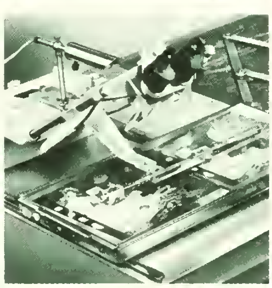
# REMOTE SENSING



## Practical Exercises on Remote Sensing in Archeology



Supplement No. 1

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## Practical Exercises on Remote Sensing in Archeology

## Supplement No. 1

to Remote Sensing: A Handbook for Archeologists and Cultural Resource Managers

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**National Park Service**
**U.S. Department of the Interior**
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# Preface

This supplement is designed for use with *Remote Sensing: A Handbook for Archeologists and Cultural Resource Managers*, by Thomas R. Lyons and Thomas Eugene Avery. The handbook may be obtained by writing the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402.

Within the next several months, the National Park Service will publish other supplements to the handbook dealing with regional applications of remote sensing for the archeologist and cultural resource manager. The reader may receive notification of these publications as they become available by writing the Superintendent of Documents (address above) and asking to be placed on mailing list N-557.

# Introduction

Trainees and other users of this supplement to *Remote Sensing: A Handbook for Archeologists and Cultural Resource Managers* will find it advantageous to have a sound grasp of the following general concepts.

1. Be able to compute:
   a. Area of a circle, or radius (and diameter) of a circle when area is known.
   b. Area of a square, or length of one side when area is known.
   c. Diagonal of a square; hypotenuse of a right triangle.
   d. Area of a rectangle or trapezoid.
   e. Volume of a cylinder or cone.
   f. Relationships of distance, rate, and time.
2. Know the basic layout and dimensions of land parcels in the U.S. Public Land Survey.
3. Be able to draw (or recognize) standard symbols used on topographic maps.
4. Have a working knowledge of ratio, proportion, map scales, compass bearings and azimuths.
5. Have a working knowledge of the International System of Units (metric system).
6. Have a working knowledge of the basic principles of photography and the operation of conventional hand-held cameras.

# Contents

# *Exercise 1*

# General Photographic Principles

References: Handbook, section 1.
Any good handbook on photography.

1. What would be the "speed" of a lens having a focal length of 70 mm and a lens diameter of 20 mm at full aperture? ____________

2. If a correct exposure can be made with a shutter speed of 1/100 second at f/8, what f/stop would you use at 1/200 second? What shutter speed would be required with an aperture setting of f/16?
   a. ____________ b. ____________

3. If a correct exposure combination for a film is 4 seconds at f/64, what is the required f/stop for a ¼-second exposure? ____________

4. What would be the focal length (in mm) of a "normal angle" lens having a negative format of 2¼ in. by 2¼ in.? What would it be for a negative format of 9 in. by 9 in.?
   a. ____________ b. ____________

5. Refer to any standard text on photography and explain what is meant by:
   a. Depth of field:

   b. Hyperfocal distance:

   c. How are these items affected by changes in relative apertures?

6. List 3 commercially available films and their corresponding A.S.A. exposure readings. What are the recommended shutter speeds and f/stops for these films under conditions of bright sunlight and strong shadows?

| Name of film | A.S.A. | Shutter speed | f/stop |
|---|---|---|---|
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7. List at least four reasons why objects may register in different tones on black-and-white aerial photographs.
   a. ____________
   b. ____________
   c. ____________
   d. ____________

8. What is the primary purpose of using photographic filters? Which filter is most commonly used with both panchromatic and infrared film? ____________

9. List relative advantages and disadvanges of taking aerial photographs for vegetation analyses during the different seasons of the year.

| Season | Foliage stage | Advantages | Disadvantages |
|---|---|---|---|
| Winter | Dormant season | | |
| Spring | Light green, immature | | |
| Summer | Dark green pigmentation | | |
| Fall | Maximum coloration | | |

10. List concomitant advantages and disadvantages for archeological and cultural analysis. (Discuss with instructor.)

11. Your instructor will supply you with a set of paired photographs (e.g., panchromatic vs. black-and-white infrared or normal color vs. infrared color). Make a list of major features that can be recognized, and compare the tonal differences of these features on the two photographs. Tabulate as follows:

| Feature identified | Panchromatic or normal color | B-W infrared or color infrared | Preferred film and comments |
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# *Exercise 2*

## A Test of Stereoscopic Perception

References: Handbook, section 2.
Moessner, Karl E. (1954). A simple test for stereoscopic perception. U.S. Forest Serv., Central States Forest Expt. Sta., Tech. Paper 144, 14 pp., illus. (Instructions are reprinted from this publication by courtesy of the U.S. Forest Service, Ogden, Utah).

1. Adjust the lenses of a pocket stereoscope to the most comfortable spacing for your eyes.
2. Set the stereoscope up over the Stereogram. Adjust the instrument so that the A's are superimposed. Then beginning with row A, record the number of each circle that appears to "float" above the datum plane formed by the paper and rest of the circles.
3. When you have completed Block A, shift the stereoscope down to rest directly over Block B. After making sure that the two B's are superimposed, proceed as in 2.
4. Repeat the process for Block C.

**Special precautions:**

A. Set the stereoscope to a lens separation normal for your eyes.

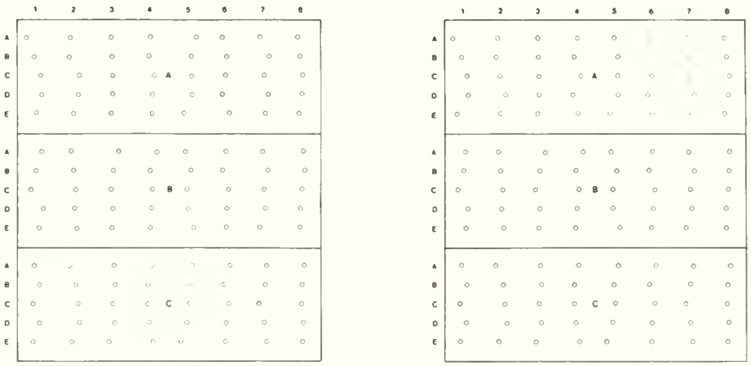
B. View the stereogram directly below the center of the lens, even though this means shifting the stereoscope to the right or left and vertically as the test progresses. Any attempt to look through the lens at an angle will produce a curved datum and make it harder to recognize the floating circles.

C. See that the letters centered in each block are superimposed; any other orientation will cause the wrong circles to float.

D. Read the stereogram systematically from left to right starting with the top line of Block A. Skipping around or reading vertically merely increases the difficulty, and may result in errors.

