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USES OF AIRPHOTOS FOR RURAL AND URBAN PLANNING

RICULTURE HANDBOOK NO. 315 U.S. DEPARTMENT OF AGRICULTURE ECONOMIC RESEARCH SERVICE

PREFACE

Rural and urban planning for the best use of natural resources is increasingly important in this country. Airphotos are a valuable tool for planners; they can be used in many ways, such as in preparing land-use maps, measuring the size of a lake or a field, selecting a school site, inventorying recreation facilities, and determining change in rate of land use. Using airphotos can save time and money, and improve accuracy of studies on which plans are based. This handbook describes how airphotos are made, and how two disciplines based on airphoto use--photogrammetry and photo interpretation--aid in preparing plans for rural and urban development.

The sources of all illustrations in the handbook are in appendix table 7.

The author received help from many people during the preparation of this handbook. Information about the availability of aerial photography was supplied by William J. Dale and Louis R. Custidero, U.S. Geological Survey; Howard D. Wolfe, U.S. Coast and Geodetic Survey; Charles E. Taylor, National Archives and Records Service; and in the Department of Agriculture, Mrs. Thelma P. Link, Agricultural Stabilization and Conservation Service; Bowman Porter, Forest Service, and Ralph M. Hooper, Soil Conservation Service. K. P. Harris, Agricultural Stabilization and Conservation Service; Ivan Hanson and William J. Donovan, Economic Research Service; Alan Lord, University of Pennsylvania; and E. B. Peterson, American Institute of Planners, provided background information.

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Summary

Airphotos have almost unlimited uses for both rural and urban planning. Two major uses of aerial photography are photogrammetry (for making reliable distance, size, and height measurements) and photo interpretation (for identifying objects and judging their significance).

Typical applications of these techniques in planning include preparing base maps, helping delineate areas where soil is unsuitable for intensive development, measuring the acreage of a lake surface, selecting a school site, determining the rate of change from rural to urban land uses, making a count of the total number of parked or moving automobiles in a city business area at one particular moment, and illustrating planning reports. Actually, the use of airphotos in planning is limited only by the training, imagination, and ingenuity of planners themselves.

There is great variety in the types of aerial photographs in general use. Airphotos may be vertical or oblique; they may be in black and white or in color. Airphotos may be square or rectangular; and they may show a small area in great detail or a large area in limited detail.

Both natural and manmade features can be identified and measured on airphotos. The level of detail discernible varies with and depends on the quality and the scale of the airphoto. On a small-scale airphoto or mosaic, such as 1:250,000, one can identify general land forms and drainage patterns, and distinguish between urban and rural areas. On airphotos having a scale of 1:20,000, natural features such as hills, valleys, and streams, and detailed land uses such as orchards, schools, gasoline stations, and swimming pools can be readily identified. At a scale of 1:4,800, the dimensions of buildings can easily be measured.

For compilation of accurate base maps and airphoto mosaics, high-quality airphotos, expensive equipment, and highly skilled technicians are needed. For most other uses of airphotos--such as bringing a land-use map up to date, measuring the size of a field, or choosing possible sites for a recreation area--good airphotos are needed, but only inexpensive equipment is necessary. The variety in the background, knowledge, and training of staff members of a planning office will often be sufficient for them to make the needed photo interpretation and measurements. However, if the experience of staff people acting as photo interpreters is not directly related to the study topic, it would be advisable to have the interpretation done by a specialist. False interpretation may be far more costly than hiring consultants or letting a contract for the work.

Airphotos are available at reasonable cost from many Federal, State, and local agencies, and from commercial firms. The use of airphotos for only one study can often save enough time to justify the cost of the photography. In addition, even a single set of airphotos of suitable scale can be used for many purposes, thus reducing the cost per use still further.

