board		
		A. fir		Photo Interp.		

DPS Ogden Utah

Figure 16.--Photo interpretation record (3- x 5-inch card) is used to record data on all plots measured on photos.

Problem 10--Dot Sampling for Areas

In this problem the student learns the process of dot sampling used in determining the areas needed in aerial estimating. He learns the advantages of determining the proportions of forest, open, and various stand conditions by tallying the dots falling in each while viewing photos in stereo. He computes areas by applying proportions obtained from the dot count to a known over-all area. He also learns that many items such as roads, streams, and small water areas, can be estimated by dot sampling where mapping may not be feasible.

The background material should include a brief resume of type mapping, strip sampling, line-plot sampling, and other stratification methods to show how dot sampling evolved from these methods. The instructor should point out that when this system is used the photo is substituted for a map, and the necessary data are measured directly from it.

The stereograms used in this problem were introduced in problem 4 and are illustrated in figure 12.

PROBLEM 10

TITLE.--DOT SAMPLING FOR AREAS

OBJECTIVE.--To acquaint you with a method of obtaining areas by dot sampling on photos.

TOOLS AND MATERIALS.--Stereoscope, stereogram of compartment, 16-dot templet, problem sheet, and fiducial chart.

EXPLANATION.--The common method of stratifying forest stands is the timber type map. This procedure, familiar to most foresters, is time-consuming and often unnecessary when aerial photos are used.

Most foresters have determined areas from type maps by means of dot counts. The same method can be used directly on the aerial photos without the need of prior type delineation.

A dot templet is oriented and taped over the area to be classified. The photos are viewed in stereo, and the classification at each dot is tallied. This tally, or proportions obtained from it, is used to prorate the over-all area of the tract.

This method is most advantageous when the areas to be classified are small, very involved, or otherwise hard to map. Dot sampling is a more objective approach than the type map, and consequently its use usually produces more consistent answers.

In dot sampling, the area classified may be the area of the dot, a 1/5-acre circle whose center is the dot, or a 1-acre circle centered over the dot. Areas larger than 1 acre are seldom used. For the purpose of this problem, the dot alone will be classified. If the dot falls on a clear division between classes, it should be classed as one or the other.

Since a forest is usually an association of many species, sizes, and conditions, the definitions used in dot sampling as well as typing can become quite involved. For the purposes of this problem, only two classes will be recognized:

Forest: When a dot lands on a tree or a clump of trees of any size class.
Nonforest: When a dot lands on openings or grass-sagebrush areas.

REQUIREMENTS.--

1. Orient your 16-dot-to-the-inch grid over the right-hand photo of your stereogram by means of the lower right-hand corner. Count dots on the 2- x 3½-inch area only.

2. Total the number of dots in each class and compute percentages for the following stereograms.

	Forest		Nonforest		Total
	No. dots	Percent	No. dots	Percent	No. dots
A					
H					
K					

Problem 11--Direct Volume Estimates from Aerial Photos

In this problem, the student learns to estimate board-foot and cubic-foot volume for a small area by direct photo methods. Using a stereogram of the tract with an overprinted dot grid, he classifies each dot, tallies this classification by strata, measures a prescribed number of dots, and records his measurements together with per acre volumes from the aerial tables. He uses number of dots tallied in a class to weight mean volume of the class and thus arrive at a mean per acre volume for the tract.

The background material should point out that this technique can be intensified as needed. For example, on small tracts having high variability, photo sampling can be stepped up to measure every acre. The instructor should discuss the possibility of adjustment and proration of volumes by species when some field plots can be measured, even though this technique is not included in the problem. This technique should be stressed as a means of obtaining quick usable estimates of areas where ground cruising is impossible within the time allotted or too expensive.

This problem demonstrates the procedures used in estimating tract volumes from photos and completes the work on stand measurements.

The stereogram used in this problem is illustrated in figure 17.

PROBLEM 11

TITLE.--VOLUME ESTIMATES FROM AERIAL PHOTOS

OBJECTIVES.--To acquaint you with a method of volume estimating by dot sample on aerial photos. To give you practice in classifying and estimating randomly selected 1/5-acre plots.

TOOLS AND MATERIALS.--Stereoscope, stereogram compartment 11B, dot shield, scale protractor, parallax wedge, crown diameter and crown cover scales, parallax table, ponderosa pine aerial volume tables, slide rule, problem sheet.

EXPLANATION.--The common method of stratifying forest stands is by use of timber type map. However, if the stratification is for volume estimating purposes only, then dot sampling may result in equally precise and often more usable stratification.

Measurements and volume estimates may be made on every plot or a proportion of the plots based on importance.

The mean of the estimates in a class when applied to the corresponding area measurement will give a volume estimate for the class. This may be refined and additional data secured by means of selected field plots.

A common practice is to record measurements and classifications on 3- x 5-inch cards for easy sorting and averaging. On small tracts this is seldom required.

On your stereogram, compartment 11B has been outlined by heavy dotted line. A dot grid having 16 dots to the inch has been printed on this stereogram. The accompanying map shows the numbering system of these dots as well as the outline of the compartment and cardinal directions. Your estimate is to be based on the numbered 1/5-acre plots surrounding the white dot in the center of each small square. Classify all dots in one of the following height classes:

Open--No trees on the 1/5-acre;
Poles--Trees 20 to 50 feet total height;
Small sawtimber--Trees 55 to 85 feet total height;
Large sawtimber--Trees 90 feet or more total height.

Sample points 1, 6, 11, etc., indicated on your map, are to be measured and classified. Measure the average height, crown diameter, and crown coverage of the dominant stand on these plots. On this tract, a single large pine may cover an appreciable percent of a 1/5-acre plot, and may represent your entire dominant stand. Do not attempt to separate classification and measurement. Rather, as you measure and classify the designated plots you should also classify those additional unmeasured ones. Look up cubic- and board-foot volumes in your ponderosa pine volume tables as you measure each plot.

Your stereogram is 1:12,500 scale.
Parallax factor has been computed at 2.5 feet per .001 inch.

REQUIREMENTS.--

1. Record classification, measurements, and volumes for each measured plot in the following table.
2. Record classification of all plots by dot tally.
3. Computations for this survey are based on the stand size stratification:
    a. Determine the total number of all classified plots, measured and unmeasured, in each stand size.
    b. Total and determine average for all measured plots in each stand size.
    c. Weight the average (b) by the total classified (a) and obtain a grand total.
    d. Divide this figure by the total number of plots in the tract (51). The result will be the average board or cubic feet per acre.

Measured Plots

Plot number	Class	Measurements: Total height Feet	Measurements: Crown diameter Feet	Measurements: Crown cover Percent	Per Acre Volumes: Cubic feet	Per Acre Volumes: Board feet Scribner
1						
6						
11						
16						
21						
26						
31						
36						
41						
46						
51						

Dot Tally All Plots

	Open	Poles	Small sawtimber	Large sawtimber
Dots				

Computations

Classification	No. plots classified	Mean volumes per acre: Cubic feet	Mean volumes per acre: Board feet	Weighted volumes
Open				
Poles				
Small sawtimber				
Large sawtimber				
		Total weighted volume		
		Mean per acre volume		

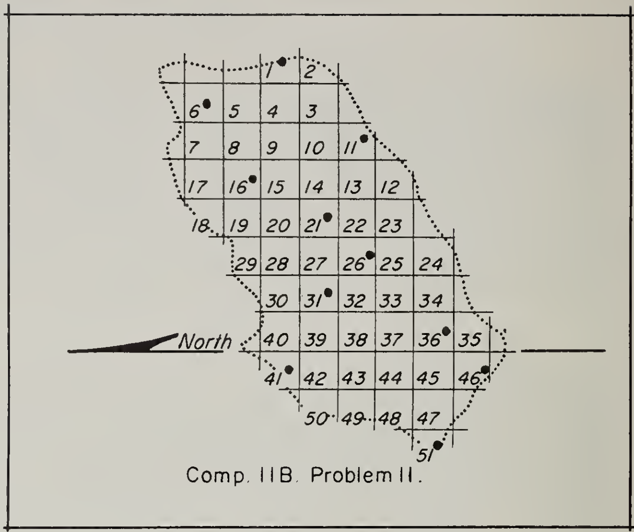


Figure 17.--Stereogram with overprinted dot grid. This stereogram of compartment 11, Boise Basin Experimental Forest, is used in the problem on direct photo estimating. (Greatly reduced.)

Problem 12--Measuring Slope Percents

This problem teaches the student to combine elevation difference, determined by parallax wedge, with distance measurement to estimate slope percent. He uses the slope percent scale to simplify computation. He learns that this measurement, as well as many other forest measurements, depends upon his ability to measure parallax.

Background material should include discussion of the use of slope percent in soil, geological, forest site, and watershed surveys, as well as its obvious application in road location. The instructor should again stress the need for proficiency in using the parallax wedge in measuring slope percents as well as other techniques.

This problem is a preliminary exercise to familiarize the student with techniques before he is given a problem in locating roads and trails.

The stereogram used in this problem was introduced in problem 2 and is illustrated in figure 10.

PROBLEM 12

TITLE.--MEASURING SLOPE PERCENTS

OBJECTIVE.--To acquaint you with the use of the slope percent scale in field surveys.

TOOLS AND MATERIALS.--Stereoscope, problem stereogram, problem sheet, parallax wedge, No. 20 slope percent scale, tables, and slide rule.

EXPLANATION.--Many types of forest surveys require determination of percent slope. Soil surveys, forest site surveys, range and watershed reconnaissance--all are interested in percent of slope, and specifically the proportion of area within certain specified slope percents.

The forester who can use aerial photos in measuring elevation differences and in sampling has a distinct advantage over one who must rely on ground data or previously prepared contour maps for this information.

The slope percent scale is designed to convert elevation differences into slope percent without computation.

To determine slope percent, measure the elevation difference between two points by parallax wedge. Select a scale line opposite this elevation change, and orient the scale over your photos with the zero line cutting one point. Read the slope percent figure where the scale line cuts the second point. When measuring slope at a specific location, select two landmarks about 500 feet apart and measure between them. Shorter lines will be less accurate. When estimating slope percent in this manner on 1:20,000-scale photos, estimates should be within 1 to 4 percent of those obtained by abney level on the ground. Your photos are the 1:20,000-scale stereograms used in problem 2. Separation of the principal points of the stereograms is as follows:

A.	5.5 inches	F.	5.3 inches
B.	5.1 inches	G.	5.9 inches
C.	5.1 inches	H.	5.3 inches
D.	5.1 inches	I.	5.7 inches
E.	5.6 inches	J.	5.5 inches

REQUIREMENTS.--

1. Determine the parallax factor for each pair of photos by solving $ho = \frac{H\text{-}h \times dp}{P + dp}$ for a dp of 0.001. Assume an average H-h for 1:20,000 photos, i.e., 13,750 feet.

2. Measure and record slope percents for the following slopes:

Stereogram A	- Between road at 6 and irrigation canal	______
Stereogram B	- Between 8 and 12	______
Stereogram C	- Bank at 16	______
Stereogram E	- Drainage at 23	______
	- Ridge slope 27	______
Stereogram G	- Between 32 and G	______
Stereogram I	- Road grade at 42	______
	- Slope at 43	______
Stereogram J	- Cirque wall at 45	______
	- Ground slope at 46	______

Problem 13--Road Planning on Photos

In this problem, the student learns a method of locating short access roads by direct measurements on aerial photos. He locates a preliminary line at a prescribed grade and learns how to locate this road on the ground by using control landmarks. During the problem he may fit curves of prescribed radii to the preliminary line, and then check cut and fill along this location. Sample cross sections may also be measured to illustrate the possibilities of direct photo measurement. However, the short roads normally located by foresters usually do not call for such detailed planning.

This road problem is intended to teach procedures useful to foresters in preparing timber sales, planning recreation, and other projects where short access roads are needed. Usually, roads of this category lie on a single stereo pair or at most a stereo triplet, and a preliminary line can furnish all the information required.

The background material should include a brief discussion of road planning in combination with timber estimating to do the entire timber appraisal problem from photo measurements. The instructor should mention the possibility of preliminary road locations almost equal to photogrammetric machine location for short roads on a single photo, but should emphasize the difficulties involved in bridging from one photo to another. He should point out that several preliminary lines can be laid out and tested on photos in less time than one can be located by conventional means.

The stereogram used in this problem is shown in figure 14 and was also used in problem 6.

TITLE.--ROAD PLANNING ON PHOTOS

OBJECTIVES.--To acquaint you with a procedure for initial planning of short access roads on contact prints. To illustrate the use of slope percent scale and preliminary road plan.

TOOLS AND MATERIALS.--Stereoscope, problem stereogram, slope percent scale, parallax wedge, tables, slide rule, and small bow compass.

EXPLANATION.--The procedures used in planning short access roads on contour maps are equally usable on contact prints of aerial photos. In fact, the trained interpreter has many advantages over the forester who must rely on the normal contour map. He not only is able to see small unmapped differences in topography but has a precise record of timber stands and cover types along the route in his stereo model. On photos of adequate scale the accuracy of his deductions as to soil, rock, slope, timber removal, and other construction factors may approach that of the man on the ground, and his estimates of cost can be equally valid for most planning purposes.