## Stereogram

(Lens separation - 2.25 inches)



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 | |

# *Exercise 3*

# Photo Nomenclature and Preparing Prints for Stereo-Viewing

Reference: Handook, section 2.

1. Obtain four or more overlapping aerial photographs of your local area. At least two flight lines should be represented. Write your name on the back of each print. Trim each print, locate principal points (PP) and conjugate principal points (CPP). Double-check to verify precise location; points picked incorrectly will appear to "float" or "sink" with respect to surrounding terrain.

2. With a drop-bow pen, circle each PP and CPP. Ink flight lines and record average photo base lengths for each overlap as directed; these values will be used later in computing object heights from parallax measurements. Values for average photo base lengths:

   ______________________________
   ______________________________
   ______________________________
   ______________________________
   ______________________________
   ______________________________
   ______________________________
   ______________________________
   ______________________________

3. Arrange prints in mosaic fashion and observe direction of flight lines and orientation of shadows. If time of day is not shown, estimate the time of day: early morning, midday, late afternoon. Obtain the exact time and record on first and last prints in each flight line.
   Time of day ______________

4. Check with your instructor, and record the following data for your own prints:
   a. Date(s) of photography ______________
   ______________________________
   b. Organization for which photos were originally flown ______________
   ______________________________
   ______________________________
   c. Project symbol, film roll, and exposure numbers ______________
   ______________________________
   d. Film-filter combination used ______
   ______________________________
   e. Approximate scale of photography ______
   ______________ ft. per in.
   f. Camera focal length (if shown on prints)
   ______________ in.
   g. Average ground elevation of local area
   ______________ ft. above sea level

5. Arrange prints in mosaic fashion and measure:
   a. Average forward overlap ______ percent
   b. Average sidelap ______ percent

6. Obtain a reliable map of the local area, such as a U.S. Geological Survey quadrangle sheet. With an engineer's scale and protractor, measure:
   a. Compass bearing of flight line 1____degrees
   b. Compass bearing of flight line 2____degrees
   c. Was the intended flight course north-south or east-west? ______________

7. Inspect all of your photographs closely and determine whether any of the following "defects" appear. Write print numbers opposite the applicable description.

Excessively long shadows: ______

Shadows fuzzy due to overcast sky: ______

Poor tonal contrast: ______

Print detail blurred, especially in corners: ______

Chemical streaks or stains: ______

Emulsion scratches or cracks: ______

Clouds or cloud shadows: ______

Smoke or smog (industrial areas): ______

Excessive snow cover on ground: ______

Floodwaters obscuring ground detail: ______

Inadequate or incorrect print titling: ______

Forward overlap excessive (over 65 percent): ______

Forward overlap deficient (less than 50 percent): ______

Sidelap excessive (over 45 percent): ______

Sidelap deficient (less than 15 percent): ______

Improper print alignment: ______

Tilted photographs (check ends of flight lines): ______

# *Exercise 4*

# Identifying Features on Your Photos

Reference: Handbook, sections 2 and 7.

1. On a 10 in. by 10 in. sheet of transparent material, draft a photo-locational grid. For 9 in. by 9 in. photos, each small square should be about 1/2 in. (or 1 cm) on a side. The columns and rows of small squares should then be *lettered* in one direction and *numbered* in the other direction.

Set up your own prints for stereoscopic study with the locational grid carefully taped over the right-hand print so that grid midpoints are aligned with the four photo fiducial marks. Then refer to the checklist of typical features and write down (by grid location) as many items as you can identify. Tabulate information as follows:

Print number under grid ________________ Locality ______________________________

| **Grid location** | **Feature identified** |
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**Checklist of Typical Features**

In the identification of unfamiliar features on vertical photographs, it has been found that the power of suggestion is often beneficial to beginning interpreters. Accordingly, the following checklist has been prepared to illustrate the kinds of features commonly encountered in the study of aerial photographs. The groupings, according to eleven general categories, are somewhat arbitrary, therefore, a given feature might logically be assigned to more than one of the classifications shown.

Archeological Features
- Linear depressions and elevations
- Circular and elliptical depressions and mounds
- Rectilinear depressions and mounds
- Geometric tonal patterns in fields and bare soils
- Geometric vegetation patterns
- Step terracing or lynchets
- Standing walls—usually unroofed
- Soil blowouts

Forests, Rangelands and Deserts
- Coniferous forests
- Hardwood forests
- Mixed coniferous and hardwood forests
- Cactus (semi-desert vegetation)
- Forest plantations
- Herbaceous rangeland
- Shrub and brush rangeland
- Mixed rangeland

Agricultural Features
- Cultivated crops (e.g., corn)
- Contour-plowed or terraced croplands
- Irrigated crops (specify type)
- Orchards (specify type)
- Vineyards
- Improved pastures
- Fences or hedgerows
- Barns or silos
- Baled hay or shocked wheat
- Livestock or wild game
- Greenhouses
- Nurseries
- Abandoned or fallow fields

Water and Natural Shoreline Features
- Shorelines and beaches
- Coastal bays and inlets
- Swamps or marshes
- Floodplains or deltas
- Permanent rivers or streams
- Inland lakes or ponds
- Sand bars or mud flats
- Limesinks or potholes
- Beach terraces

Physiographic and Geologic Features
- Active glaciers
- Cirques or cliffs
- Eskers or drumlins
- Talus slopes and alluvial fans
- Gully erosion
- Sheet erosion
- Volcanic lava flows or cones
- Rock outcrops
- Hogbacks
- Anticlines and synclines
- Faults and dikes
- Dune fields

Mining and Excavation
- Strip-mining (e.g., coal)
- Placer-mining (e.g., gold)
- Open-pit mining (e.g., copper)
- Sand and gravel excavations
- Rock quarries
- Oil drilling and development
- Channel dredging
- Land-clearing operations

Urban-Residential Patterns
- Apartment houses
- Mobile homes
- Garages
- Schools (specify type)
- Churches and cemeteries
- Parks or playgrounds
- Statues or monuments
- Civic or recreational centers
- Shopping centers
- Downtown business districts
- Gas stations
- Automobile sales
- Mobile home sales
- Motels or hotels
- Drive-in theaters
- Country clubs
- Swimming pools
- Golf courses

Tennis courts
Football fields
Other athletic fields
Race tracks
Auto junkyards
Prisons
County rest homes
Hospitals