If existing photography is not suitable, then a contract would have to be written for a commercial aerial photographic firm for new photography. Before ordering, it is helpful to compile a list of all uses the aerial photography is likely to serve and to group these uses according to both priority of need and probable time of use. Consideration must be given to the types of qualitative data needed from the airphotos, and to the kinds of measurement and levels of accuracy that will be needed, whether such measurements are to be made from the airphotos themselves, from maps to be prepared by photogrammetric methods, or from airphoto mosaics.

If several agencies in one geographic area can use airphotos of the same type and scale, a joint contract for flying the photography can save each agency money. Even if airphotos of different areas or different scales are needed, grouping the orders may reduce the cost. In addition, coordinating requirements for airphotos would prevent needless and costly overlaps in orders, leading to further savings.

Uses of Airphotos for Rural and Urban Planning

by

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Introduction

Airphotos are an excellent and versatile tool for both rural and urban planning. Used properly, airphotos can help planners save both time and money, improve the accuracy of their work, and help them explain to the public the problems of change and the benefits of good planning for rural counties, small towns, cities, and metropolitan areas.

Airphotos can be used for any of a number of single and interrelated purposes. These might be preparing a new base map, delineating watersheds, identifying present land uses, determining the rate of land-use change, inventorying recreation facilities, helping to delineate areas where soil is unsuitable for intensive development, bringing obsolete maps up to date, determining extent of flood damage, estimating utilities and services needed in a developing area, making traffic and parking surveys, inventorying slum buildings, selecting sites for new parks and firehouses, preparing general plans such as those for neighborhoods, preparing precise plans such as those for sewers and streets, or illustrating planning reports. The remarkable versatility of airphotos as a planning tool needs more widespread recognition.

This handbook describes ways in which airphotos are useful to planners; it also provides information about existing airphotos and ways to order both available and new photography.

DEFINITIONS

Airphotos

Airphotos are any photographs taken from the air. The quality of airphotos is continually being improved, and additional uses for them continue to be found.

Photogrammetry and photo interpretation are major uses of airphotos. Both can be very helpful to planners.

Photogrammetry

Photogrammetry is defined in The Manual of Photographic Interpretation (2, p. 851)[1] as "the science or art of obtaining reliable measurements by means of photography." Maps and charts, which are important tools for planning, are made or brought up to date accurately and quickly, and (compared with conventional ground survey techniques) relatively inexpensively by photogrammetric methods. Another use of photogrammetry that is of increasing importance to planners is the securing of quantitative land-use data directly from airphotos.

Photo Interpretation

The term "photo interpretation" has been defined in many different ways. The simplest and clearest definition is: "The act of examining photographic images for the purpose of identifying objects and judging their significance" (2, p. 852). Photo interpretation involves step-by-step methodical procedures which are briefly described on pages 31 and 32 in this report.

Mosaics

A mosaic is "an assemblage of overlapping aerial photographs whose edges have

[1] Underscored numbers in parentheses refer to the Selected References, p. 24.

been matched to form a continuous photographic representation of a portion of the earth's surface" (2).

There are three types of mosaics: uncontrolled, semicontrolled, and controlled.

Uncontrolled mosaics are compiled so that most image details of the individual airphotos match. These mosaics usually contain errors in both position and scale; reliable measurements cannot be made from them. The relationship of the image of one object to another on the airphoto may be somewhat different than the true geographical relationships of the objects, and both distances and size of images may be distorted.

Semicontrolled mosaics are constructed so that image details match, and errors in position and scale are distributed systematically over the entire mosaic. These errors are not great and therefore are difficult to perceive. Semicontrolled mosaics are adequate for general land-use and other studies, but they should not be used for mapping or for other work requiring accurate measurements.

Controlled mosaics are compiled from airphotos rectified to eliminate distortions caused by tilt; they are constructed so that image details are well matched, and position and scale errors do not exceed specified limits. Within these limits, precise measurements can be made from controlled mosaics.