The slope percent scale is designed to aid you in laying out preliminary road grades, as well as in measuring slope percent. On medium (1:15,000 or 1:20,000) scale photos, the slope percent scale is frequently printed to agree with the nominal scale of the photos. Road grades may then be read direct by using the technique illustrated in problem 12. On large scale photos, the distance scale at the top used in comparison with the percent scales will indicate slope for a given elevation difference and tangent or elevation difference for a given tangent and slope.

To lay out a preliminary road location on your photos:

1. Study the photos and decide on a possible route you wish to follow.
2. Set your small bow compass for a short tangent (500 feet) at the average scale of your photos. Scribe an arc up and down slope using your starting point as a center.
3. Determine the parallax difference in 0.001 inch for the percent slope you wish to mark off. For example: at 500 feet, 6 percent slope means an elevation difference of 30 feet. If your parallax factor is 3.7 feet per 0.001 inch, a (dp) of 0.008 inch will be required in 500 feet.
4. Indicate the point on your 500-foot arc which measures a (dp) of 0.008 inch above your starting point.
5. Repeat the process step by step, recomputing your parallax factor as needed until you have reached the termination point of your road. After completing the initial alignment, check measurements of each point; straighten tangents and regularize curves as needed to keep within specifications.

Suggestion--Around points of hills and on tight curves, use a 200-foot tangent. In these areas you may wish to keep a level grade and gain most of your elevation on longer tangents.

When changing from one stereo pair to the other, it is necessary to bridge, that is, record both wedge readings for the same point.

REQUIREMENTS.--

1. You wish to locate a road from point A to the vicinity of point B, an air line distance of about 1,500 feet. Control survey indicates elevation of point A as 6,030 and point B as 6,300 feet above sea level. For purposes of this problem, assume the average scale of your reduced stereogram to be 1:10,000. Parallax factors have been computed as 3.7 feet per 0.001 inch at point A on the right-hand stereogram, 3.4 feet at point 2 on the left stereogram, and 3.2 feet for point B on the right stereogram. These average factors should be used in your measurements.
2. Specifications call for an average grade of 6 percent, but allow slopes of 10 percent for distances not exceeding 500 feet. Curves must have radius 200 feet or more. Within the specifications the road should be as short as possible.
3. Lay out a preliminary road location on the center photo of your stereo triplet, crossing the stream with an approximately level grade between A and C. Use 500-foot tangents and reduce these to 200 feet on turns. Record your initial data on scratch paper; then check back over your location moving up or down slope as needed to meet specifications. Show final location in red pencil on the center photo of your stereo triplet.

4. Measure data at 500-foot stations along your final location and record in the following table.

Station	Parallax reading Inches	Parallax difference Inches	Elevation difference Feet	Elevation above sea level Feet	Average grade alignment Percent
Right pair					
0 + 00 (A)	________	--	--	6,030	--
________	________	________	________	________	________
________	________	________	________	________	________
________	________	________	________	________	________
________	________	________	________	________	________
________	________	________	________	________	________
________	________	________	________	________	________
Left pair					
________	________	________	________	________	________
________	________	________	________	________	________
________	________	________	________	________	________
________	________	________	________	________	________
________	________	________	________	________	________
________	________	________	________	________	________
Right pair					
________	________	________	________	________	________
________	________	________	________	________	________
________	________	________	________	________	________
________	________	________	________	________	________
________	________	________	________	________	________
________	________	________	________	________	________
		Total	________	Average	________

NOTES

A P P E N D I X

Accepted solutions to problems

Glossary of terms

Answer Section

The following section includes an approved solution to all questions asked in this set of training problems. All measurements are subject to error. In photo measurements, errors include those introduced by the photos themselves, the interpretation aids used to measure them, and by the technique and skill of the interpreter. Wherever possible, the source of these answers, as well as statistical error limits set by experience, has been included in the comments.

Stereoperception Test--"Floating Circles Stereogram."

These answers apply to either Stereogram I or II on the test sheet.

Block A: A-5, B-7, C-2, D-4, E-1, and E-6
Block B: A-1, B-8, C-3, D-1, D-5, and E-6
Block C: A-2, A-5, B-7, C-3, D-1, and E-8
Block D: A-1, B-4, B-7, C-2, C-5, D-3, and E-6.

Problem 1--Positioning Photos for Best Stereovision

No approved solution. Check photos to be sure principal and conjugate principal points are pinpricked precisely, that photos are taped tightly along outer edge, and that the points are precisely in a straight line with either right or left photo on top.

Problem 2--Recognition of Ground and Cover Conditions

Answers given here are the consensus of four experienced interpreters familiar with the general area covered by these photos.

1c--orchard
2a--bridge
3c--irrigation canal
4b--farm pond
5a--farm buildings
6d--road
7d--ranch buildings
8b--cottonwood
9a--irrigated field
10c--baled hay piles
11b--grass-sagebrush
12a--irrigation ditch
13b--lava rock ledge
14b--conifers
15a--hard rock cliff
16d--rapids
17a--fence line
18c--tillage pattern
19b--grass-sagebrush
20c--drainage canal
21a--marsh pattern
22a--clay piles
23b--narrow gage grade
24c--mine buildings
25a--abandoned mine
26b--improved road
27a--water ditch
28a--pine trees
29b--pine saplings
30d--exploration pit
31b--fireline road
32a--aspen poles
33d--mountain meadow
34d--hardwood brush
35b--rock dike
36a--main haul road
37a--clearcutting
38d--old beaver meadows
39a--cutting line
40b--lodgepole pine
41c--beaver pond
42a--main haul road
43d--jammer roads
44d--road junction
45c--cirque wall
46a--toe slope with boulders
47d--talus slope
48c--spruce, alpine fir
49a--timberline fir
50d--snow

Problem 3--Determining Photo Scales

An accepted solution. Measurements made on photos by an experienced interpreter. Allowable error limits in determining PSR: within ±500 units two times in three.

Line	Photo distance	Map distance	Mean elevation	PSR
1 - 2	0.138	0.114	7,010	19,826
2 - 3	.113	.092	7,170	19,539
6 - 7	.166	.129	7,660	18,650
6 - 9	.244	.188	7,530	18,491
7 - 11	.325	.252	7,700	18,609

3. The following lines have been chained on the ground. Select the chain scale you would use in this vicinity and record R/F.

Line	Ground chainage	R/F
1 - 14	17.80	1:20,000
5 - 6	15.25	1:18,500
7 - 8	23.50	1:18,500
10 - 11	16.20	1:18,500
12 - 13	13.90	1:18,000

Problem 4--Determining Project Scale and Flying Height

An accepted solution. Measurements by an experienced interpreter. Initial flight plan specified flying height of 12,500 feet above sea level.

Table 1.

Base line	Measured distance: Ground	Measured distance: Photo	Mean elev. above sea level (h)	Computed PSR	Flying height above: Ground (H-h)	Flying height above: Sea level (H)
	Feet		Feet		Feet	
A	936	0.168	8,600	5,571	3,830	12,430
B	533	.095	8,490	5,611	3,858	12,348
C	948	.176	8,695	5,386	3,703	12,398
D	842	.146	8,635	5,767	3,965	12,600
E	842	.147	8,635	5,728	3,938	12,573
F	776	.139	8,375	5,583	3,838	12,213
G	752	.132	8,690	5,697	3,917	12,607
H	467	.080	8,230	5,838	4,014	12,244
I	785	.132	8,490	5,947	4,089	12,579
J	739	.108	8,030	6,843	4,705	12,735
K	631	.108	8,400	5,843	4,017	12,417
L	741	.123	8,510	6,024	4,142	12,652
				Average	4,001	12,483
						$\sigma = \pm 166$
						$\sigma_{\bar{x}} = \pm 50$

(Problem 4, cont.)

Table 2.--PSR + (H-h) for ground elevations

Elevation	PSR	H-h	Elevation	PSR	H-h
Feet			Feet		
7,000	7,975	5,483	8,000	6,521	4,483
7,200	7,684	5,283	8,200	6,230	4,283
7,400	7,393	5,083	8,400	5,939	4,083
7,600	7,102	4,883	8,600	5,648	3,883
7,800	6,811	4,683	8,800	5,357	3,683

Allowable standard error mean flying height ±2 percent of mean H-h.

Problem 5--Measuring Distance and Bearing

An accepted solution by an experienced interpreter. Average error of point location on the ground using this technique is ±0.5 chain. Allowable error limits in determining distance = ±0.5 chain, and bearing = ±1° two times in three.

Base line	Length Chains	Bearing	PSR	Line	Length Chains	Bearing
5 - 6	15.25	N. 70° W.	18,500	5 - A	13.50	N. 20° W.
--	--	--	18,500	4 - B	12.50	S. 45° E.
10 - 11	16.20	N. 28° W.	18,500	10 - C	11.25	N. 39° E.
12 - 13	13.90	S. 28° E.	18,000	13 - D	19.50	N. 42° E.
1 - 14	17.80	S. 20° E.	20,000	14 - E	14.25	S. 18° W.
				Field corner - D	5.50	N. 53° E.

Problem 6--Determining Relative Elevation by Parallax Wedge

An accepted solution by an experienced interpreter.

Left Stereo Model			Right Stereo Model		
No.	Ground reading	Parallax difference (dp) from 30	No.	Ground reading	Parallax difference (dp) from 29
30	2.214		29	2.282	
31	2.104	0.110	41	2.214	0.068
41	2.110	.104	43	2.254	.028
43	2.170	.044	51	2.234	.048
1	2.120	.094	53	2.226	.056
2	2.160	.054	3	2.140	.142
PP_2	2.166	.048	B	2.190	.092
			PP_2	2.268	.014

	Inches		Inches
PP_1 to PP_2	3.200	PP_2 to PP_3	3.250
Reading 30	2.214	Reading 29	2.282
P for 30	.986	P for 29	.968
H-h for 30	3,890	H-h for 29	3,800

No.	dp	Elevation difference	Elevation above sea level	No.	dp	Elevation difference	Elevation above sea level
30			5,870	29			5,960
1	0.094	339	6,209	3	0.142	486	6,446
2	.054	202	6,072	B	.092	330	6,290
PP_2	.048	181	6,051	PP_2	.014	54	6,014

Allowable error limits, largely introduced by different photo prints, = $\pm$0.007 inch dp or $\pm$20 feet two times in three. Instrument control elevation of PP_2 is 6,061. Variation in computed elevations is due largely to tilt in the original contact prints.

Problem 7--Measurement of Tree and Stand Heights by Parallax Wedge

An accepted solution obtained by abney level readings on the ground. Readings are converted to (dp) using parallax factors given in the problem. Allowable error limits in determining (dp) = ±0.004 inch two times in three.

Stereo-gram	Tree No.	Wedge readings: Ground	Wedge readings: Tree top	dp	Tree ht.	Stereo-gram	Tree No.	Wedge readings: Ground	Wedge readings: Tree top	dp	Tree ht.
		- -0.001 inch- -			Feet			- -0.001 inch- -			Feet
A	1	____	____	0.033	52	C	1	____	____	0.024	34
	2	____	____	.046	73		2	____	____	.037	54
B	1	____	____	.008	14		3	____	____	.067	94
	2	____	____	.020	36		4	____	____	.058	82
	3	____	____	.025	45		5	____	____	.046	65

Set the appropriate parallax factor on your slide rule and record (dp) and computed height only, for the remainder.

Stereo-gram	Tree No.	dp Inches	Tree ht. Feet	Stereo-gram	Tree No.	dp Inches	Tree ht. Feet	Stereo-gram	Tree No.	dp Inches	Tree ht. Feet
D	1	0.043	64	G	1	0.042	58	J	1	0.026	52
	2	.045	67		2	.061	85		2	.032	64
	3	.018	27		3	.031	43				
E	1	.043	64		4	.038	53	K	1	.035	53
	2	.045	67	H	2	.028	47		2	.040	6
	3	.018	27	I	1	.029	46				
F	1	.010	17		2	.038	61				
	2	.060	102		3	.041	66	L	3	.026	42
	3	.070	120		4	.036	57		4	.032	51

Problem 8--Estimating Crown Diameter and Crown Coverage

An accepted solution. Measurements made on photos by an experienced interpreter. Allowable error limits on crown diameter of individual trees = ±0.005-inch two times in three. Allowable error limits on crown coverage = ±10 percent two times in three.