Transportation and Communication Features
Four-lane, divided highways
Three-lane, paved highways
Two-lane paved highways
Graded, nonsurfaced roads
Woods road or Jeep trails
Traffic circles and interchanges
Overpasses-underpasses
Railroads
Railroad terminals
Bus terminals
Trucking terminals
Airports
Radio or TV transmission towers
Radar antennas
Railroad coal-dumping spurs
Boat docks and piers

Industrial and Utility Features
Electrical power plants
Electrical power substations
Steel towers for electrical lines
Cleared rights-of-way
Buried pipelines
Sewage disposal plants
Water purification plants
Petroleum or chemical industries
Petroleum products storage tanks
Sawmills and lumber yards
Pulp and paper mills
Furniture manufacturing plants
Automobile manufacturing plants
Steel or other metal industries
Cement block manufacturing
Ready-mixed concrete plants
Stockyards or meat-packing plants

Engineering Structures
Dams (describe type of material)
Bridges (describe type of material)
Road cuts and fills
Levees
Athletic stadiums
Fire lookout tower
Water tanks
Canals or drainage ditches
Reservoirs
Ferry landings

Military and Defense Installations
Post headquarters
Barracks and residences
Temporary encampments
Ammunition dumps
Rifle or artillery ranges
Tanks
Warships
Shipyards and drydocks
Missile test sites
Operational missile base
Airfields and planes
Radar installations

# Exercise 5

## Problems on Scale and Focal Length

Reference: Handbook, section 3

1. Determine the representative fraction (RF) of a photograph taken from 15,000 ft. above mean sea level (MSL) over a land surface having an elevation of 1,250 ft. above MSL. Assume a camera focal length of 8.25 in.
RF= ______________________

2. Two points along a highway are known to be exactly one mi. apart. If the corresponding photo distance is 0.330 ft., what is the RF of the photograph?
RF= ______________________

3. Suppose you wish to obtain photographs at a scale of 4 in. per mi. with a camera focal length of 6 in. Average ground elevation of the area to be photographed is 1,500 ft. above MSL. What flight altitude above MSL must be maintained to obtain the desired scale? ______________________ ft.

4. On 1:2,400 photographs of a regulation baseball diamond, what photo measurement would be obtained for the distance from home plate to second base? __________ in.

5. Assume that railroad passenger cars are 90 ft. long and that freight cars are 40 ft. long. What would be the lengths of these images on 1:20,000 aerial photographs?
Passenger cars ______________________ in.
Freight cars ______________________ in.

6. How many sq. mi. are covered by 9 in. by 9 in. photographs at scales of:
a. 1:5,000? ______________________ sq. mi.
b. 1:10,000? ______________________ sq. mi.
c. 1:20,000? ______________________ sq. mi.

7. Suppose the smallest image that can be consistently distinguished on aerial photographs has a diameter of 1/200 in. If your aerial camera has a focal length of 6 in., what is the *maximum* flight altitude at which objects 2 ft. in diameter could be recognized?
______________________ ft.

8. A cultivated field measures 1.5 in. by 3 in. on a photograph taken at a scale of 1:11,000. How many a are in the field?
______________________ a
How many ha.? ______________________ ha

*Exercise 6*

# Determining the Scale of Your Photos

Reference: Handbook, section 3.

1. The *nominal* scale of your own photographs is __________________________
   For a more precise determination, compute the scale for each of your prints by ratios of several photo and ground distances. (Ground distances may be obtained from U.S.G.S. maps, from the lengths of known features such as section lines, or from actual field measurements.) Record below:

| Description of line | Ground or map distance | Photo distance | RF |
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Average scale (RF) ____________

2. Refer to Table 3-1 in the Handbook and convert the average scale to the following units:
   a. ____________ ft. per in.
   b. ____________ chains per in.
   c. ____________ in. per mi.
   d. ____________ a per sq. in.

3. If the camera focal length is known, compute the flying height of the photographic aircraft above ground ________________ ft.
   Next, determine the flying height above MSL ____________________ ft.

# *Exercise 7*

# Distances, Bearings, and Areas

Reference: Handbook, section 3.

1. Measure the dimensions of several accessible features on your photographs and convert them to ground distance. Then, check these distances by ground measurement. Compare and explain possible reasons for differences.

| Description of feature | Photo-derived dimensions | Ground check |
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2. Determine the approximate compass bearing of several straightline features on your photographs. Then, check these bearings on the ground by use of a hand compass or transit. Compare and explain possible reasons for differences.

| Description of linear feature | Photo-derived bearing | Ground check |
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3. Using your own photographs, select several areas of irregular shape and determine their acreages by using both a planimeter and an appropriate dot grid. Record results to two decimal places in the table below and compare differences obtained.

| Description of area | Area by dot grid (____dots/sq. in.) | Area by planimeter (Avg. 3 readings) | Difference in readings |
|---|---|---|---|
| | ----------------- Acres | ----------------- | ----------------- |
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# Exercise 8

# Heights by Parallax Measurement

Reference: Handbook, section 3.

1. Complete the following form for use in measuring heights on your own photographs. Determine the *exact* scale of your prints before computing flying height. Then solve the parallax formula to determine (1) the change in elevation per mm of dP, and (2) the change in elevation per 0.002 in. of dP.

| Stereo-overlap no. | Flight altitude (H) (ft.) | Av. photo base length (P) | | Change in height or elevation | |
|---|---|---|---|---|---|
| | | (mm) | (in.) | Per 1.00 mm dP | Per 0.002 in. dP |
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2. Locate several objects such as trees, buildings, or smokestacks within the overlap zones of your photographs. Select features that are not likely to have changed since your exposures were made. Measure their heights with a stereometer (floating mark device) and record below. If feasible, check these heights by ground measurement for a comparison of results.

| Stereo-overlap no. | Description of object | dP | Photo height | Ground check | Difference (+ or −) |
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# Exercise 9

# A Sample Flight Plan

Reference: Handbook, section 4.

1. This example illustrates the various calculations involved in preparing an aerial flight plan for an area of 80 sq. mi. Basic information required is as follows:

Desired photographic scale: 1,320 ft. per in.
Scale of base map: 1:62,500 or
1 in. = 5,208 ft.
Size of area: 8 mi. E-W by 10 mi. N-S, or
42,240 ft. by 52,800 ft.
Average ground elevation above *mean sea level*: 1,200 ft.
Average forward overlap: 60 percent
Sidelap: 15 to 45 percent, averaging approximately 30 percent.
Negative format: 9 in. x 9 in., or 11,880 ft. by
11,880 ft. on the ground
Camera focal length: 6 in. or 0.5 ft.