Since 1958, the Soil Conservation Service (SCS) of the U.S. Department of Agriculture has been using controlled aerial photomosaics as the background or map base on which soil boundaries and symbols are printed in red and certain cultural features (such as roads, houses, and schools) are printed in black. Most of these soil maps are at a scale of 1:20,000. The mosaics, of course, provide details of natural and cultural features that are not shown on ordinary line maps, yet the photomosaic soil maps are less expensive to prepare. A portion of a photomosaic soil map is shown in figure 3.[2]

Photo-Index Sheets

Photo-index sheets are a type of uncontrolled mosaic. Most index sheets are compiled so that the upper right corner of each photo (which indicates the area identification symbol, the roll number, and the print number) is shown. A portion of a photo-index sheet is shown in figure 7. Access to an index sheet of available photography is helpful if one wishes to select and order prints of a number of airphotos. After the prints are received, the photo-index sheet provides a working index to this collection of airphotos. If prints of available photography are ordered, and a photo-index sheet for this photography is not available, it is desirable and easy to prepare an index.[3]

Index sheets are very inexpensive and generally cost less than prints of comparable scale of other mosaics. They are quite useful for obtaining information about land use, but should not be used for measurement.

APPLICATIONS OF AIRPHOTOS

Included among the many applications of airphotos for planning are the following:

a. The airphoto itself may be used as a type of map.[4]
b. The airphoto, with identifying marks and annotations shown on the photo itself or on an overlay, may be used as a map base.
c. A number of overlapping airphotos may be connected to form an airphoto mosaic (figs. 7 and 14).
d. One or more airphotos may be used as information and education devices.

Photogrammetry has two basic types of uses for planning: Measurement and mapmaking.

Planners can use relatively simple photogrammetric methods to ascertain data such as the length and slope of shoreline at sites considered for a waterfront park, the number of square feet (and the approximate number of parking places) in center city

[2] The airphotos used by SCS as field worksheets are generally at a scale of 1:15,840 (1" = 1,320'). All airphotos in the report are grouped starting on p. 13.

[3] To prepare an index, lay the prints out in order by flight line on a large piece of cork or wallboard. Place the prints in approximately correct positions (so that roads are a continuous line rather than a broken line, for example), and in such fashion that the identification symbols on each print can be seen. Fasten the prints with small pins or staples. Photograph this crude mosaic, using fine-grain film and a camera producing the largest possible format. Have enlargements made from the negative so that an individual print in the index is large enough for images of large buildings, streets, and so forth, to be distinguished (as in fig. 7).

[4] A map should show scale and directional orientation; an airphoto is not constant in scale.

parking garages, the total unused acreage (and estimated number of burial plots) in all cemeteries in a region, and the heights of trees and buildings in airport approach and takeoff patterns.

Planners make extensive use of topographic or planimetric maps, many of which were compiled or brought up-to-date by photogrammetric methods. In topographic maps, the emphasis is on depicting land forms (i.e., changing land elevations), while planimetric maps accent the land-use detail. New maps prepared for special purposes, such as topographic maps of routes for extension of water and sewer pipelines and large-scale planimetric maps of central business districts, often can be made more quickly and cheaply using photogrammetry rather than land-survey methods.

Some planners have found aerial photo interpretation a very helpful technique for such diverse purposes as traffic surveys, inventories of outdoor recreation facilities, and estimates of the rate of change from rural to urban land uses. A frequent use of airphotos and photo interpretation is checking the accuracy of maps, which often are out of date.

Photo-index sheets, mosaics, and airphotos are useful both in the office and in the field. In the office, they are an excellent means of becoming familiar with the general area, and are very useful for study of a relatively small area before fieldwork is commenced. In the field, they are used first for orientation, and then to verify land uses, delineate and code land uses, note changes in land use since the photography was flown, and so forth.

USE OF AIRPHOTOS CAN SAVE TIME AND MONEY, AND IMPROVE ACCURACY

The use of airphotos and airphoto techniques for many aspects of planning studies for both rural and urban areas saves time, costs less than alternative methods, and makes greater accuracy possible. For example, use of airphotos for mapping can, for many areas, save 75 percent or more of the time needed if only ground-survey techniques were used. The cost of having new airphotos made for this purpose is more than offset by the overall savings.