		Readings: Photo Inches	Readings: Ground Feet			Readings: Photo Inches	Readings: Ground Feet
A	1.	0.020	9	C	3.	0.045	21
B	1.	.015	7		5.	.027	13
	3.	.037	18	D	2.	.042	20

Stereo-gram		Total height (Feet)	Crown diameter (Feet)	Crown cover (Percent)	Stereo-gram		Total height (Feet)	Crown diameter (Feet)	Crown cover (Percent)
A	1.	32	6	75	H	1.	70	8	45
	2.	45/32	7/5	2/25		2.	75	12	65
B	1.	110	15	45		3.	34	6	85
	2.	83	9	55	I	1.	48	8	75
C	1.	80	15	25		2.	65	7	65
	2.	95	10	15	J	1.	55	7	95
D	1.	100	15	65		2.	40	5	15
	2.	60	9	35	K	1.	55	10	45
E	1.	90	17	25		2.	50	12	75
F	1.	68/45	15/7	25/55	L	1.	65/50	11/6	25/35
	2.	28	6	35		2.	35	6	55
G	1.	75	15	55		3.	32	5	85
	2.	75	12	25					

Problem 9--Estimating Board-Foot and Cubic-Foot Volume on Plots

An accepted solution. Measurements made on photos by an experienced interpreter. Allowable error limits are total height ±6 feet, crown diameter ±5 feet, crown coverage ±10 percent, two times in three.

		Average Measurements of Dominant Stand			Per Acre Volumes	
		Total height	Crown diameter	Crown cover	Cubic feet	Board feet
A	1.	32	6	75	850	--
B	2.	83	9	55	3,950	18,500
C	1.	80	15	25	2,900	13,500
D	1.	100	15	65	5,750	32,500
E	1.	90	17	25	3,900	20,800
F	1.	68	15	25	2,100	8,600
G	1.	75	15	55	3,150	13,500
H	1.	70	8	45	2,500	8,500
I	2.	48	8	75	1,700	4,200
J	1.	55	7	95	2,350	7,100
K	1.	55	10	45	1,300	4,000
L	1.	65	11	25	1,600	5,400
			Total volume recorded		32,050	136,600
			Av. per acre volume		2,671	12,418

Problem 10--Dot Sampling for Areas

An accepted solution. Dot counts on photos by an experienced interpreter. Error limits on estimating the percent in forest two times in three based on 112 samples.

A ±8 percent, B ±6 percent, C ±10 percent.

	Forest		Nonforest		Total
	No. dots	Percent	No. dots	Percent	No. dots
A	65	58	47	42	112
H	79	71	33	29	112
K	50	45	62	55	112

Problem 11--Volume Estimates from Aerial Photos

An accepted solution. Measurements made on photos by a trained interpreter. Error limits on photo estimating of gross board-foot (Scribner) volume two times in three.

Interpreters with limited training	±25 percent
Interpreters with adequate training	±10 percent

Measured Plots

Plot number	Class	Measurements: Total height (Feet)	Crown diameter (Feet)	Crown cover (Percent)	Per Acre Volumes: Cubic feet	Board feet (Scribner)
1	SST	60	15	35	1,500	4,400
6	SST	58	22	5	1,250	4,300
11	LST	102	22	15	4,370	22,300
16	SST	75	15	5	1,610	6,200
21	LST	122	20	35	5,500	26,700
26	LST	110	20	25	4,910	24,000
31	LST	112	32	5	4,720	23,900
36	LST	100	27	5	4,190	21,900
41	POLES	38	15	45	760	1,100
46	LST	98	17	15	4,230	21,400
51	LST	130	22	15	5,760	29,700

Dot Tally All Plots

	Open	Poles	Small sawtimber	Small sawtimber
Dots	0	12	20	19

Computations

Classification	No. plots classified	Mean volumes per acre: Cubic feet	Mean volumes per acre: Board feet	Weighted volumes: Cubic feet	Weighted volumes: Board feet
Open	0	0	0	0	0
Poles	12	760	1,100	9,120	13,200
Small sawtimber	20	1,453	4,967	29,060	99,340
Large sawtimber	19	4,811	24,271	91,409	461,149
		Total weighted volume		129,589	573,689
		Mean per acre volume		2,541	11,249

100 percent ground measurement gave mean volume of 11,386 board feet (Scribner).
Difference: 1.20 percent.

Problem 12--Measuring Slope Percents

An accepted solution. Measurements made on photos by a trained interpreter. Field check by abney level indicates error limit to be ± 1 to 5 percent two times in three with maximum errors occurring on slopes of 50 to 75 percent.

		P	PF			P	PF
A.	5.5 inches	3.2	4.3	F.	5.3 inches	3.0	4.6
B.	5.1 inches	2.7	5.1	G.	5.9 inches	3.4	4.0
C.	5.1 inches	2.8	4.9	H.	5.3 inches	3.0	4.6
D.	5.1 inches	2.8	4.9	I.	5.7 inches	3.4	4.0
E.	5.6 inches	3.3	4.1	J.	5.5 inches	3.4	4.0

Stereogram A	- Between road at 6 and irrigation canal	130/520	25
Stereogram B	- Between 8 and 12	71/900	8
Stereogram C	- Bank at 16	370/520	71
Stereogram E	- Drainage at 23	123/410	30
	- Ridge slope 27	330/480	69
Stereogram G	- Between 32 and G	120/360	33
Stereogram I	- Road grade at 42	64/1060	6
	- Slope at 43	160/450	35
Stereogram J	- Cirque wall at 45	415/520	80
	- Ground slope at 46	65/320	20

Problem 13--Road Planning on Photos

An accepted solution. Measurements made on photos by an experienced interpreter. Error limits those of horizontal and vertical measurements and slope percents.

Station	Parallax reading Inches	Parallax difference Inches	Elevation difference Feet	Elevation above sea level Feet	Average grade alignment Percent
Right pair					
0 + 00 (A)	2.274	--	--	6,030	--
5 + 00	2.266	0.008	30	6,060	6.0
10 + 00	2.258	.008	30	6,090	6.0
15 + 00	2.250	.008	30	6,120	6.0
Left pair					
15 + 00	2.150	--	--	6,120	--
20 + 00	2.142	.008	28	6,148	5.6
25 + 00	2.140	.002	7	6,155	1.4
30 + 00	2.136	.004	14	6,169	2.8
35 + 00	2.128	.008	28	6,197	5.6
Right pair					
35 + 00	2.218	--	--	6,197	--
40 + 00	2.208	.010	32	6,229	6.4
45 + 00	2.199	.009	29	6,258	5.8
50 + 70	2.190	.009	29	6,287	5.8
Control-5070			257	Cont. 6,300	Av. 5.1

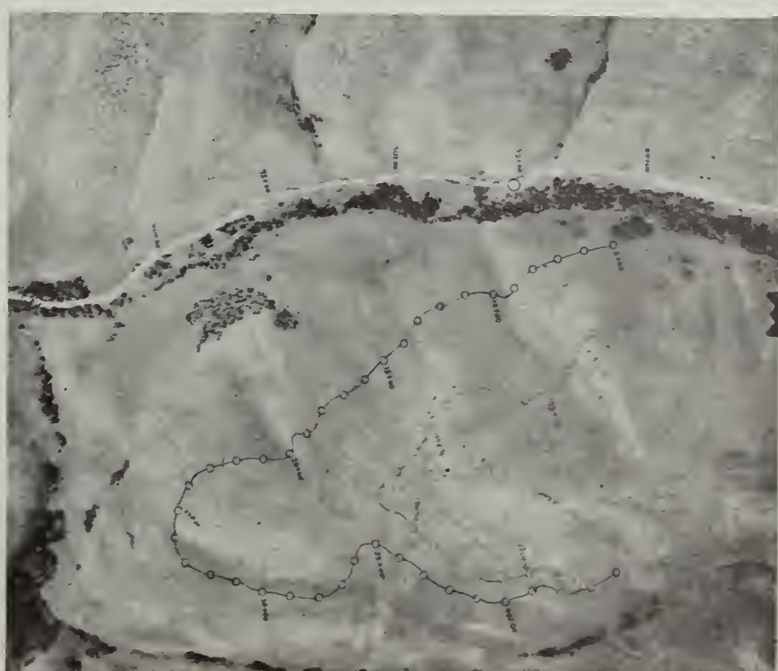


Figure 18.--Photo showing a portion of preliminary line as located by photogrammetric plotter.

Aerial photograph--A photograph of a portion of the earth's surface taken by a camera mounted in an aircraft.

Aerotriangulation--Any type of triangulation for control extension accomplished by means of aerial photographs. (See also radial triangulation.)

Air base (photogrammetry)--The line joining two air stations or the length of this line; also the distance, at the scale of the stereoscopic model, between adjacent perspective centers as reconstructed in the plotting instrument. Photo base--The length of the air base as represented on a photograph. See camera station.

Alignment guide--Kite-shaped device used in locating principal points and in aligning photos for parallax measurement.

Angle of coverage--The apex angle of the cone of rays passing through the front nodal point of a lens. Normal-angle lens--A lens having an angle of coverage up to 75^{o}; wide-angle lens--A lens having an angle of coverage between 75^{o} and 100^{o}; ultra-wide-angle lens--A lens having an angle of coverage greater than 100^{o}.

Auto positive film and paper--A material which gives a positive print from a positive transparency (or a negative from a negative) by direct development. Also called direct copy or direct positive.

Average crown diameter--Average visible crown diameter of the dominant crowns on acre.

Average stand height--Average total height of the dominant trees on the acre.

Azimuth line (photogrammetry)--A radial line from the principal point, isocenter, or nadir point of a photograph which represents the direction to a similar point of an adjacent photograph in the same flight line, used extensively in radial triangulation.

Base-height ratio--The ratio (B:H) between the air base length and the flight height of a stereoscopic pair of photographs. This ratio commonly varies from one-third for normal-angle lens to two-thirds for wide-angle lens vertical aerial photography.

Bridging (photogrammetry)--The extension and adjustment of photogrammetric surveys between bands of ground control.

Camera--A chamber or box in which the images of exterior objects are projected upon a sensitized surface. Aerial camera--A camera specially designed for use in aircraft. The prefix aerial is not essential where the context clearly indicates the use of an aerial camera rather than a ground camera. Continuous strip camera--A camera in which a continuous strip exposure is made by rolling the film continuously past a narrow slit opening at a speed proportional to the speed of the aircraft. Horizon camera (aerial photography)--A camera used in conjunction with an aerial surveying camera in vertical photography, to photograph the horizon simultaneously with the vertical photographs. The horizon photographs indicate the tilts of the vertical photographs. Mapping camera or surveying camera--A camera specially designed for the production of photographs to be used in surveying. The prefix mapping or surveying indicates that the camera is equipped with mechanism to maintain and to indicate the interior orientation of the photographs with sufficient accuracy for surveying purposes. A mapping camera may be an aerial mapping camera or terrestrial mapping camera.

Camera axis--A line perpendicular to the focal plane of the camera and passing through the interior perspective center or emergent nodal point of the lens system.

Camera station (photogrammetry)--The point in space, in the air, or on the ground, occupied by the camera lens at the moment of exposure. Also called the exposure station.

Collimate (physics and astronomy)--To render parallel to a certain line or direction; to render parallel, as rays of light; to adjust the line of sight or lens axis of an optical instrument so that it is in its proper position relative to the other parts of the instrument (photogrammetry). To adjust the fiducial marks of a camera so that they define the principal point.

Compilation--The gathering together of source material such as existing maps, photographs, surveys, etc., and the symbolization on a map of the physical and cultural features of the earth or a section thereof as defined by the source materials. (See also delineation.)

Composite photograph (aerial photography)--A photograph made by assembling the separate photographs made by each lens of a multiple-lens camera during the same simultaneous exposure into the equivalent of a photograph taken with a single wide-angle lens. (See also camera.)

Conjugate distance--The corresponding distances of object and image from the nodal points of the lens. The conjugate distances O and I and the focal length F of the lens are related by the formula:

$$\frac{1}{F} = \frac{1}{I} + \frac{1}{O}$$

This relation may also be expressed in Newton's form as:

$$X X^1 = F^2$$

$$\text{where} \quad X = I - F, \quad X^1 = O - F$$

Note: The total distance from object to image equals the sum of the two conjugate distances plus or minus (depending on lens design) a small distance called the nodal point separation.

Conjugate image point--The images on two (or more) overlapping photographs of a single object point. (See also corresponding images.)

Contour (line)--An imaginary line connecting the points on a land surface that have the same elevation; also the line representing this on a map or chart. Depression contour--A closed contour inside of which the ground is at a lower elevation than outside. (See also form line.)

Contrast (photography)--The actual difference in density between the highlights and the shadows on a negative or paper. Contrast is not concerned with the magnitude of density but only with the difference in densities. Also the rating of a photographic material corresponding to the relative density difference which it exhibits.

Control point (photogrammetry)--Any station in a horizontal and/or vertical control system that is identified on a photograph and used for correlating the data shown on that photograph, also called photo control point, picture control point, and ground control point.

Control strip (aerial photography)--A strip of aerial photographs taken to aid in planning and accomplishing later aerial photography, or to serve as control in assembling other strips.

Corresponding images--A point or line in one system of points or lines homologous to a point or line in another similar system; for example, corresponding image points, usually called conjugate points, are the images on two or more photographs of the same object point.

Course (air navigation)--The direction in which a pilot attempts to fly an aircraft; the line drawn on a chart or map as the intended track. Its direction is always measured in degrees from the true meridian and the true course is always meant unless it is otherwise qualified, as a magnetic or compass course.