Items to be computed in preparing the flight plan are:

a. Flying height above ground and height above *mean sea level*.
b. Direction and number of flight lines
c. Ground distance between flight lines
d. Actual percent of sidelap
e. Map distance between flight lines
f. Ground distance between exposures on each line
g. Map distance between exposures on each line
h. Number of exposures on each line and total number of exposures.

**Flight Map Computations**

a. Flying height above ground datum:
height = focal length × scale denominator,
or
H = 0.5 ft. × 15,840 = 7,920 ft. above ground
Flying height above *mean sea level*: 7,920 + 1,200 = 9,120 ft.

b. Direction of flight lines: North-South, following long dimension of tract.
Number of flight lines: Assuming an average sidelap of 30 percent, the lateral gain from one line to another is 70 percent of the print width, or 0.70 × 11,880 = 8,316 ft. between lines. The number of *intervals* between lines is found by dividing the tract width (42,240 ft.) by 8,316. The result is 5.08 or 5 *intervals* and 6 *flight lines*.

c. Ground distance between flight lines:
Tract width (42,240)÷5 intervals = 8,448 ft. between lines.

d. Actual percent of sidelap, assuming exterior flight lines are centered over tract boundaries:

$$\text{Sidelap percent} = \frac{\text{Print width (ft.)} - \text{Spacing (ft.)}}{\text{Print width (ft.)}} \times 100$$

$$\text{Sidelap percent} = \frac{11{,}880 - 8{,}448}{11{,}880} \times 100 = 28.9\%$$

e. Map distance between flight lines (map scale: 1 in. = 5,208 ft.):

$$\frac{1''}{5{,}208'} = \frac{X''}{8{,}448'}\ ;\quad X = 1.62'' \text{ between lines on map}$$

f. Ground distance between exposures on each line: Assuming an average forward overlap of 60 percent, the spacing between successive exposures is 40 percent of the print width, or 0.40 × 11,880 = 4,752 ft.

g. Map distance between exposures on each line:

$$\frac{1''}{5{,}208'} = \frac{X''}{4{,}752'}\ ;\quad X = 0.91''\ \text{between exposures on map}$$

h. Number of exposures on each line: Number of *intervals* between exposures is found by dividing tract length (52,800 ft.) by 4,752 = 11.11 *intervals*. This would require 12 exposures *inside* the area, assuming that the first exposure is centered over one tract boundary. In addition, two extra exposures are commonly made at the ends of each line; thus a total of 12 + 2 + 2 = 16 *exposures* would be taken on each flight line.
Total number of exposures required to cover entire tract: 6 lines × 16 exposures per line = 96 exposures.

2. Assume you must plan a photographic mission for an area covered by a standard topographic map. Your instructor will supply basic data on photo scale desired, overlap, camera focal length, and so on. Compute the following values by the methods outlined in the preceding example:
   a. Flying height above ground datum ____ ft.
      Flying height above MSL ________ ft.
   b. Direction of flight lines ____________
      Number of flight lines ____________
   c. Ground distance between flight lines ____ ft.
   d. Actual percent of sidelap ______ percent
   e. Map distance between flight lines ____ in.
   f. Ground distance between exposures on each line ____________ ft.
   g. Map distance between exposures on each line ____________ in.
   h. Number of exposures on each line ______
      Total number of exposures __________

3. Use the foregoing data to convert your topographic map into a finished flight plan. Show location, direction, and altitude of all flight lines, positions of all print centers, actual percent of sidelap, and so on. Add an appropriate title at the bottom of the map sheet.

# Level I Land-Use Mapping From Landsat Imagery

References: Handbook, sections 5 and 6.
Anderson, J.R., *et al* (1976). A land use and land cover classification system for use with remote sensor data. U.S.G.S. Prof. Paper 964, Government Printing Office, Washington, D.C. 28 pp., illus.

1. Your instructor will supply you with LANDSAT imagery in two or more spectral bands, a county map, overlay material, and Level I land classification data.
2. Prepare a transparent film overlay for the LANDSAT imagery. Note the frame identification numbers, spectral bands, and geographic coordinates on each overlay.
3. Locate county boundaries and trace onto overlays.
4. Delineate and code Level I land use/land cover on overlays.
5. Summarize the *number* of land parcels in each land use category and determine the total *area* of each category. Tabulate on the form provided here.
6. Prepare a brief (one-page) writeup on your findings. Comment on the following items:
   a. Which categories of land are easy to identify?
   b. Which categories of land are difficult to identify?
   c. Which spectral band is preferred, and why?
   d. Was the date (season) of imagery critical? If so, why?

County__________ Geographic coordinates ____________________

Date of LANDSAT imagery______ Interpreter ________________

| **Level I land use and code no.** | **Spectral band______** | | **Spectral band______** | |
|---|---|---|---|---|
| | **No. of parcels** | **Total area** | **No. of parcels** | **Total area** |
| 1. Urban or built-up land | | | | |
| 2. Agricultural land | | | | |
| 3. Rangeland | | | | |
| 4. Forest land | | | | |
| 5. Water | | | | |
| 6. Wetland | | | | |
| 7. Barren land | | | | |
| 8. Tundra | | | | |
| 9. Perennial snow or ice | | | | |
| Grand totals | | | | |

# Convergence of Evidence in Site Prediction

Reference: Handbook, sections 7-9.

1. There are important areas of prehistoric or historic interest in most parts of the world. Make an attempt to delineate the most *probable* areas in your region for the discovery of new sites. Use available maps, photographs, and historical documents in compiling your evidence. Use the checklist provided, and add any categories necessary.

| **Locale of possible site** | **Reliable water source?** | **Game or edible plants?** | **Shelter and protection?** | **Access via land or water?** | **Favorable climate, etc.?** |
|---|---|---|---|---|---|
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2. Narrow your search to one or two of the most promising locales. Then inspect these "possible" sites from low-flying aircraft and/or ground expeditions. Summarize your findings in a brief report.

# Exercise 12

# Archeological Resource Identification and Evaluation

Reference: Handbook, sections 7-9.

An important use of black-and-white, color, and color infrared aerial photographs is in archeological field surveys. Photographs can be used as direct and as indirect locators of sites, as mapping tools and as source of environmental data. Figure 2 is an aerial view of a segment of Chaco Canyon National Monument. On this image, you should be able to identify: 1) at least 6 Anasazi architectural sites, 2) three types of transport facilities, 3) canyon floor, cliffs and ledges, benches or mesas, and 4) incised stream channels.

For partial answers see Figure 3.

On Figure 3, Point X is the hypothetical location of a lithic scatter which cannot be directly identified on Figure 2. Note, however, that its location can be accurately plotted on Figure 2 by determining the scale of the image and by reference to the nearby cliff, large pueblo ruin, and vegetation pattern. Plot the location of Site X on Figure 2.

