

# REMOTE SENSING

## Practical Exercises on Remote Sensing in Archeology



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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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# 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.

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# 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 1/4-second exposure? \_\_\_\_\_
4. What would be the focal length (in mm) of a "normal angle" lens having a negative format of 2 1/4 in. by 2 1/4 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
_____	_____	_____	_____
_____	_____	_____	_____
_____	_____	_____	_____
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 disadvantages 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.)

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## Exercise 2

### A Test of Stereoscopic Perception

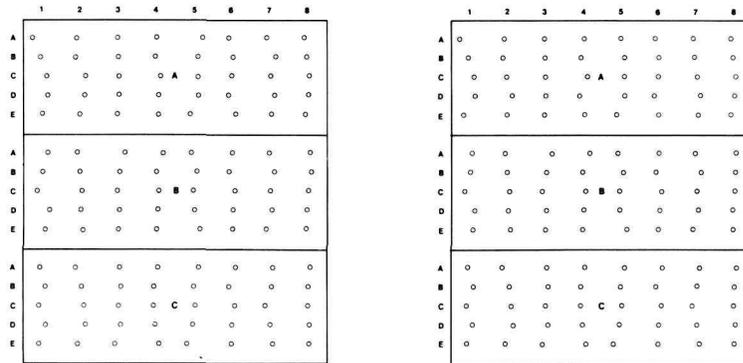
References: Handbook, section 2.

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	



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 per-  
cent): \_\_\_\_\_  
Forward overlap deficient (less than 50 per-  
cent): \_\_\_\_\_  
Sidlap excessive (over 45 percent): \_\_\_\_\_  
Sidlap deficient (less than 15 percent): \_\_\_\_\_  
Improper print alignment: \_\_\_\_\_  
Tilted photographs (check ends of flight  
lines): \_\_\_\_\_



## 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

- 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= \_\_\_\_\_
- 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= \_\_\_\_\_
- 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.
- 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.
- 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.
- How many sq. mi. are covered by 9 in. by 9 in. photographs at scales of:
  - 1:5,000? \_\_\_\_\_ sq. mi.
  - 1:10,000? \_\_\_\_\_ sq. mi.
  - 1:20,000? \_\_\_\_\_ sq. mi.
- 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.
- A cultivated field measures 1.5 in. by 3 in. on a photograph taken at a scale of 1:11,000. How many a \_\_\_\_\_ a  
How many ha.? \_\_\_\_\_ ha



# 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

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







## 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:

- Flying height above ground and height above *mean sea level*.
- Direction and number of flight lines
- Ground distance between flight lines
- Actual percent of sidelap
- Map distance between flight lines
- Ground distance between exposures on each line
- Map distance between exposures on each line
- Number of exposures on each line and total number of exposures.

### Flight Map Computations

- a. Flying height above ground datum:

height = focal length  $\times$  scale denominator,  
or

$$H = 0.5 \text{ ft.} \times 15,840 = 7,920 \text{ ft. above ground}$$

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  $0.70 \times 11,880 = 8,316$  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)  $\div$  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.):

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

- 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  $0.40 \times 11,880 = 4,752$  ft.
- g. Map distance between exposures on each line:

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

- 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  $\times$  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:
- Flying height above ground datum \_\_\_\_ ft.  
Flying height above MSL \_\_\_\_\_ ft.
  - Direction of flight lines \_\_\_\_\_  
Number of flight lines \_\_\_\_\_
  - Ground distance between flight lines \_\_\_\_ ft.
  - Actual percent of sidelap \_\_\_\_\_ percent
  - Map distance between flight lines \_\_\_\_ in.
  - Ground distance between exposures on each line \_\_\_\_\_ ft.
  - Map distance between exposures on each line \_\_\_\_\_ in.
  - 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				