Crab (air navigation)--Any turning of an airplane which causes its longitudinal axis to vary from the track of the airplane. (Aerial photograph)--The condition caused by failure to orient the camera with respect to the track of the airplane as indicated in vertical photography by the edges of the photographs not being parallel to the air base lines.

Crown coverage--Percent of the acre covered by tree crowns.

Culture (mapping)--Those features of the terrain that have been constructed by man such as roads, trails, buildings, and canals; also, boundary lines, and all names and legends.

Datum, horizontal control datum--The position on the spheriod of reference assigned to the horizontal control (triangulation and traverse) of an area and defined by (1) the position (latitude and longitude) of one selected station in the area, and (2) the azimuth from the selected station to an adjoining station. The horizontal control datum may be for a continent or a small area. A datum for a small area is usually called a local datum and is given a proper name. The horizontal control datum for the North American continent is known as the North American Datum of 1927, the selected station for which is "Meades Ranch," Kansas with the azimuth to the adjoining station "Waldo." All geodetic positions on the North American Datum of 1927 depend on the position of "Meades Ranch" to "Waldo." Vertical control datum--Any level surface, as for example mean sea level, taken as a surface of reference from which to reckon elevations. Also called the datum level. Although a level surface is not a plane, the vertical control datum is frequently referred to as the datum plane. Geoid horizontal plane--A plane perpendicular to the direction of gravity; any plane tangent to the geoid or parallel to such a plane.

Delineation (cartography)--The distinguishing of mapworthy features on various possible source materials by outlining the features on the source material or by visual selection as when operating a stereoscopic plotting instrument; also an advanced step in compilation. Photo delineation--The delineation of features on a photograph. (See also compilation.)

Diapositive (photogrammetry)--A positive photographic print on a transparent medium, usually on glass. The term is generally used to refer to a transparent positive on a glass plate used in a plotting instrument, a projector, or a comparator.

Direction of tilt--The direction (azimuth) of the principal plane of a photograph. Also the direction of the principal line on a photograph.

Displacement--The movement of images on a photograph from their true relative positions. Relief displacement--Displacement radial from the nadir point of the photograph caused by differences in elevation of the corresponding ground objects. Tilt displacement--Displacement radial from the isocenter of the photograph caused by the tilt of the photograph.

Dot grid--Film positive with regularly spaced dots used in determining areas.

Elevation--Vertical distance from the datum, usually mean sea level, to a point or object on the earth's surface. Not to be confused with altitude which refers to points or objects above the earth's surface.

Emulsion (photography)--A suspension of a light-sensitive silver salt, especially silver chloride or silver bromide, in a colloidal medium, usually gelatin, used for coating photographic films, plates, or papers.

Exposure (photograph)--The total quantity of light received per unit area which may be expressed as the product of the illumination and exposure time, such as meter-candle-seconds. Also used to mean the act of exposing a section of film, and exposure time.

Exposure interval--The time permitted to elapse between successive exposures. Exposure scale (photography)--The useful exposure scale is the ratio of the maximum exposure to the minimum exposure between which the emulsion yields satisfactory reproduction.

Eye base--The distance between the centers of rotation of the eyeballs of an observer, sometimes called interpupillary distance or interocular distance.

Fiducial axes (photogrammetry)--The lines joining opposite fiducial marks on a photograph. The x-axis is generally considered to be the one nearly parallel with the line of flight.

Fiducial marks (photogrammetry)--Index marks, usually four, rigidly connected with the camera lens through the camera body and forming images on the negative which usually define the principal point of the photograph. Also those marks usually four in number in any instrument which define the axes whose intersection fix the principal point of a photograph or negative and fulfill the requirements of interior orientation.

Field inspection (photogrammetry)--The process of comparing aerial photographs with conditions as they exist on the ground and of obtaining information to supplement or clarify that not readily discernible on the photographs themselves.

Flight altitude--The vertical distance above a given datum of an aircraft in flight or during a specified portion of a flight. In aerial photography the datum is usually the mean ground level of the area being photographed. Also called flight height.

Floating mark (photogrammetry)--A mark seen as occupying a position in the three dimensional space formed by the stereoscopic fusion of a pair of photographs and used as a reference mark in examining or measuring the stereoscopic model. The mark may be formed (1) by one real mark lying in the projected object space; (2) by two real marks lying in the projected or virtually projected object spaces of the two photographs; (3) by two real marks lying in the planes of the photographs themselves; (4) by two virtual marks lying in the image planes of the binocular viewing apparatus. Index mark (photogrammetry)--A real mark such as a cross or dot lying in the plane or the object space of a photograph and used singly as a reference mark in certain types of monocular instruments or as one of a pair to form a floating mark as in certain types of stereoscopes.

Focal length, equivalent--The distance measured along the lens axis from the rear nodal point to the plane of best average definition over the entire field used in the aerial camera. (In general usage the term also applies to the distance from the rear nodal point to the plane of best axial definition, but in photogrammetry, this meaning is rarely used and will not be understood unless the term is accompanied by a qualifying phrase.) Back focal distance--The distance measured along the lens axis from the rear vertex of the lens to the plane of best average definition. This value is used in setting the lens in the aerial camera. Calibrated focal length--An adjusted value of the equivalent focal length so computed as to distribute the effect of lens distortion over the entire field used in the aerial camera. Also stated as the distance along the lens axis from the interior perspective center to the image plane; the interior center of perspective being selected so as to distribute the effect of lens distortion over the entire field. The calibrated focal length is used when determining the setting of diapositives in plotting instruments and in photogrammetric computations based on linear measurements on the negative (such as those made with a precision comparator). Principal distance--The perpendicular distance from the internal perspective center to the plane of a particular finished negative or print. This distance is equal to the calibrated focal length corrected for both the enlargement or reduction ratio and the film or paper shrinkage or expansion and maintains the same perspective angles at the internal perspective center to points on the finished negative or print, as existed in the taking camera at the moment of exposure. This is a geometrical property of each particular finished negative or print.

Focus--The point toward which rays of light converge to form an image after passing through lens. Also defined as the condition of sharpest imagery.

Form lines--Lines having the same appearance as contour lines but which have been sketched from visual observation to show the shape of the terrain rather than the elevation. (See also contour.)

Grain (photography)--One of the discrete silver particles resulting from the development of an exposed light-sensitive material. Granularity--The graininess of a developed photographic image evident particularly on enlargement, and due to agglomerations of developed grains, or to an overlapping pattern of grains.

Grid method (photogrammetry)--A method of plotting detail from oblique photographs by superimposing a perspective of a map grid on a photograph and transferring the detail by eye, the latter being guided by the corresponding lines of the map grid and its perspective.

Halation (photography)--A spreading of a photographic image beyond its proper boundaries, particularly due to reflection from the side of the film or plate support opposite to that on which the emulsion is coated. Particularly noticed in photographs of bright objects against a darker background.

Index map (photogrammetry)--A map showing the location and numbers of the flight strips and photographs. Photo index--An index map made by assembling the individual photographs into their proper relative positions and copying the assembly photographically at a reduced scale.

Infrared (photography)--Pertaining to or designating those rays of light just beyond the red end of the visible spectrum, such as are emitted by a hot body. They are invisible and are detected by their thermal and photographic effects. Their wave lengths are longer than those of visible light and shorter than those of radio waves.

Interpolation--Determination of an intermediate value between fixed values from some known or assumed rate or system of change.

Isocenter--(1) The unique point common to the plane of a photograph, its principal plane, and the plane of an assumed truly vertical photograph taken from the same camera station and having an equal principal distance. (2) The point of intersection on a photograph of the principal line and isometric parallel. (3) The point on a photograph intersected by the bisector of the angle between the plumb line and the photograph perpendicular. The isocenter is significant because it is the center of radiation for displacements of images due to tilt.

Isoline--A line representing the intersection of the plane of a vertical photograph with the plane of an overlapping oblique photograph. If the vertical photograph were tilt free, the isoline would be the isometric parallel of the oblique photograph.

Lens (optics)--A piece, or combination of pieces, of glass or other transparent material shaped to form an image by means of refraction. (See angle of coverage.)

Line of constant scale--Also called line of equal scale. Any line on a photograph which is parallel to the true horizon or to the isometric parallel.

Mosaic (photogrammetry)--An assemblage of aerial photographs the edges of which have been torn, or cut, and matched to form a continuous photographic representation of a portion of the earth's surface. Also called aerial mosaic though the adjective is unnecessary where the context clearly indicates the meaning. Controlled mosaic--A mosaic laid on ground control to improve the accuracy of representation as regards distances and directions.

Nadir--That point on the celestial sphere directly beneath the observer, and directly opposite to the zenith. Photograph nadir (photogrammetry)--That point at which a vertical line through the perspective center of the camera lens pierces the plane of the photograph. Also referred to as the nadir point. Ground nadir--The point on the ground vertically beneath the perspective center of the camera lens. Map nadir--The point on the map vertically beneath the perspective center of the camera lens.

Negative (photography)--A sensitized plate or film which has been exposed in a camera and which has the lights and shades in inverse order to those of the original subject. The plate or film does not become a negative until it is exposed, after which it may be an undeveloped or a developed negative.

Oblique photograph--A photograph taken with the camera axis directed intentionally between the horizontal and the vertical. High-oblique--An oblique photograph in which the apparent horizon is shown. Low-oblique--An oblique photograph in which the apparent horizon is not shown.

Orientation (photogrammetry) Exterior orientation--A set of quantities which fixes the position of the camera station and the angular orientation of the photograph. Such a set consists of three elements of position and two elements of angular orientation. The position is usually expressed in terms of three rectangular coordinate distances, X, Y, and Z. The elements of angular orientation are essentially the tilt of the photograph perpendicular and the azimuth of the principal plane. Interior orientation--The establishment of the principal distance and the position of the principal point of a photograph with respect to the fiducial marks of the camera. Also, the positioning of a diapositive of proper principal distance in register with the fiducial marks of the projector of a stereoscopic plotting instrument. Interior orientation is an attempt to duplicate in the projector the cone of rays which was captured by the aerial camera lens at the instant of exposure. Relative orientation--The reconstruction of the same perspective conditions between a pair of photographs which existed when the photographs were taken.

In a stereoscopic pair this is achieved when each pair of conjugate image rays lies in an epipolar plane. Absolute orientation--Following relative orientation which establishes the model, absolute orientation fixes the scale position and orientation of the model with reference to the ground coordinates.

Overlap (photography)--Amount by which one photograph overlaps the area covered by another, customarily expressed as a percentage. The overlap between aerial photographs in the same flight is distinguished as the end lap, and the overlap between photographs in adjacent parallel flights is called the side lap.

Overlapping pair (photogrammetry)--Two photographs taken at different exposure stations in such a manner that a portion of one photograph shows the same terrain as shown on a portion of the other photograph. This term covers the general case and does not imply that the photographs were taken for stereoscopic examination. (See also stereoscopy.)

Overlay (mapping)--A record on a transparent medium to be superimposed on another record; example, maps showing original land grants (or patents) prepared as tracing cloth overlays in order that they may be correlated with the maps showing present ownership, also the names overlay for a manuscript map.

Parallax--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. Absolute stereoscopic parallax (photogrammetry)--Considering a pair of truly vertical photographs of equal principal distances, taken from equal flight heights, or a pair of rectified photographs; the absolute stereoscopic parallax of a point is the algebraic difference, parallel to the air base, of the distances of the two images from their respective principal points. In photogrammetry the term parallax is generally used to denote absolute stereoscopic parallax and also to denote similar measurements when the above theoretical conditions are not strictly attained, as for example, when measuring parallax on unrectified aerial photographs. Linear parallax, x-parallax, and horizontal parallax are synonymous with absolute stereoscopic parallax but are not preferred. Parallax difference--The difference in the absolute stereoscopic parallaxes of two points imaged on a pair of photographs. Customarily used in the determination of the difference in elevations of the objects. y-parallax (photogrammetry)--The y-parallax of a point is the difference of the perpendicular distances of its two images from the vertical plane containing the air base. The existence of y-parallax is an indication of tilt in either or both photographs and/or a difference in flying height and will interfere with stereoscopic examination of the pair. Also called want of correspondence and vertical parallax though the latter is not preferred. Angular parallax--The angle subtended by the eye base of the observer at the object viewed. Also called parallactic angle or angle of convergence.

Parallax factor--A factor computed for a given flying height on a given pair of photos, listing the elevation difference in feet for a differential parallax of 0.001 inch.

Pass point--A point whose horizontal and/or vertical position is determined from photographs by photogrammetric methods and which is intended for use after the manner of a ground control point in the orientation of other photographs.

Photogrammetry--The science or art of obtaining reliable measurements by means of photography. Aerial photogrammetry--Photogrammetry utilizing aerial photographs. Terrestrial photogrammetry--Photogrammetry utilizing ground photographs. Also called ground photogrammetry though this term is not perferred. Stereophotogrammetry--Photogrammetry with the aid of stereoscopic equipment and methods.