As a cartographic exercise, make an overlay of a portion of Figure 2. Map the cliffs, canyon floor, incised arroyo, pueblo ruins, benches, roads, etc. For clear differentiation of features, arbitrary color coding is useful.

Figure 1 is a portion of a USGS topographic map. Transfer to Figure 1 some of the cultural and natural features you have identified on Figure 2 or on Figure 3 which do not appear on this USGS topographic map. Conversely, identify on the photograph features on the USGS topo map such as the cemetery, ruins, roads, etc.

With reference to Figure 2 in this supplement and to Plate 1 in the Handbook, briefly describe the environmental setting of the many archeological sites in terms of landform and vegetative cover.

Refer to Section 8 and Figure 8-8 in the Handbook. Where would you anticipate locating the longest cultural sequence? 1) In the vicinity of the playa lakes? 2) On the beach terraces? 3) To the right or east of the beach terraces? Why?

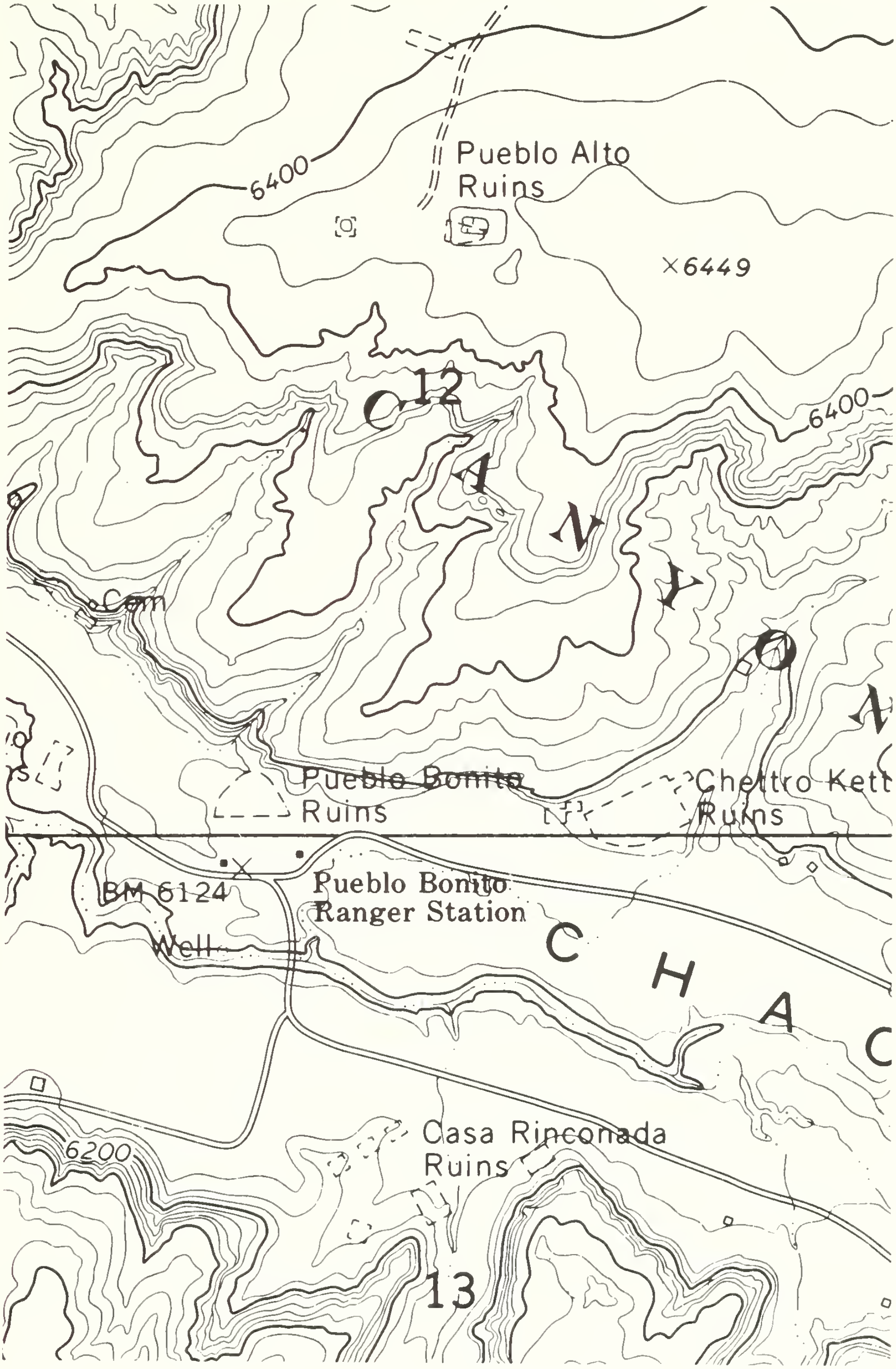



**Figure 1** An enlarged portion of a USGS topographic map of Chaco Canyon National Monument, New Mexico.
Scale: ca. 1:12,000 Contour Interval: 20 feet Datum: Mean Sea Level