## 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.

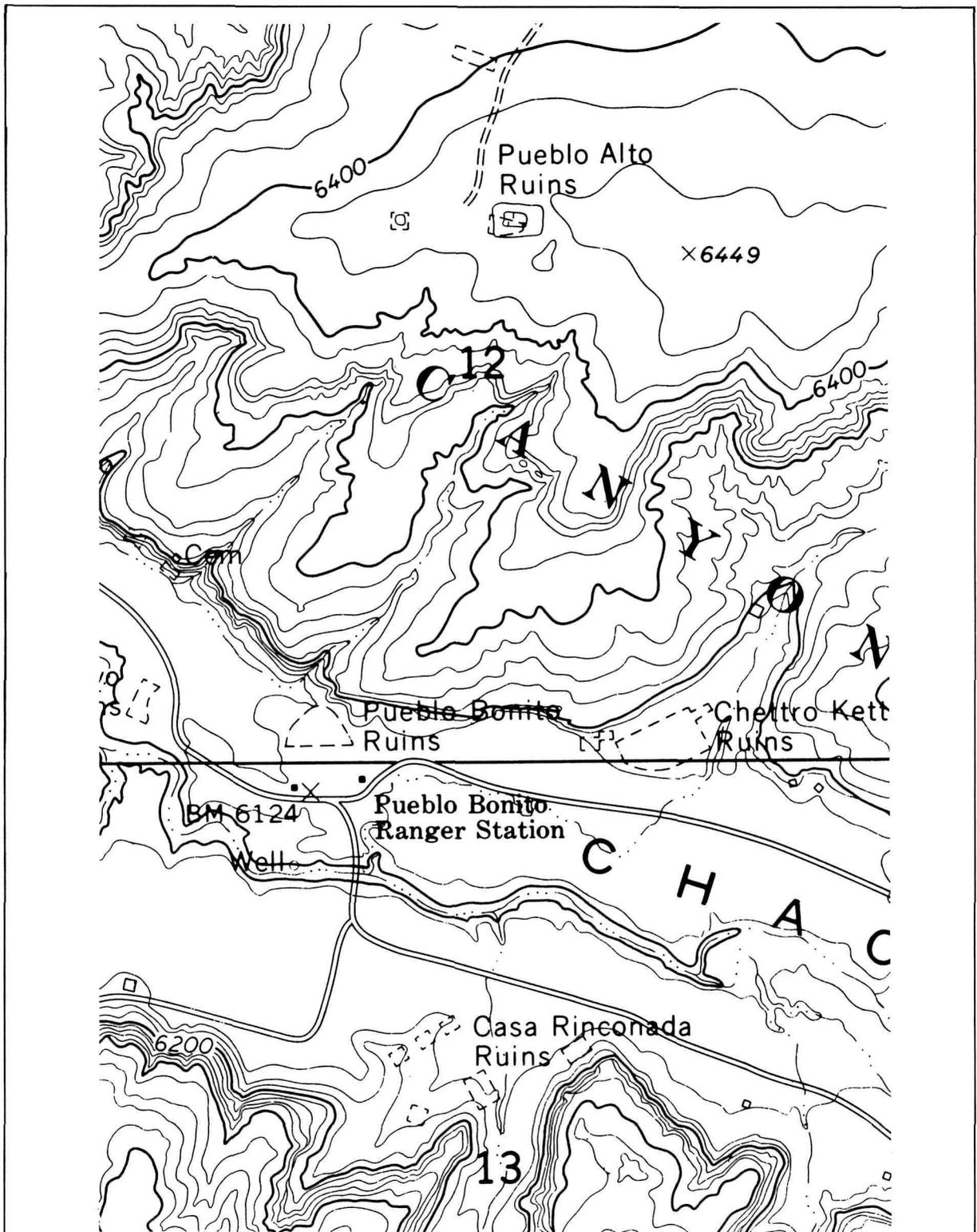
On Figure 3, Point X is the hypothetical location of a lithic scatter which cannot be directly identified on Figure 2. Note, however, that its location can be accurately plotted on Figure 2 by determining the scale of the image and by reference to the nearby cliff, large pueblo ruin, and vegetation pattern.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