Photograph center--The center of a photograph as indicated by the images of the fiducial mark or marks of the camera. In a perfectly adjusted camera the photograph center and the principal point are identical.

Photographic interpretation--The determination of the nature and description of objects that are imaged on a photograph.

Photo dot sampling--Recording forest classification by interpretation of the forest at each dot.

Principal point (photogrammetry)--The foot of the perpendicular from the interior perspective center to the plane of the photograph, i.e., the foot of the photograph perpendicular.

Print (photography)--A photographic copy made by projection or contact printing from a photographic negative or from a transparent drawing as in blueprinting. Contact print--A print made with the negative or transparent drawing in contact with the sensitized surface. Ratio print--A print, the scale of which has been changed from that of the negative by enlargement or reduction.

PSR--Photo scale reciprocal, i.e. 20,000 instead of 1:20,000. R/F--Representative fraction.

Radial (photogrammetry)--A line or direction from the radial center to any point on a photograph. The radial center is assumed to be the principal point unless otherwise designated as for example nadir radial--A radial from the nadir point or isoradial from the isocenter.

Radial center--The selected point on a photograph from which radials (directions) to various image points are drawn or measured, i.e., the origin of radials. The radial center is either the principal point, the nadir point, the isocenter, or a substitute center.

Radial triangulation (photogrammetry)--A method of triangulation either analytic or graphic, utilizing overlapping vertical, nearly vertical, or oblique aerial photographs for the location of points, imaged on the photographs, in their correct relative position to one another. The center of each vertical photograph (radial center) or the approximate nadir point of each oblique, serves as a station from which directions to points imaged on the photograph are traced, or measured, and used to extend the triangulation by intersection and by resection. A radial triangulation is also correctly called a radial plot or a minor control plot.

Relative tilt--In near vertical photography, the tilt of a photograph with reference to an arbitrary plane, not necessarily a horizontal plane, such as the preceding or subsequent photograph in a strip. Also defined as the tilt of the photograph with respect to a polar axis parallel to the photograph perpendicular to another photograph such as the preceding or subsequent photograph in a strip.

Resection--The graphical or analytical determination of a position as the intersection of at least three lines of known direction to corresponding points of known position. Space resection--The analytical determination of the three rectangular coordinates of an exposure station with reference to the ground survey coordinate system.

Scale (photogrammetry)--The ratio of a distance on a photograph to a corresponding distance on the ground. The scale of a photograph varies from point to point because of displacements caused by tilt and relief, but is usually taken as f/H where f is the principal distance of the camera and H is the altitude of the camera station above mean ground elevation.

Stereometer--A measuring device comprising a micrometer movement by which the separation of two index marks can be changed in order to measure parallax difference on a stereoscopic pair of photographs. Also called parallax bar.

Stereoscopy--The science and art which deals with stereoscopic effects and the methods by which they are produced. Stereoscope--An optical instrument for assisting the observer to view two properly prepared photographs, or diagrams to obtain the mental impression of a three dimensional model. Binocular vision--Simultaneous vision with both eyes. Stereoscopic vision--That particular application of binocular vision which enables the observer to view an object or two different perspectives of an object (as two photographs taken from different camera stations) so as to obtain therefrom the mental impression of a three dimensional model. Stereoscopic fusion--That mental process which combines the two perspective images on the retinas of eyes in such a manner as to give a mental impression of a three dimensional model. Stereoscopic image--That mental impression of a three dimensional model which results from stereoscopic fusion. Also called stereoscopic model. When the photos of a stereoscopic pair are reversed from their normal position a pseudoscopic image is formed in which the ground relief appears to be inverted. Stereoscopic pair (photogrammetry)--Two photographs of the same area taken from different camera stations in such a manner as to afford stereoscopic vision. Stereogram--A stereoscopic pair of photographs or drawings correctly oriented and mounted for stereoscopic viewing.

Survey--The act or operation of making measurements for determining the relative positions of points on or beneath the earth's surface; also the results of such operations; also an organization for making surveys. Photogrammetric survey--Utilizing either ground photographs or aerial photographs. Aerial surveys--A survey utilizing aerial photographs as part of the surveying operations; also the taking of aerial photographs for surveying purposes; also the photographs taken of an area for surveying purposes. <u>Ground survey</u>--A ground survey made by ground methods, as distinguished from an <u>aerial survey</u>. A ground survey may, or may not, include the use of ground photographs but does not include the use of aerial photographs.

<u>Templet</u> (photogrammetry)--A templet used in radial triangulation to represent the aerial photograph; the templet is a record of the directions or radials taken from the photograph. <u>Hand templet</u>--A templet made by tracing the radials from the photograph onto a transparent medium, as on celluloid; hand templets are laid out and adjusted by hand to form the radial triangulation. <u>Celluloid templet</u>--A hand templet made on celluloid. <u>Slotted templet</u>--A templet on which the radials are represented as a slot cut in a sheet of cardboard, metal, or other material. <u>Spider templet</u>--A <u>mechanical templet</u> which is fabricated by attaching slotted steel arms representing radials to a center hub. The spider templet is characterized by the fact that it can be disassembled and the parts used again. <u>Stereotemplet</u>--A composite slotted templet adjustable in scale and representative of the horizontal plot of a stereoscopic model. An assembly of stereotemplets provides a means of bridging for horizontal position with a stereoscopic plotting instrument of nonbridging design.

<u>Topography</u>--The features of the actual surface of the earth considered collectively as to form. A single feature as a mountain or valley is called a <u>topographic feature</u>. Topography is subdivided into <u>hypsography</u> (the relief features), <u>hydrography</u> (the water and drainage features), and <u>culture</u> (man-made features).

<u>Vertical photograph</u> (aerial photography)--An aerial photograph made with the camera axis vertical or as nearly vertical as practicable in an aircraft.

All definitions in the GLOSSARY OF TERMS are from the Manual of Photogrammetry by permission of the American Society of Photogrammetry, 1515 Massachusetts Avenue, N. W., Washington, D. C., except for the following: <u>Alignment guide</u>, <u>Average crown diameter</u>, <u>Average stand height</u>, <u>Crown coverage</u>, <u>Dot grid</u>, <u>Parallax factor</u>, and <u>PSR</u>.

Parallax factors by parallax (P) and photo scale reciprocal (PSR) for 8.25-inch focal length cameras

Parallax (P) or (P+dp) (inches)	PSR in 1,000's																					Parallax (P) or (P)+dp) (inches)
	5.0	6.0	7.0	8.0	9.0	10.0	11.0	12.0	13.0	14.0	15.0	16.0	17.0	18.0	19.0	20.0	21.0	22.0	23.0	24.0	25.0	
	Change in feet per 0.001-inch parallax difference																					
2.0	1.7	2.0	2.3	2.6	3.0	3.4	3.7	4.1	4.3	4.7	5.1	5.4	5.8	6.0	6.4	6.8	7.2	7.5	7.8	8.2	8.8	2.0
2.1	1.6	1.9	2.2	2.5	2.9	3.2	3.5	3.9	4.1	4.5	4.9	5.2	5.5	5.8	6.1	6.5	6.8	7.2	7.6	7.8	8.4	2.1
2.2	1.5	1.8	2.1	2.4	2.7	3.0	3.4	3.7	4.0	4.3	4.6	4.9	5.3	5.6	5.9	6.2	6.5	6.8	7.2	7.5	8.0	2.2
2.3	1.5	1.7	2.0	2.3	2.6	2.9	3.2	3.5	3.8	4.2	4.4	4.7	5.0	5.3	5.6	6.0	6.2	6.5	6.8	7.2	7.6	2.3
2.4	1.4	1.7	2.0	2.2	2.5	2.8	3.1	3.3	3.6	4.0	4.3	4.5	4.8	5.1	5.4	5.7	5.9	6.3	6.5	6.8	7.3	2.4
2.5	1.3	1.6	1.9	2.1	2.4	2.7	3.0	3.2	3.5	3.8	4.1	4.3	4.6	4.9	5.2	5.5	5.6	5.9	6.2	6.6	6.9	2.5
2.6	1.3	1.6	1.8	2.1	2.3	2.6	2.9	3.1	3.4	3.6	3.9	4.2	4.4	4.7	5.0	5.3	5.5	5.8	6.0	6.3	6.6	2.6
2.7	1.2	1.5	1.7	2.0	2.2	2.5	2.8	3.0	3.3	3.5	3.8	4.1	4.3	4.5	4.8	5.1	5.3	5.6	5.8	6.1	6.4	2.7
2.8	1.2	1.5	1.7	2.0	2.1	2.4	2.7	2.9	3.2	3.4	3.7	3.9	4.1	4.4	4.6	4.9	5.1	5.4	5.6	5.9	6.1	2.8
2.9	1.1	1.4	1.6	1.9	2.1	2.3	2.6	2.8	3.1	3.3	3.5	3.7	4.0	4.2	4.4	4.8	4.9	5.2	5.4	5.7	5.9	2.9
3.0	1.1	1.4	1.6	1.8	2.0	2.2	2.5	2.7	3.0	3.2	3.4	3.6	3.9	4.1	4.3	4.6	4.8	5.0	5.3	5.5	5.8	3.0
3.1	1.1	1.3	1.5	1.7	2.0	2.2	2.4	2.6	2.9	3.1	3.3	3.5	3.7	3.9	4.1	4.4	4.6	4.9	5.1	5.3	5.6	3.1
3.2	1.0	1.3	1.5	1.6	1.9	2.1	2.3	2.5	2.8	3.0	3.2	3.4	3.6	3.8	4.0	4.3	4.5	4.7	4.9	5.2	5.4	3.2
3.3	1.0	1.2	1.4	1.6	1.9	2.1	2.3	2.5	2.7	2.9	3.1	3.3	3.5	3.7	3.9	4.1	4.4	4.6	4.8	5.0	5.2	3.3
3.4	1.0	1.2	1.4	1.5	1.8	2.0	2.2	2.4	2.6	2.8	3.0	3.2	3.4	3.6	3.8	4.0	4.2	4.4	4.6	4.9	5.1	3.4
3.5	.9	1.2	1.4	1.5	1.7	1.9	2.1	2.3	2.5	2.7	2.9	3.1	3.3	3.5	3.7	3.9	4.1	4.3	4.5	4.7	4.9	3.5
3.6	.9	1.1	1.3	1.5	1.7	1.9	2.1	2.3	2.4	2.7	2.8	3.0	3.2	3.4	3.6	3.8	4.0	4.2	4.4	4.6	4.8	3.6
3.7	.9	1.1	1.3	1.4	1.6	1.8	2.0	2.2	2.4	2.6	2.8	2.9	3.1	3.3	3.5	3.7	3.9	4.1	4.3	4.5	4.7	3.7
3.8	.9	1.1	1.3	1.4	1.6	1.8	2.0	2.2	2.3	2.5	2.7	2.9	3.0	3.2	3.4	3.6	3.8	4.0	4.2	4.4	4.6	3.8
3.9	.9	1.1	1.2	1.4	1.5	1.7	1.9	2.1	2.3	2.4	2.6	2.8	3.0	3.2	3.3	3.5	3.7	3.9	4.1	4.3	4.5	3.9
4.0	.8	1.0	1.2	1.4	1.5	1.7	1.9	2.1	2.2	2.4	2.6	2.7	2.9	3.1	3.2	3.5	3.6	3.8	4.0	4.2	4.4	4.0
4.1	.8	1.0	1.2	1.3	1.5	1.6	1.8	2.0	2.2	2.3	2.5	2.7	2.8	3.0	3.2	3.4	3.5	3.7	3.9	4.1	4.3	4.1
4.2	.8	1.0	1.1	1.3	1.4	1.6	1.8	2.0	2.1	2.3	2.4	2.6	2.8	2.9	3.1	3.3	3.4	3.6	3.8	4.0	4.2	4.2

Forest Survey, Intermountain Forest & Range Experiment Station, Ogden, Utah. 1954.