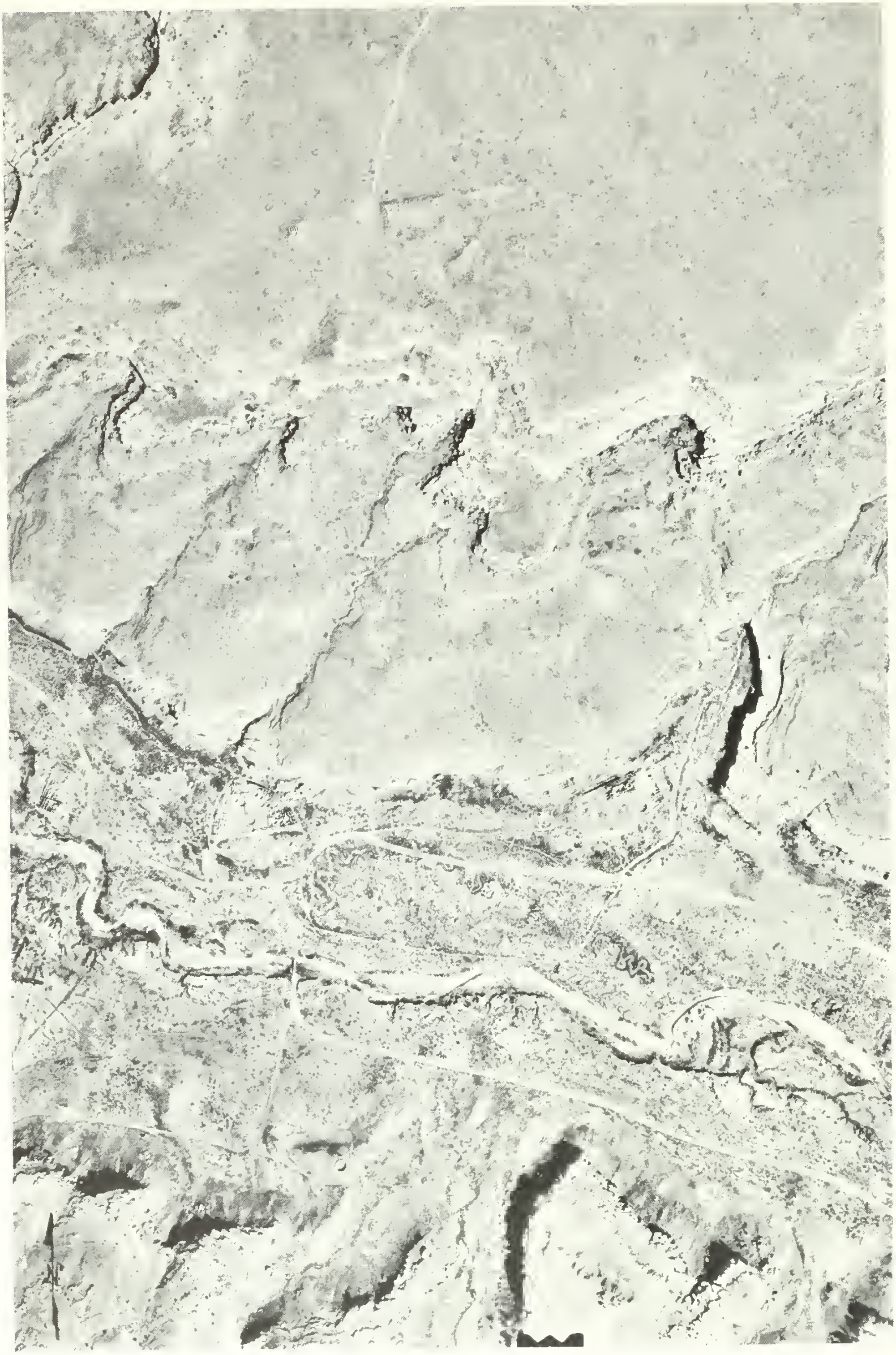


**Figure 2** A vertical black and white aerial photograph of a portion of Chaco Canyon National Monument, New Mexico.
Scale: ca. 1:12,000

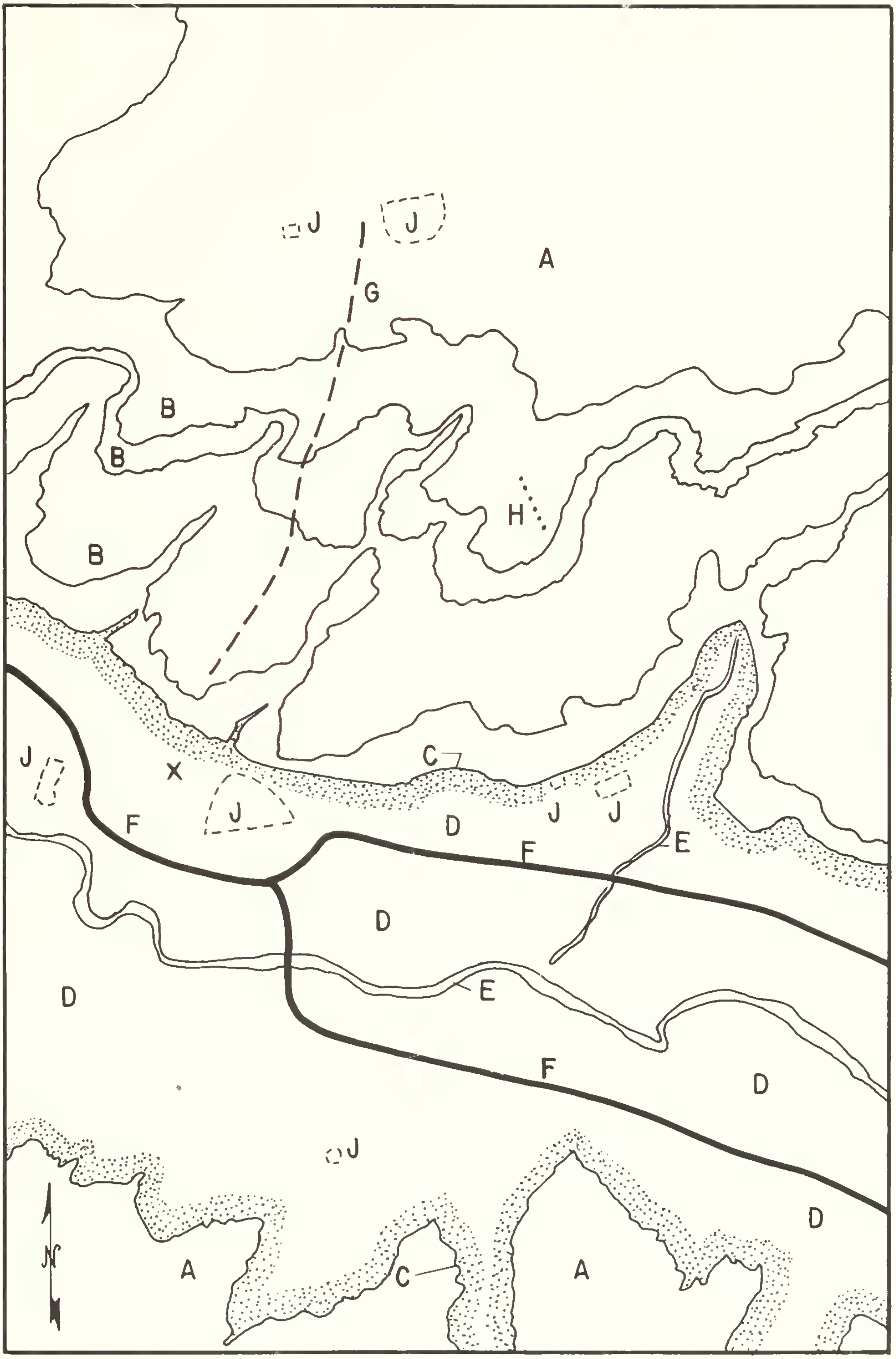



**Figure 3** Reference Map for Figure 2: Scale: ca. 1:12,000
A Mesa Top B Benches C Canyon Rim D Canyon Floor E Incised Arroyos F Modern Roads G Modern Foot Path H Prehistoric Roadway J Pueblo Ruins X Hypothetical Location of a Prehistoric Site

# *Exercise 13*

# Metric Conversion Problems

References: U.S. Department of the Army (1967). Percentages and the metric system. Lesson reference file, U.S. Army Engineer School, Fort Belvoir, Virginia. Pub. S046-315, 21 pp. (Some problems are taken from this publication).
U.S. Department of Commerce (1972). The International System of Units (SI). National Bureau of Standards, Special pub. 330, Government Printing Office, Washington, D.C., 42 pp.
Set of metric/English conversion tables (included here).