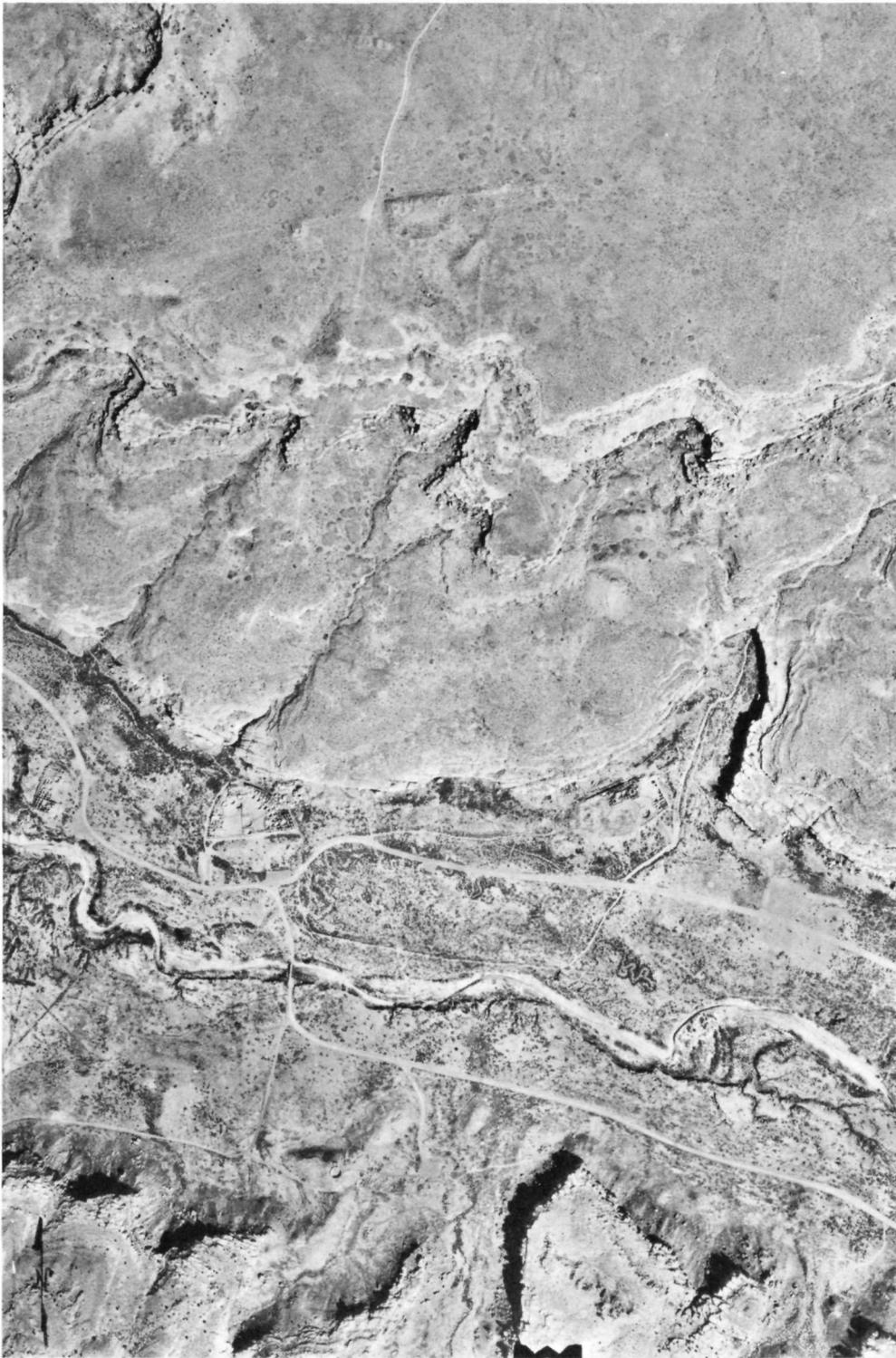
Figure 1 is a portion of a USGS topographic map. Transfer to Figure 1 some of the cultural and natural features you have identified on Figure 2 or on Figure 3 which do not appear on this USGS topographic map. Conversely, identify on the photograph features on the USGS topo map such as the cemetery, ruins,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