Parallax factors by parallax (P) and flying height (H-h)

Parallax: (P) or (P+dp) (inches)	2.0	2.5	3.0	3.5	4.0	4.5	5.0	5.5	6.0	6.5	7.0	7.5	8.0	8.5	9.0	9.5	10.0	10.5	Parallax (P) or (P+dp) (inches)
	Flying height (H-h) in thousands of feet																		
	Parallax factor (ho) in feet per 0.001 inch (dp)																		
1.5	1.3	1.7	2.0	2.3	2.7	3.0	3.3	3.7	4.0	4.3	4.7	5.0	5.3	5.6	6.0	6.4	6.7	7.0	1.5
1.6	1.3	1.6	1.9	2.2	2.5	2.8	3.1	3.4	3.7	4.0	4.3	4.7	5.0	5.3	5.6	6.0	6.3	6.6	1.6
1.7	1.2	1.5	1.8	2.1	2.3	2.6	2.9	3.2	3.5	3.8	4.1	4.4	4.7	5.0	5.3	5.6	5.9	6.2	1.7
1.8	1.1	1.4	1.7	2.0	2.2	2.5	2.8	3.0	3.3	3.6	3.9	4.2	4.4	4.7	5.0	5.3	5.5	5.8	1.8
1.9	1.1	1.3	1.6	1.9	2.1	2.4	2.6	2.9	3.1	3.4	3.7	4.0	4.2	4.5	4.7	5.0	5.2	5.5	1.9
2.0	1.0	1.2	1.5	1.8	2.0	2.3	2.5	2.7	3.0	3.2	3.5	3.8	4.0	4.2	4.5	4.7	5.0	5.2	2.0
2.1	1.0	1.2	1.4	1.7	1.9	2.1	2.4	2.6	2.8	3.1	3.3	3.6	3.8	4.0	4.3	4.5	4.8	5.0	2.1
2.2	0.9	1.1	1.4	1.6	1.8	2.0	2.3	2.5	2.7	2.9	3.2	3.4	3.6	3.9	4.1	4.3	4.5	4.8	2.2
2.3	0.9	1.1	1.3	1.5	1.7	2.0	2.2	2.4	2.6	2.8	3.0	3.2	3.5	3.7	3.9	4.1	4.3	4.6	2.3
2.4	0.8	1.0	1.3	1.4	1.7	1.9	2.1	2.3	2.5	2.7	2.9	3.1	3.3	3.5	3.7	3.9	4.1	4.4	2.4
2.5	0.8	1.0	1.2	1.4	1.6	1.8	2.0	2.2	2.4	2.6	2.8	3.0	3.2	3.4	3.6	3.8	4.0	4.2	2.5
2.6	0.8	1.0	1.2	1.3	1.5	1.7	1.9	2.1	2.3	2.5	2.7	2.9	3.1	3.3	3.5	3.7	3.8	4.0	2.6
2.7	0.7	0.9	1.1	1.3	1.5	1.7	1.8	2.0	2.2	2.4	2.6	2.8	3.0	3.2	3.3	3.5	3.7	3.9	2.7
2.8	0.7	0.9	1.1	1.3	1.4	1.6	1.8	2.0	2.1	2.3	2.5	2.7	2.9	3.0	3.2	3.4	3.6	3.7	2.8
2.9	0.7	0.9	1.0	1.2	1.4	1.6	1.7	1.9	2.1	2.2	2.4	2.6	2.8	2.9	3.1	3.3	3.4	3.6	2.9
3.0	0.7	0.8	1.0	1.2	1.3	1.5	1.7	1.8	2.0	2.2	2.3	2.5	2.7	2.8	3.0	3.2	3.3	3.5	3.0
3.1	0.6	0.8	1.0	1.1	1.3	1.5	1.6	1.8	1.9	2.1	2.2	2.4	2.6	2.7	2.9	3.1	3.2	3.4	3.1
3.2	0.6	0.8	0.9	1.1	1.2	1.4	1.6	1.7	1.8	2.0	2.2	2.3	2.5	2.7	2.8	3.0	3.1	3.3	3.2
3.3	0.6	0.8	0.9	1.1	1.2	1.4	1.5	1.7	1.8	2.0	2.1	2.3	2.4	2.6	2.7	2.9	3.0	3.2	3.3
3.4	0.6	0.7	0.9	1.0	1.2	1.3	1.5	1.6	1.7	1.9	2.1	2.2	2.3	2.5	2.6	2.8	2.9	3.1	3.4
3.5	0.6	0.7	0.9	1.0	1.1	1.3	1.4	1.6	1.7	1.9	2.0	2.1	2.3	2.4	2.6	2.7	2.8	3.0	3.5
3.6	0.6	0.7	0.8	1.0	1.1	1.3	1.4	1.5	1.6	1.8	2.0	2.1	2.2	2.4	2.5	2.6	2.8	2.9	3.6
3.7	0.5	0.7	0.8	0.9	1.1	1.2	1.4	1.5	1.6	1.8	1.9	2.0	2.2	2.3	2.4	2.6	2.7	2.8	3.7
3.8	0.5	0.7	0.8	0.9	1.1	1.2	1.3	1.4	1.5	1.7	1.8	2.0	2.1	2.2	2.4	2.5	2.6	2.8	3.8
3.9	0.5	0.6	0.8	0.9	1.0	1.2	1.3	1.4	1.5	1.7	1.8	1.9	2.1	2.2	2.3	2.4	2.6	2.7	3.9
4.0	0.5	0.6	0.8	0.9	1.0	1.1	1.3	1.4	1.5	1.6	1.7	1.9	2.0	2.1	2.3	2.4	2.5	2.6	4.0
4.1	0.5	0.6	0.7	0.9	1.0	1.1	1.2	1.3	1.4	1.6	1.7	1.8	2.0	2.1	2.2	2.3	2.4	2.5	4.1
4.2	0.5	0.6	0.7	0.8	1.0	1.1	1.2	1.3	1.4	1.5	1.7	1.8	1.9	2.0	2.1	2.3	2.4	2.5	4.2
4.3	0.5	0.6	0.7	0.8	0.9	1.0	1.1	1.3	1.3	1.5	1.6	1.7	1.9	2.0	2.0	2.2	2.3	2.4	4.3
4.4	0.5	0.6	0.7	0.8	0.9	1.0	1.1	1.2	1.3	1.5	1.6	1.7	1.8	1.9	2.0	2.2	2.3	2.4	4.4

Flying height (H-h) in thousands of feet

Inches	11.0	11.5	12.0	12.5	13.0	13.5	14.0	14.5	15.0	15.5	16.0	16.5	17.0	17.5	18.0	18.5	19.0	19.5	Inches
	Parallax factor (ho) in feet per 0.001 inch (dp)																		
1.5	7.3	7.7	8.0	8.3	8.7	9.0	9.3	9.7	10.0	10.3	10.7	11.0	11.3	11.6	12.0	12.4	12.7	13.0	1.5
1.6	6.9	7.2	7.5	7.8	8.1	8.5	8.7	9.0	9.4	9.7	10.0	10.3	10.6	11.0	11.2	11.6	11.8	12.2	1.6
1.7	6.5	6.8	7.1	7.3	7.6	7.9	8.2	8.5	8.8	9.1	9.4	9.7	10.0	10.3	10.6	10.8	11.2	11.4	1.7
1.8	6.1	6.4	6.7	6.9	7.2	7.5	7.8	8.1	8.3	8.6	8.9	9.2	9.5	9.7	10.0	10.3	10.6	10.8	1.8
1.9	5.8	6.1	6.3	6.6	6.8	7.1	7.4	7.7	7.9	8.2	8.4	8.7	9.0	9.2	9.5	9.7	10.0	10.2	1.9
2.0	5.5	5.8	6.0	6.3	6.5	6.7	7.0	7.3	7.5	7.8	8.0	8.3	8.5	8.8	9.0	9.3	9.5	9.8	2.0
2.1	5.2	5.5	5.7	5.9	6.2	6.4	6.7	6.9	7.1	7.4	7.6	7.9	8.1	8.3	8.6	8.8	9.0	9.3	2.1
2.2	5.0	5.2	5.5	5.7	5.9	6.1	6.4	6.6	6.8	7.0	7.3	7.5	7.7	7.9	8.2	8.4	8.6	8.9	2.2
2.3	4.8	5.0	5.2	5.4	5.7	5.9	6.1	6.3	6.5	6.7	7.0	7.2	7.4	7.6	7.8	8.0	8.3	8.5	2.3
2.4	4.6	4.8	5.0	5.2	5.4	5.6	5.8	6.0	6.2	6.4	6.7	6.9	7.1	7.3	7.5	7.7	7.9	8.1	2.4
2.5	4.4	4.6	4.8	5.0	5.2	5.4	5.6	5.8	6.0	6.2	6.4	6.6	6.8	7.0	7.2	7.4	7.6	7.8	2.5
2.6	4.2	4.4	4.6	4.8	5.0	5.2	5.4	5.6	5.8	6.0	6.2	6.3	6.5	6.7	6.9	7.1	7.3	7.5	2.6
2.7	4.1	4.3	4.4	4.6	4.8	5.0	5.2	5.4	5.6	5.7	5.9	6.1	6.3	6.5	6.7	6.9	7.0	7.3	2.7
2.8	3.9	4.1	4.3	4.5	4.6	4.8	5.0	5.2	5.4	5.5	5.7	5.9	6.1	6.3	6.4	6.6	6.8	7.0	2.8
2.9	3.8	4.0	4.1	4.3	4.5	4.6	4.8	5.0	5.2	5.3	5.5	5.7	5.9	6.0	6.2	6.4	6.6	6.7	2.9
3.0	3.7	3.8	4.0	4.2	4.3	4.5	4.7	4.9	5.0	5.2	5.3	5.5	5.7	5.8	6.0	6.2	6.3	6.5	3.0
3.1	3.5	3.7	3.9	4.0	4.2	4.3	4.5	4.7	4.8	5.0	5.2	5.3	5.5	5.6	5.8	6.0	6.1	6.3	3.1
3.2	3.4	3.6	3.7	3.9	4.1	4.2	4.4	4.5	4.7	4.8	5.0	5.1	5.3	5.4	5.6	5.8	5.9	6.1	3.2
3.3	3.3	3.5	3.6	3.8	3.9	4.1	4.3	4.4	4.5	4.7	4.8	5.0	5.2	5.3	5.5	5.6	5.7	5.9	3.3
3.4	3.2	3.4	3.5	3.7	3.8	4.0	4.1	4.3	4.4	4.6	4.7	4.8	5.0	5.1	5.3	5.4	5.6	5.7	3.4
3.5	3.1	3.3	3.4	3.6	3.7	3.9	4.0	4.1	4.3	4.4	4.6	4.7	4.9	5.0	5.1	5.3	5.4	5.6	3.5
3.6	3.0	3.2	3.3	3.5	3.6	3.8	3.9	4.0	4.2	4.3	4.4	4.6	4.7	4.9	5.0	5.1	5.3	5.4	3.6
3.7	3.0	3.1	3.2	3.4	3.5	3.7	3.8	3.9	4.0	4.2	4.3	4.5	4.6	4.7	4.9	5.0	5.1	5.3	3.7
3.8	2.9	3.0	3.2	3.3	3.4	3.6	3.7	3.8	3.9	4.1	4.2	4.3	4.5	4.6	4.7	4.9	5.0	5.1	3.8
3.9	2.8	2.9	3.1	3.2	3.3	3.5	3.6	3.7	3.8	4.0	4.1	4.2	4.4	4.5	4.6	4.7	4.9	5.0	3.9
4.0	2.7	2.9	3.0	3.1	3.2	3.4	3.5	3.6	3.7	3.9	4.0	4.1	4.2	4.4	4.5	4.6	4.7	4.9	4.0
4.1	2.7	2.8	2.9	3.0	3.2	3.3	3.4	3.5	3.7	3.8	3.9	4.0	4.1	4.3	4.4	4.5	4.6	4.8	4.1
4.2	2.6	2.7	2.9	3.0	3.1	3.2	3.3	3.5	3.6	3.7	3.8	3.9	4.0	4.2	4.3	4.4	4.5	4.6	4.2
4.3	2.6	2.7	2.8	2.9	3.0	3.1	3.3	3.4	3.5	3.6	3.7	3.8	3.9	4.1	4.2	4.3	4.4	4.5	4.3
4.4	2.5	2.6	2.7	2.8	3.0	3.1	3.2	3.3	3.4	3.5	3.6	3.7	3.9	4.0	4.1	4.2	4.3	4.4	4.4

Photo scale reciprocals (PSR) by flying heights (H-h) in thousands of feet for 8.25-inch focal length camera

H-h	PSR	H-h	PSR	H-h	PSR	H-h	PSR	H-h	PSR
1.0	1,450	2.0	2,910	3.0	4,360	4.0	5,820	5.0	7,270
1.2	1,750	2.2	3,200	3.2	4,650	4.2	6,110	5.2	7,560
1.4	2,040	2.4	3,490	3.4	4,950	4.4	6,400	5.4	7,850
1.6	2,330	2.6	3,780	3.6	5,240	4.6	6,690	5.6	8,150
1.8	2,620	2.8	4,070	3.8	5,530	4.8	6,980	5.8	8,440
6.0	8,730	7.0	10,180	8.0	11,640	9.0	13,090	10.0	14,550
6.2	9,020	7.2	10,470	8.2	11,930	9.2	13,380	10.2	14,840
6.4	9,310	7.4	10,760	8.4	12,220	9.4	13,670	10.4	15,130
6.6	9,600	7.6	11,050	8.6	12,510	9.6	13,960	10.6	15,420
6.8	9,890	7.8	11,350	8.8	12,800	9.8	14,250	10.8	15,710
11.0	16,000	12.0	17,450	13.0	18,910	14.0	20,360	15.0	21,820
11.2	16,290	12.2	17,740	13.2	19,200	14.2	20,650	15.2	22,110
11.4	16,580	12.4	18,040	13.4	19,490	14.4	20,950	15.4	22,400
11.6	16,870	12.6	18,330	13.6	19,780	14.6	21,240	15.6	22,690
11.8	17,160	12.8	18,620	13.8	20,070	14.8	21,530	15.8	22,980
16.0	23,270	17.0	24,730	18.0	26,180	19.0	27,640	20.0	29,090
16.2	23,560	17.2	25,020	18.2	26,470	19.2	27,930	20.2	29,380
16.4	23,850	17.4	25,310	18.4	26,760	19.4	28,220	20.4	29,670
16.6	24,150	17.6	25,600	18.6	27,050	19.6	28,510	20.6	29,960
16.8	24,440	17.8	25,890	18.8	27,350	19.8	28,800	20.8	30,250