**Problem set A**

1. Convert to m: 834 cm, 1742 mm, 1423 dm, 16 km.
2. Convert to mm: 32.6 km, 3 m, 143 cm.
3. Convert 456 in. to m.
4. Convert 43.5 ft. to cm.

**Problem set B**

1. Find the difference (in in.) between 3 15/16 in. and 10 cm.
2. A man is 174 cm tall. How tall is he in in.?
3. A man weighs 72 kg. What is his weight in lb.?
4. Washington is 105 mi. from Richmond. How far is this in k?

**Problem set C**

1. Three roads will have pavement thicknesses of 2.5 in., 1.8 in., and 3.0 in., respectively. What are their thicknesses in cm?
2. A soil sample weighs 1.3 lb. What is the equivalent weight in kg? in g?
3. How many ha are there in a 7.5-a. tract of land?
4. How many ha are there in a section of land?

Approximate conversions for metric and English units

| | | | | | | |
|---|---|---|---|---|---|---|
| LENGTH | 1 centimeter | = 0.3937 | inch | 1 inch | = 2.54 | centimeters |
| | 1 meter | = 3.2808 | feet | 1 foot | = 0.3048 | meter |
| | 1 meter | = 1.0936 | yards | 1 yard | = 0.9144 | meter |
| | 1 kilometer | = 0.6214 | mile | 1 mile | = 1.6093 | kilometers |
| AREA | 1 square centimeter | = 0.155 | square inch | 1 square inch | = 6.4516 | square centimeters |
| | 1 square meter | = 10.764 | square feet | 1 square foot | = 0.0929 | square meter |
| | 1 square meter | = 1.196 | square yards | 1 square yard | = 0.8361 | square meter |
| | 1 square kilometer | = 0.3861 | square mile | 1 square mile | = 2.59 | square kilometers |
| | 1 hectare | = 2.471 | acres | 1 acre | = 0.4047 | hectare |
| VOLUME | 1 cubic centimeter | = 0.061 | cubic inch | 1 cubic inch | = 16.3871 | cubic centimeters |
| | 1 cubic meter | = 35.315 | cubic feet | 1 cubic foot | = 0.02832 | cubic meter |
| MASS | 1 kilogram | = 2.205 | pounds | 1 pound | = 0.4536 | kilogram |
| | 1 metric ton | = 1.102 | short tons | 1 short ton | = 0.9072 | metric ton |
| | 1 metric ton | = 0.9842 | long ton | 1 long ton | = 1.016 | metric ton |
| | 1 metric ton | = 19.684 | hundredweight (of 112 pounds) | 1 hundredweight (of 112 pounds) | = 0.0508 | metric ton |
| | 1 metric ton | = 22.046 | hundredweight (of 100 pounds) | 1 hundredweight (of 100 pounds) | = 0.04536 | metric ton |
| DENSITY | 1 kilogram per cubic meter | = 0.06243 | pound per cubic foot | 1 pound per cubic foot | = 16.018 | kilograms per cubic meter |
| OTHER | 1 square meter per hectare | = 4.346 | square feet per acre | 1 square foot per acre | = 0.2296 | square meter per hectare |
| | 1 cubic meter per hectare | = 14.291 | cubic feet per acre | 1 cubic foot per acre | = 0.07 | cubic meter per hectare |

# Answer Key for Selected Questions

Solutions are provided for part or all of Exercises 1, 2, 5, 12, and 13. Remaining exercises are dependent on local photography or special information provided by an instructor, hence no "standard" answers can be supplied.

It should be recognized that certain problems covered by this key may be correctly solved by more than one procedure. Minor differences in final answers can often be attributed to variations in "rounding off" numbers during intermediate phases of a solution.

Suggestions or comments regarding the answer key should be addressed to:

Remote Sensing Division
Southwest Cultural Resources Center
National Park Service
P.O. Box 26176
Albuquerque, N.M. 87125

**Exercise 1**

1. f/ = 70 ÷ 20 = f/3.5
2. a. f/5.6 b. 1/25 second
3. f/16
4. a. $1.414 \times 2.25 \times 25.4 = 80.8$ mm
   b. $1.414 \times 9 \times 25.4 = 323.24$ mm
5. a. Depth of field is defined as the distance between the points nearest to and farthest from the camera which are acceptably "sharp" or in focus.
   b. Hyperfocal distance is the distance from the camera lens to the nearest object in focus, when the lens is focused at infinity.
   c. The larger the f/stop number (the smaller the lens opening), the greater the depth of field. Likewise, smaller apertures reduce the hyperfocal distance, i.e., the near point in focus. For example, with a 6-in. focal length lens, the hyperfocal distance is 214 ft. at f/3.5 and 34 ft. at f/22.
6.

| Name of film | A.S.A. rating | Shutter-speed | f/stop |
|---|---|---|---|
| Kodachrome II (daylight - color) | 25 | 1/100-1/125 | f/8 |
| High-speed Ektachrome (daylight - color) | 160 | 1/200-1/250 | f/16 |
| Verichrome-pan or Plus-X (B & W) | 80 | 1/100-1/125 | f/16 |

(Note: Several other film emulsions may be cited in lieu of those listed.)

7. Four reasons why objects may register in different tones on black-and-white aerial photographs:
   a. Seasonal changes in foliage coloration.
   b. Spectral reflectance of objects photographed.
   c. Spectral sensitivity of film used.
   d. Angle and intensity of sunlight.
8. Filters are used to cut atmospheric haze (blue light) and prevent it from passing through the camera lens to the film. A yellow or minus-blue filter is most commonly used with panchromatic and infrared film.

9.