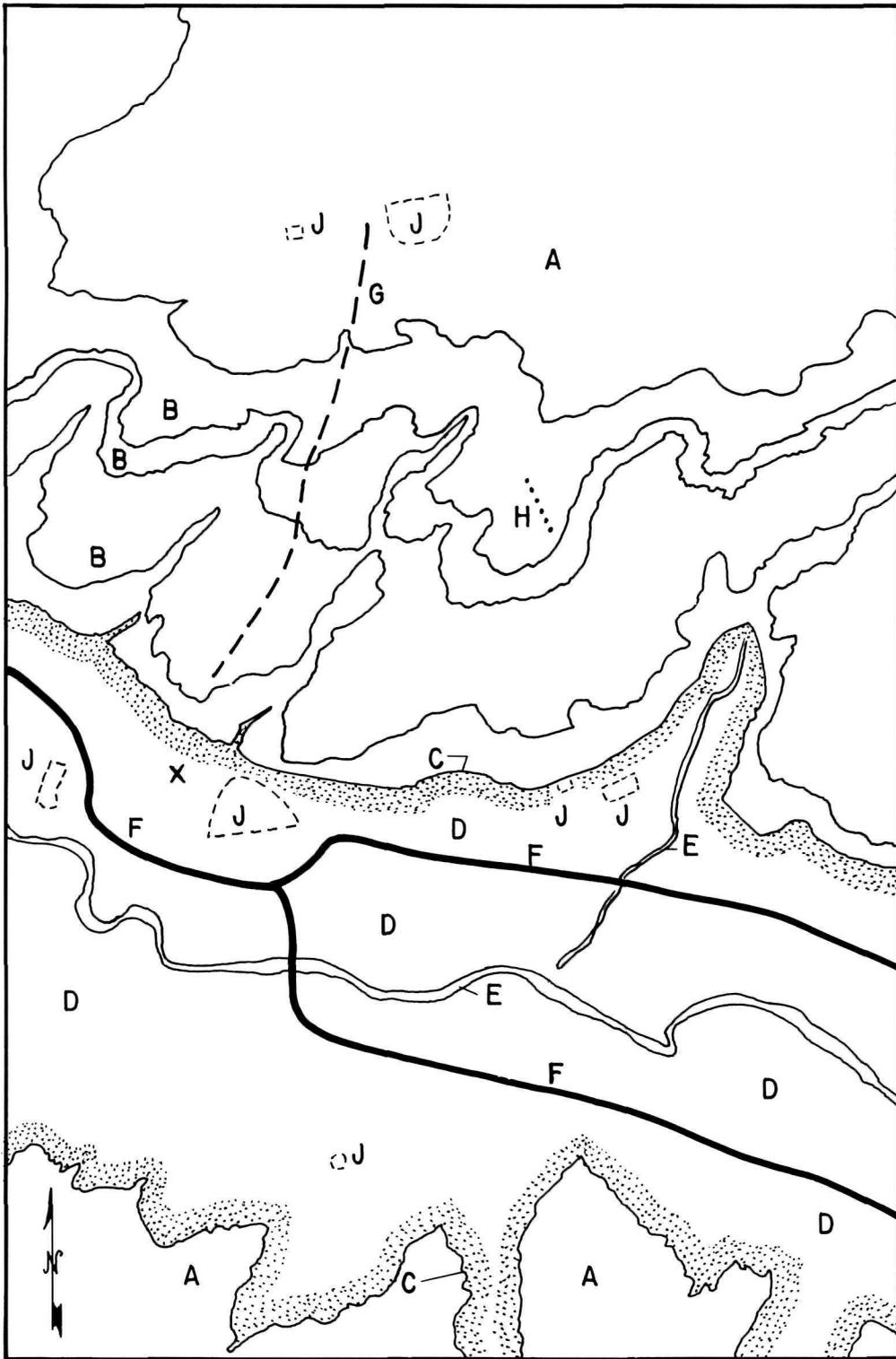
Refer to Section 8 and Figure 8-8 in the Handbook. Where would you anticipate locating the longest cultural sequence? 1) In the vicinity of the playa lakes? 2) On the beach terraces? 3) To the right or east of the beach terraces? Why?



**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  $\frac{15}{16}$  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.  $f/ = 70 \div 20 = f/3.5$
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  $f/\text{stop}$  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	$f/\text{stop}$
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