Crown diameter conversion table

Photo measurement (0.001-inch)	PSR in 1,000's																		
	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
	Feet on ground																		
2.5	1	1	1	1	2	2	2	2	3	3	3	3	4	4	4	4	4	5	5
5.0	2	2	3	3	4	4	5	5	5	6	6	7	7	7	8	8	9	9	10
7.5	3	4	4	5	6	6	7	7	8	9	9	10	11	11	12	13	13	14	14
10.0	4	5	6	7	8	8	9	10	11	12	13	13	14	15	16	17	18	18	19
12.5	5	6	7	8	9	10	11	12	14	15	16	17	18	19	20	21	22	23	24
15.0	6	7	9	10	11	12	14	15	16	17	19	20	21	22	24	25	26	27	29
17.5	7	9	10	12	13	15	16	17	19	21	22	23	25	26	28	29	31	32	34
20.0	8	10	12	13	15	17	18	20	22	23	25	27	28	30	32	33	35	37	38
22.5	8	11	13	15	17	19	20	22	24	26	28	30	32	34	36	38	39	42	--
25.0	10	12	15	17	19	21	23	25	27	29	31	33	35	38	40	42	44	--	--
27.5	11	14	16	18	21	23	25	27	30	32	34	37	39	41	44	--	--	--	--
30.0	12	15	17	20	23	25	27	30	33	35	37	40	43	45	--	--	--	--	--
32.5	14	16	19	22	24	27	30	32	35	38	41	43	--	--	--	--	--	--	--
35.0	15	17	20	23	26	29	32	35	38	41	44	--	--	--	--	--	--	--	--
37.5	16	19	22	25	28	31	34	37	41	44	--	--	--	--	--	--	--	--	--
40.0	17	20	24	27	30	33	37	40	43	--	--	--	--	--	--	--	--	--	--

Forest Survey, Intermountain Forest & Range Experiment Station, Ogden, Utah. 1954.

PRELIMINARY AERIAL VOLUME TABLE - CONIFER SPECIES

Gross Cubic Foot Volume Per Acre by Average Stand Height, Average Crown Diameter, and Crown Cover

4- TO 7-FOOT CROWN DIAMETER

Average stand height (Feet)	Crown cover (Percent) 5	15	25	35	45	55	65	75	85	95
	- - -	- - -	- - -	- - -	- - Ten	cubic	feet - -	- - -	- - -	- - -
30		10	30	45	55	65	75	85	100	115
35		20	40	55	65	75	85	100	120	140
40		30	50	65	75	85	100	115	140	165
45	5	40	60	75	85	95	110	130	155	180
50	10	50	70	85	100	115	135	160	185	210
55	20	60	85	105	120	140	160	185	210	235
60	35	80	110	135	160	180	200	225	250	275
65	50	105	140	170	195	215	235	255	280	305

8- TO 12-FOOT CROWN DIAMETER

Average stand height (Feet)	5	15	25	35	45	55	65	75	85	95
30		15	35	50	60	70	80	95	120	135
35		25	45	60	75	85	95	110	130	150
40		35	55	70	85	95	105	125	150	175
45		40	65	80	95	110	125	145	170	195
50	10	50	70	95	110	125	145	170	195	215
55	30	70	90	110	130	150	175	200	225	250
60	45	90	120	150	175	195	215	235	255	265
65	70	120	160	190	210	230	250	270	290	310
70	90	160	200	230	250	270	285	300	320	330
75	120	200	240	270	285	300	320	340	360	380
80	170	250	280	310	330	345	360	380	400	420
85	220	300	330	355	375	395	415	435	455	475

13- TO 17-FOOT CROWN DIAMETER

Average stand height (Feet)	5	15	25	35	45	55	65	75	85	95
30		20	40	55	70	80	90	105	120	135
35		30	50	70	80	90	105	120	150	170
40		40	60	80	90	100	125	145	170	195
45	10	50	70	85	100	115	135	160	185	210
50	20	60	85	100	115	135	160	185	210	235
55	30	75	100	125	150	170	190	215	235	255
60	50	100	130	160	185	205	225	245	265	285
65	75	130	170	200	220	240	260	280	300	320
70	100	170	210	240	260	275	290	310	330	350
75	130	210	250	275	295	315	330	350	370	390
80	180	260	290	320	340	360	375	390	410	430
85	230	310	345	370	390	405	420	440	460	480
90	280	360	390	415	435	450	465	485	505	525
95	330	410	440	460	480	500	520	540	560	580
100	370	450	485	515	535	555	575	595	615	635

Forest Survey, Intermountain Forest and Range Experiment Station, Ogden, Utah, April 1956

18- TO 22-FOOT CROWN DIAMETER

Average stand height (Feet)	Crown cover (Percent) 5	15	25	35	45	55	65	75	85	95
	- - -	- - -	- - -	- - -	- - Ten	cubic	feet - -	- - -	- - -	- - -
30		30	50	70	80	90	105	120	140	160
35		40	65	80	90	105	120	140	160	180
40	10	50	75	90	105	120	140	160	180	200
45	20	60	85	105	120	140	160	180	200	220
50	35	75	100	120	140	160	180	205	225	245
55	45	85	115	140	165	190	210	230	250	270
60	65	115	150	180	205	225	245	265	285	305
65	85	150	190	220	240	260	275	290	310	330
70	110	190	230	255	275	290	310	330	350	370
75	160	240	270	295	310	325	345	365	385	405
80	195	275	305	330	350	370	390	410	430	450
85	250	330	360	385	405	425	440	455	475	495
90	290	370	405	430	450	470	485	505	530	550
95	340	420	450	480	500	520	540	560	580	600
100	390	470	500	530	550	570	590	610	630	650
105	460	540	580	600	620	640	655	670	685	705
110	520	600	640	660	680	700	720	740	760	780

23+ FOOT CROWN DIAMETER

Average stand height (Feet)	5	15	25	35	45	55	65	75	85	95
30	10	50	75	90	105	125	145	165	190	215
35	20	65	85	105	125	145	165	185	210	235
40	30	75	100	120	140	160	180	205	230	255
45	40	85	110	135	160	180	200	225	250	275
50	55	100	130	160	185	205	225	245	265	285
55	70	120	160	190	210	230	250	270	290	310
60	85	155	195	225	245	265	285	305	325	345
65	120	190	230	255	275	290	310	330	350	370
70	155	225	265	290	310	330	345	365	385	405
75	205	275	305	330	350	365	380	400	420	440
80	245	315	345	370	390	405	420	440	460	480
85	290	360	395	420	440	455	470	490	510	530
90	340	410	440	465	485	505	525	545	565	585
95	385	455	485	515	535	555	575	595	615	635
100	440	510	540	570	590	610	625	640	660	680
105	510	580	610	640	655	670	685	700	715	730
110	660	640	670	690	705	720	735	750	770	785
115	615	690	720	740	760	775	790	805	820	835

Note: Stand height, crown diameter, and crown cover from photo measurements of field plots. Volume from field measurements computed by Forest Survey total height-DBH cubic volume tables.

Based on 168 field plots taken in southeastern Idaho, southwestern Wyoming, and northeastern Utah.

Aggregate deviation: Table 1.5% low
Standard error of estimate: $\leq$ 48% of average plot volume

PRELIMINARY AERIAL VOLUME TABLE - CONIFER SPECIES

Gross Board Foot Volume Per Acre by Average Stand Height, Average Crown Diameter, and Crown Cover

4- TO 7-FOOT CROWN DIAMETER

Average stand height (Feet)	Crown cover (Percent) 5	15	25	35	45	55	65	75	85	95
	- - - - - - - - - - Hundred board feet - - - - - - - - - -									
40						3	5	7	9	11
45				3	6	8	10	12	14	17
50		2	6	9	12	15	18	21	25	29
55	2	7	11	15	19	23	26	30	35	40
60	6	12	18	23	28	33	38	44	50	57
65	14	21	28	35	42	48	53	60	68	77

8- TO 12-FOOT CROWN DIAMETER

Average stand height (Feet)	5	15	25	35	45	55	65	75	85	95
40		1	5	8	11	14	16	18	20	24
45	3	7	10	13	16	20	24	28	32	37
50	7	12	17	22	27	32	37	42	47	53
55	14	22	29	35	40	45	50	56	63	71
60	20	30	38	46	54	61	68	75	83	91
65	33	43	54	63	72	80	88	95	103	108
70	43	56	67	76	85	93	101	108	116	124
75	71	85	96	106	115	123	130	137	142	150
80	96	110	121	131	140	149	157	164	171	179
85	130	145	157	167	176	185	193	200	207	215
90	165	180	194	205	215	224	232	239	246	254

13- TO 17-FOOT CROWN DIAMETER

Average stand height (Feet)	5	15	25	35	45	55	65	75	85	95
40		5	8	11	14	17	20	24	28	33
45	6	10	14	18	22	27	32	37	42	47
50	11	17	23	29	35	41	47	53	60	67
55	18	27	35	43	50	57	64	71	78	85
60	28	38	48	57	65	73	80	87	94	101
65	43	55	65	75	84	93	100	107	114	121
70	59	73	86	96	105	112	119	126	133	140
75	83	97	110	119	127	135	143	150	157	165
80	107	122	135	145	153	160	167	174	181	189
85	142	157	170	180	189	198	205	212	220	230
90	180	195	208	218	228	237	244	252	260	270
95	220	235	247	257	267	276	284	292	300	310
100	250	275	287	297	307	317	325	333	341	351

18 ≠ FOOT CROWN DIAMETER

Average stand height (Feet)	5	15	25	35	45	55	65	75	85	95
50	14	23	30	36	42	48	54	61	68	75
55	24	35	44	52	60	68	76	83	90	97
60	35	47	58	67	76	84	91	98	105	112
65	50	63	76	86	95	103	110	117	124	131
70	70	83	96	106	115	122	129	136	143	150
75	93	106	119	129	138	145	152	159	166	174
80	129	132	145	155	164	171	178	185	192	200
85	155	168	180	190	200	209	218	225	232	240
90	190	205	218	228	238	247	255	263	270	279
95	230	245	259	270	280	289	297	305	313	322
100	270	285	300	311	322	332	341	350	360	370
105	303	320	335	348	360	371	382	392	402	412
110	350	368	384	398	411	424	437	450	463	475

Note: Stand height, crown diameter, and crown cover from photo measurements of field plots. Volume from field measurements computed by Forest Survey total height-DBH board foot volume tables based on International 1/4-inch rule.

Based on 168 field plots taken in southeastern Idaho, southwestern Wyoming, and northeastern Utah.

Aggregate deviation: Table 1.1% high
Standard error of estimate: ≠ 62% of average plot volume

Forest Survey, Intermountain Forest and Range Experiment Station, Ogden, Utah, April 1956

PRELIMINARY AERIAL VOLUME TABLE - LODGEPOLE PINE

Gross Board Foot Volume Per Acre by Average Stand Height, Average Crown Diameter, and Crown Cover

4- TO 7-FOOT CROWN DIAMETER

Average stand height (Feet)	Crown cover (Percent) 5	15	25	35	45	55	65	75	85	95
	- - - - - - - - - - Hundred board feet - - - - - - - - - -									
55							1	2	4	6
60			1	5	7	9	11	13	15	18
65	4	8	12	16	18	20	22	25	28	31
70	14	18	22	26	29	32	35	38	41	45
75	25	30	35	40	44	47	50	53	56	60

8- TO 12-FOOT CROWN DIAMETER

Average stand height (Feet)	5	15	25	35	45	55	65	75	85	95
45						1	3	5	8	10
50		1	5	8	11	13	15	17	19	22
55	8	12	16	19	22	24	27	30	35	40
60	18	24	29	34	37	40	42	45	50	55
65	35	40	45	50	53	55	57	60	63	66
70	47	52	57	62	65	67	69	71	75	80
75	58	63	68	72	75	78	81	85	89	95
80	70	75	80	85	90	94	97	100	105	112

13- TO 17-FOOT CROWN DIAMETER

Average stand height (Feet)	5	15	25	35	45	55	65	75	85	95
45	2	4	6	9	11	13	15	17	21	25
50	7	12	16	19	22	25	28	31	35	40
55	20	25	30	34	37	40	43	46	50	55
60	35	40	45	50	53	56	58	61	65	70
65	50	55	60	64	67	69	71	74	78	84
70	60	65	70	75	80	83	86	90	95	101
75	75	80	85	90	95	98	102	106	112	118
80	90	97	103	108	113	117	120	123	127	133
85	105	114	120	125	129	133	136	140	144	150

18 ≠ FOOT CROWN DIAMETER

Average stand height (Feet)	5	15	25	35	45	55	65	75	85	95
45	10	14	17	20	23	26	29	32	35	39
50	21	26	31	36	39	42	45	48	51	55
55	36	41	46	51	54	57	60	63	66	70
60	49	54	59	64	67	70	73	76	80	85
65	62	67	72	77	81	85	89	93	98	103
70	77	82	87	92	97	101	105	109	114	120
75	95	102	108	113	118	122	126	130	135	142
80	111	118	124	129	134	138	142	146	151	157
85	128	135	141	147	152	156	160	164	169	175
90	144	151	158	164	169	173	177	181	186	193

Note: Stand height, crown diameter, and crown cover from photo measurements of field plots. Volume from field measurements computed by Forest Survey total height-DBH tables based on International 1/4-inch rule.