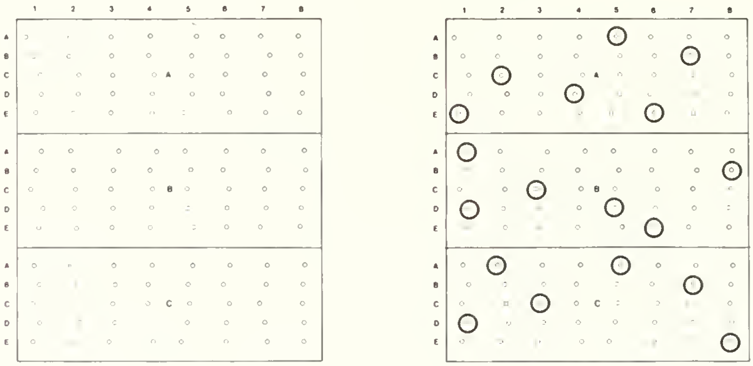
| Season | Foliage stage | Advantages | Disadvantages |
|---|---|---|---|
| Winter | Dormant season | Easy separation of evergreen vs. deciduous vegetation | Difficult to accurately measure leafless vegetation |
| Spring | Light green, immature | Good contrast in pigments and leaf structure | Hard to capture uniform colors over wide areas |
| Summer | Dark green pigmentation | All plants in a given species-group register in same or similar tone | Insufficient tonal contrast between various plant species |
| Fall | Maximum coloration | Easy separation of species with varying leaf coloration | Hard to capture uniform colors over wide areas |

10. No standardized solution.
11. No standardized solution.

**Exercise 2**
Stereoscopic test answers

## Stereogram

(Lens seperation - 2.25 inches)



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

**Block A**

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 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 |
| D | 1 | 2 | 3 | **4** | 5 | 6 | 7 | 8 |
| E | **1** | 2 | 3 | 4 | 5 | **6** | 7 | 8 |

**Block B**

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 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 |
| D | **1** | 2 | 3 | 4 | **5** | 6 | 7 | 8 |
| E | 1 | 2 | 3 | 4 | 5 | **6** | 7 | 8 |

**Block C**

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 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 |
| D | **1** | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| E | 1 | 2 | 3 | 4 | 5 | 6 | 7 | **8** |

**Exercises 3 and 4**
No standardized solutions.

**Exercise 5**

1. $RF = \dfrac{0.6875}{15{,}000 - 1{,}250} = 1{:}20{,}000$

2. $RF = \dfrac{0.330}{5{,}280} = 1{:}16{,}000$

3. For 6″ focal length — For 12″ focal length

$$\frac{1}{15{,}840} = \frac{0.5}{H - 1{,}500} \qquad \frac{1}{15{,}840} = \frac{1.0}{H - 1{,}500}$$

H (altitude) = 9,420 ft. — H (altitude) = 17,340 ft.

4. Baseball diamond is 90 ft. square; home plate to second base is 127.3 ft.

RF of 1:2,400 is 1″ = 200′

$\dfrac{1''}{200'} = \dfrac{X''}{127.3'}$ ; X (photo measurement) is 0.636″

5. RF of 1:20,000 is 1 in. = 1,667 ft.

Image length-passenger cars

$$\frac{1''}{1{,}667'} = \frac{x''}{90'}$$

X (length) = 0.054″

Image length-freight cars

$$\frac{1''}{1{,}667'} = \frac{x''}{40'}$$

X (length) = 0.024″

6. a. Scale 1:5,000

$$\frac{(9'' \times 5{,}000)^2}{(63{,}360)^2} = 0.504 \text{ sq. mi.}$$

b. Scale 1:10,000

$$\frac{(9'' \times 10{,}000)^2}{(63{,}360)^2} = 2.018 \text{ sq. mi.}$$

c. Scale 1:20,000

$$\frac{(9'' \times 20{,}000)^2}{(63{,}360)^2} = 8.071 \text{ sq. mi.}$$

7. $RF = \dfrac{\text{photo distance}}{\text{ground distance}} = \dfrac{0.005''}{24''} = 1{:}4{,}800$

and, $\dfrac{1}{4{,}800} = \dfrac{0.5'}{\text{altitude}}$; Altitude = 2,400 ft.

8. From Table 3-1 in the Manual, the formula for acres/sq. in. is

$$\frac{(11{,}000)^2}{6{,}272{,}640} = 19.29$$

Field is 1.5 × 3 in. = 4.5 sq. in.; 19.29 × 4.5 = 86.805 a., and 86.805 ÷ 2.47 = 35.144 ha

**Exercises 6, 7, 8, 9, 10, 11**
No standardized solutions.

**Exercise 12**
Number 3
Reason: Areas 1 and 2 were flooded by the waters of Lake Estancia during Pleistocene and early Holocene times.

**Exercise 13**

**Problem set A**

1. $834 \text{ cm} \times \dfrac{1}{100} = 8.34 \text{ m}$

$1742 \text{ mm} \times \dfrac{1}{1{,}000} = 1.742 \text{ m}$

$1423 \text{ dm} \times \dfrac{1}{10} = 142.3 \text{ m}$

16 km × 1,000 = 16,000 m

2. 32.6 km × 1000 × 1000 = 32,600,000 mm
3 m × 1,000 = 3,000 mm
143 cm × 10 = 1,430 mm

3. 456 in. × 0.0254 = 11.58 m
4. 43.5 ft. × 30.48 = 1325.88 cm

**Problem set B**

1. $10 \text{ cm} \times \dfrac{1}{100} \times 39.37 = 3.9370 \text{ in.}$

3 15/16 in. = 3.9375 in.; difference = 0.0005 in.

2. 174 cm × 0.3937 = 68.50 in.
3. 72 kg × 2.2 = 158.4 lb.
4. 105 mi. × 1.6 = 168 km

**Problem set C**

1. 2.5 in. × 2.54 = 6.350 cm
   1.8 in. × 2.54 = 4.572 cm
   3.0 in. × 2.54 = 7.620 cm
2. 1.3 lbs. × 0.45 = 0.585 kg
   0.585 kg × 1000 = 585 g
3. 7.5 × 0.4047 = 3.04 ha
4. 1 sq. mi. = 640 a  640 ÷ 2.47 = 259.1 ha

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As the Nation's principal conservation agency, the Department of the Interior has responsibility for most of our nationally owned public lands and natural resources. This includes fostering the wisest use of our land and water resources, protecting our fish and wildlife, preserving the environmental and cultural values of our national parks and historical places, and providing for the enjoyment of life through outdoor recreation. The Department assesses our energy and mineral resources and works to assure that their development is in the best interests of all our people. The Department also has a major responsibility for American Indian reservation communities and for people who live in Island Territories under U.S. administration.