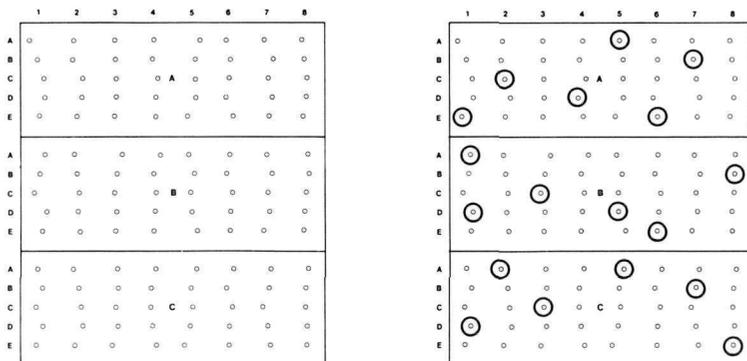
Winter	Dormant season	Easy separation of evergreen vs. deciduous vegetation	Difficult to accurately measure leafless vegetation
Spring	Light green, immature	Good contrast in pigments and leaf structure	Hard to capture uniform colors over wide areas
Summer	Dark green pigmentation	All plants in a given 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 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.

<b>A</b>	1	2	3	4	5	6	7	8	
<b>B</b>	1	2	3	4	5	6	7	8	
<b>C</b>	1	2	3	4	5	6	7	8	<b>Block A</b>
<b>D</b>	1	2	3	4	5	6	7	8	
<b>E</b>	1	2	3	4	5	6	7	8	
<b>A</b>	1	2	3	4	5	6	7	8	
<b>B</b>	1	2	3	4	5	6	7	8	
<b>C</b>	1	2	3	4	5	6	7	8	<b>Block B</b>
<b>D</b>	1	2	3	4	5	6	7	8	
<b>E</b>	1	2	3	4	5	6	7	8	
<b>A</b>	1	2	3	4	5	6	7	8	
<b>B</b>	1	2	3	4	5	6	7	8	
<b>C</b>	1	2	3	4	5	6	7	8	<b>Block C</b>
<b>D</b>	1	2	3	4	5	6	7	8	
<b>E</b>	1	2	3	4	5	6	7	8	

**Exercises 3 and 4**

No standardized solutions.

**Exercise 5**

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

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

3. 

<u>For 6" focal length</u>	<u>For 12" focal length</u>
$\frac{1}{15,840} = \frac{0.5}{H - 1,500}$	$\frac{1}{15,840} = \frac{1.0}{H - 1,500}$

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'

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

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. $\frac{\text{Scale } 1:5,000}{(9'' \times 5,000)^2}$	b. $\frac{\text{Scale } 1:10,000}{(9'' \times 10,000)^2}$
$\frac{1}{(63,360)^2}$	$\frac{1}{(63,360)^2}$
= 0.504 sq. mi.	= 2.018 sq. mi.

c. 
$$\frac{\text{Scale } 1:20,000}{(9'' \times 20,000)^2}$$
$$\frac{1}{(63,360)^2}$$
$$= 8.071 \text{ sq. mi.}$$

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

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

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

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

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

$$16 \text{ km} \times 1,000 = 16,000 \text{ m}$$

2.  $32.6 \text{ km} \times 1000 \times 1000 = 32,600,000 \text{ mm}$   
 $3 \text{ m} \times 1,000 = 3,000 \text{ mm}$   
 $143 \text{ cm} \times 10 = 1,430 \text{ mm}$

3.  $456 \text{ in.} \times 0.0254 = 11.58 \text{ m}$

4.  $43.5 \text{ ft.} \times 30.48 = 1325.88 \text{ cm}$

**Problem set B**

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

$$3 \frac{15}{16} \text{ in.} = 3.9375 \text{ in.}; \text{ difference} = 0.0005 \text{ in.}$$

2.  $174 \text{ cm} \times 0.3937 = 68.50 \text{ in.}$
3.  $72 \text{ kg} \times 2.2 = 158.4 \text{ lb.}$
4.  $105 \text{ mi.} \times 1.6 = 168 \text{ km}$

**Problem set C**

1.  $2.5 \text{ in.} \times 2.54 = 6.350 \text{ cm}$   
 $1.8 \text{ in.} \times 2.54 = 4.572 \text{ cm}$   
 $3.0 \text{ in.} \times 2.54 = 7.620 \text{ cm}$
2.  $1.3 \text{ lbs.} \times 0.45 = 0.585 \text{ kg}$   
 $0.585 \text{ kg} \times 1000 = 585 \text{ g}$
3.  $7.5 \times 0.4047 = 3.04 \text{ ha}$
4.  $1 \text{ sq. mi.} = 640 \text{ a}$   $640 \div 2.47 = 259.1 \text{ ha}$



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.