Based on 60 field plots taken in southeastern Idaho, southwestern Wyoming, and northeastern Utah.

Aggregate deviation: Table 5.8% low
Standard error of estimate: ≠ 75% of average plot volume

Forest Survey, Intermountain Forest and Range Experiment Station, Ogden, Utah, April 1956

AERIAL VOLUME TABLE--PONDEROSA PINE

Gross cubic-foot volume per acre by average stand height, crown diameter, and crown cover

1- TO 10- (5) FOOT CROWN DIAMETER

Average stand height (feet)	Crown cover (percent) 5	15	25	35	45	55	65	75	85	95
	Ten cubic-feet									
25	--	--	--	2	11	20	30	40	47	54
30	--	--	7	17	28	38	48	56	64	72
35	--	14	26	37	47	56	65	74	82	88
40	22	35	47	58	67	75	84	93	99	105
45	52	64	76	87	95	103	111	119	125	131
50	81	92	102	111	119	128	136	144	152	160
55	96	107	118	127	135	143	152	162	172	182
60	109	120	130	139	148	159	170	182	194	206
65	119	129	140	152	164	176	188	200	214	230

11- TO 20- (15) FOOT CROWN DIAMETER

Average stand height (feet)	5	15	25	35	45	55	65	75	85	95
25	--	--	--	12	22	31	40	48	55	62
30	--	4	16	28	39	48	55	62	70	78
35	10	23	36	48	58	67	75	83	90	97
40	31	44	55	66	76	84	92	99	106	113
45	61	73	84	94	103	111	119	126	132	138
50	89	100	111	120	128	136	144	153	163	173
55	103	115	125	134	143	152	163	174	185	196
60	116	126	137	148	159	170	182	195	210	225
65	126	137	148	160	173	186	201	217	233	249
70	137	148	162	176	190	205	223	241	258	275
75	161	176	194	214	235	255	275	290	305	319
80	190	213	237	262	282	299	315	330	345	357
85	245	275	295	317	335	350	365	380	395	405
90	299	321	342	362	380	396	410	422	434	445
95	353	373	392	410	426	440	453	465	475	485
100	403	423	441	457	471	483	495	506	516	525
105	430	449	466	481	494	505	516	527	537	545
110	457	475	491	506	517	528	538	548	558	567
115	482	499	515	529	540	551	561	571	580	589
120	506	523	537	550	562	572	582	591	600	608

Forest Survey, Intermountain Forest and Range Experiment Station, Ogden, Utah, 1958.

21- TO 30- (25) FOOT CROWN DIAMETER

Average stand height (feet)	Crown cover (percent) 5	15	25	35	45	55	65	75	85	95
	Ten cubic-feet									
25	--	--	10	22	32	42	50	58	66	73
30	1	15	27	38	48	57	66	75	82	89
35	21	35	47	58	68	76	84	92	98	10[illegible]
40	43	54	65	76	86	94	102	109	116	123
45	72	84	94	104	112	120	128	135	142	149
50	98	109	120	129	137	145	155	165	175	185
55	113	124	134	144	154	165	176	188	200	214
60	125	136	147	158	171	184	199	215	231	245
65	136	148	161	174	188	204	222	240	258	275
70	146	160	176	193	210	227	245	264	283	297
75	173	190	213	236	257	276	294	310	324	336
80	208	234	260	282	301	318	333	348	362	375
85	270	293	315	336	353	369	384	399	411	422
90	317	340	361	381	398	412	425	438	450	461
95	369	393	413	430	443	456	469	481	492	500
100	417	437	455	471	485	496	507	518	529	537
105	445	463	480	496	507	518	529	539	549	557
110	472	488	503	517	539	541	552	561	570	578
115	496	512	528	542	552	562	572	582	592	600
120	520	535	550	563	574	584	594	604	613	620
125	541	556	571	584	594	604	613	622	631	640
130	562	576	590	602	612	622	632	641	649	657
135	580	594	607	618	628	638	648	658	666	674
140	598	611	624	636	646	655	664	673	682	690
145	614	627	640	652	662	672	682	691	699	707
150	630	643	656	667	677	687	697	706	714	722

Note: Stand height, crown diameter, and crown cover from photo measurements of field plots. Volumes from field measurements computed by Forest Survey total height-d.b.h. cubic-foot volume tables.

Based on 84 field plots measured in Idaho, Utah, Colorado, and the Black Hills.

Aggregate deviation: Table 0.31 percent low.

Standard error of estimate: ±41 percent of the average plot volume.

AERIAL VOLUME TABLE--PONDEROSA PINE

Gross board-foot volume per acre (Scribner) by average stand height, crown diameter, and crown cover

1- TO 10- (5) FOOT CROWN DIAMETER

Average stand height (feet)	Crown cover (percent) 5	15	25	35	45	55	65	75	85	95
	Hundred board-feet									
30	--	--	1	2	3	4	5	6	7	7
35	2	3	4	5	5	6	7	8	9	9
40	4	5	6	7	8	9	10	12	15	17
45	6	7	8	9	10	13	17	21	23	26
50	9	10	13	17	20	23	27	31	33	36
55	16	20	24	28	31	34	38	41	42	43
60	27	30	35	38	41	43	45	47	48	50
65	38	41	43	45	47	49	52	55	58	60

11- TO 20- (15) FOOT CROWN DIAMETER

Average stand height (feet)	5	15	25	35	45	55	65	75	85	95
30	2	3	4	5	5	6	7	8	9	9
35	4	5	6	7	8	9	10	12	15	17
40	7	8	9	10	11	14	18	22	25	27
45	9	10	13	17	21	24	27	30	33	35
50	15	18	22	26	30	34	37	40	42	43
55	26	29	33	37	40	42	44	46	47	48
60	37	40	42	44	46	48	50	53	56	59
65	44	46	48	51	54	57	61	65	69	72
70	51	54	58	62	66	70	75	81	86	90
75	62	67	72	77	82	88	94	100	105	110
80	78	84	90	96	102	108	115	122	129	135
85	106	113	120	127	135	144	154	163	171	178
90	140	149	158	167	176	184	191	197	202	205
95	184	191	197	202	206	210	214	218	221	224
100	210	214	218	222	226	230	235	239	243	246
105	220	224	228	232	236	241	246	250	254	257
110	231	236	240	244	248	253	258	264	270	275
115	240	245	250	255	260	266	273	279	285	290
120	251	256	261	267	274	281	289	297	305	311

21- TO 30- (25) FOOT CROWN DIAMETER

Average stand height (feet)	Crown cover (percent) 5	15	25	35	45	55	65	75	85	95
	Hundred board-feet									
40	9	10	13	16	19	22	26	29	32	35
45	13	17	21	25	28	31	34	37	40	42
50	23	27	31	34	37	40	42	44	46	47
55	33	37	41	43	44	46	48	50	53	56
60	43	45	47	49	52	55	58	62	65	68
65	49	52	55	58	62	66	71	76	81	85
70	59	63	67	73	77	82	88	94	100	105
75	73	79	85	91	97	103	109	115	121	127
80	91	98	105	112	118	125	133	141	148	155
85	120	129	139	148	157	166	175	182	188	193
90	162	172	180	187	192	197	203	208	211	214
95	197	202	207	212	215	218	223	227	230	233
100	219	223	227	231	235	239	245	249	253	257
105	228	233	238	243	247	251	256	261	266	271
110	239	245	250	255	260	266	272	278	284	289
115	250	255	260	266	272	279	287	295	303	310
120	262	268	275	282	289	298	308	320	330	338
125	275	283	291	299	307	318	333	349	362	373
130	288	297	308	320	332	345	362	380	397	410
135	308	320	335	350	365	382	404	426	445	460
140	335	354	373	391	410	431	457	478	499	519
145	372	390	410	431	453	475	497	520	542	562
150	407	429	451	472	493	513	533	553	573	592

Note: Stand height, crown diameter, and crown cover from photo measurements of field plots. Volume from field measurements computed by Forest Survey total height-d.b.h. board-foot (Scribner) volume tables.

Based on 84 field plots measured in Idaho, Utah, Colorado, and the Black Hills.

Aggregate deviation: Table 1.5 percent low.

Standard error of estimate: ±52 percent of the average plot volume.

Forest Survey, Intermountain Forest and Range Experiment Station, Ogden, Utah, 1958.

AERIAL VOLUME TABLE--PONDEROSA PINE

Gross board foot volume per acre (International ¼-inch) by average stand height, crown diameter, and crown cover

1- TO 10- (5) FOOT CROWN DIAMETER

Average stand height (feet)	5	15	25	35	45	55	65	75	85	95
	Hundred board-feet									
35	--	--	--	--	1	2	4	5	6	7
40	--	1	3	5	6	7	9	11	13	14
45	3	4	6	8	10	12	14	17	20	22
50	6	8	10	13	16	19	23	28	32	34
55	10	13	16	20	24	28	33	38	42	44
60	16	20	25	30	35	40	45	50	54	56
65	25	31	36	41	46	51	57	63	68	72

11- TO 20- (15) FOOT CROWN DIAMETER

Average stand height (feet)	5	15	25	35	45	55	65	75	85	95
30	--	--	--	--	--	1	2	4	5	6
35	--	1	2	4	5	6	8	10	12	13
40	4	5	7	9	11	14	17	20	23	25
45	7	9	12	15	18	21	25	30	34	36
50	12	15	19	24	28	32	36	41	45	48
55	19	23	29	34	39	44	49	54	58	61
60	29	34	39	44	49	54	60	66	72	76
65	40	45	51	57	63	69	76	83	90	94
70	52	58	65	72	78	84	91	100	108	112
75	71	77	85	95	103	110	117	126	133	137
80	95	105	114	122	130	137	144	151	158	162
85	130	138	146	155	162	168	175	184	191	195
90	168	176	186	195	202	209	215	221	226	230
95	198	207	217	225	231	237	245	254	261	265
100	222	230	240	249	257	265	273	281	288	293
105	242	251	261	271	279	287	295	304	312	318
110	263	275	286	296	305	314	323	332	339	345
115	284	295	305	315	325	334	343	353	361	367
120	304	314	325	335	345	354	363	372	380	386

21- TO 30- (25) FOOT CROWN DIAMETER

Average stand height (feet)	5	15	25	35	45	55	65	75	85	95
	Hundred board-feet									
40	6	8	11	14	16	19	22	27	31	34
45	11	14	17	21	25	29	33	38	42	45
50	17	22	27	32	36	40	45	51	56	59
55	27	31	36	42	47	52	58	65	70	73
60	36	41	47	53	59	65	71	78	83	87
65	49	55	63	69	75	81	88	97	105	110
70	63	69	76	83	90	98	107	115	122	126
75	80	88	99	109	117	123	130	138	144	149
80	110	119	128	137	144	150	157	165	171	175
85	142	150	159	167	175	182	190	198	204	208
90	184	191	200	208	214	220	227	235	241	246
95	213	220	228	236	244	251	259	269	276	280
100	235	244	255	264	272	279	287	296	304	308
105	258	267	277	286	295	303	312	322	329	335
110	280	290	300	311	320	329	338	348	355	360
115	298	308	319	330	340	349	358	368	375	380
120	320	330	340	351	360	369	377	385	393	399
125	340	350	361	371	380	388	396	406	414	420
130	362	372	382	391	400	409	418	427	435	441
135	381	390	400	411	420	428	436	445	453	459
140	401	410	421	431	440	447	455	464	472	478
145	420	430	440	449	458	466	474	483	490	496
150	440	449	460	470	478	485	493	502	510	516

Note: Stand height, crown diameter, and crown cover from photo measurements of field plots. Volumes from field measurements computed by Forest Survey total height-d.b.h. board-foot (International ¼-inch) table.

Based on 84 field plots measured in Idaho, Utah, Colorado, and the Black Hills.

Aggregate deviation: Table 1.79 percent high.

Standard error of estimate: ±54 percent of the average plot volume.

Forest Survey, Intermountain Forest and Range Experiment Station, Ogden, Utah, 1958.

(DPS, Ogden, Utah)