SCS estimates that field use of airphotos for soil surveys for farm and ranch planning, watershed planning, and the like, provides a tremendous saving in time and cost as well as great improvement in the degree of accuracy. The use of airphoto mosaics rather than planimetric or topographic maps as bases for the soil maps included with soil survey publications provides additional savings in both time and direct costs, and in addition makes possible greater precision in soil mapping. Stereopairs of airphotos are also used in producing topographic maps with small contour intervals; these are used to great advantage for many engineering applications.

The Agricultural Stabilization and Conservation Service (ASCS), U.S. Department of Agriculture, uses airphotos to check farmers' compliance with farm programs for which they have agreed to plant within specified acreage allotments. The photographs are taken to the farms, fields and crops are identified, and measurements are made to establish new field boundaries when necessary. The photographs are then returned to the county ASCS office, where acreage is determined by using planimeters. Without airphotos, ASCS could not do its work within the time limits imposed by the length of the growing season and program requirements.

The Forest Service (FS), U.S. Department of Agriculture, uses aerial photography for many purposes. These include topographic mapping of forest areas, tentative selection of sites for forest roads and bridges, forest recreation research, and recreation area planning. Special-purpose color airphotos are sometimes used to assess damage caused by forest insects. A major use of air photos is for forest inventory; this includes selecting the points to be sampled, locating the points on the ground, and using the airphotos as part of the permanent record so that the location of the same sample points can be found for remeasurement of the trees to determine growth or mortality. Aerial photography also is used for preliminary evaluation of areas to be logged. In each of these uses, aerial photography saves the Forest Service time and money.

START WITH THE MOST ECONOMICAL MATERIALS

Although it is desirable to use only up-to-date, accurate maps or controlled mosaics for measurement, it is not always possible to stretch a small budget enough to pay for these. Instead, compromises must be made.

It is useful to list the kinds of qualitative information needed, the types of measurement that must be made, and the required level of accuracy of these measurements. This list might make it apparent that there is no real need for great precision in measurement at the outset of a planning program and, instead, that the principal needs are to know the types of land uses in the area, what is located where, the geographic relationships between land uses, the intensity of land use, and the approximate acreage in various land uses. If so, airphoto index sheets, together with planimetric or topographic maps and other available materials, would be adequate sources of data for the initial stages of planning.

Later in the planning process, it may be necessary to bring the available maps up to date. This can be done rather quickly but somewhat crudely by transferring to the maps details from recent airphotos or even photo-index sheets. An alternative would be to make an uncontrolled mosaic, using only the center portions of contact prints (because there are fewer distortions and scale is more accurate in the center) of recent aerial photographs and assembling the prints so that there is the least possible amount of visible distortion (for example, matching lines so that roads are straight, not zigzag).

Still later in the planning process, more accurate measurements of total acreages in various land uses and estimates of the size of various parcels of land may be needed. Photo-index sheets, uncontrolled mosaics, contact prints, and similar materials are too crude for such use. Scaled maps brought up to date with little concern for precise measurements of the added data also would be misleading. At this stage, measurements with the needed accuracy could be obtained by using ratioed prints (reduced or enlarged to a specific scale) of the latest available photographs.

As soon as the budget warrants it, and at least by the time it becomes necessary to have both up-to-date and accurate inventories, measurements, and so forth, new aerial photography should be ordered and a controlled mosaic should be compiled from this photography or, for greatest accuracy, a planimetric or topographic map should be prepared from the aerial photography by photogrammetric methods. These three tools are the best means of acquiring up-to-date data quickly, accurately, and at costs relatively low compared with alternative sources of comparable data.

Types of Airphotos in General Use

PHOTO ANGLES

Airphotos are taken from either approximately vertical or oblique angles. Both have special uses.

Vertical airphotos are taken with the optical axis of the camera at a 90-degree angle or as nearly vertical as practicable to the earth's surface. Verticals are used for photogrammetric mapping because they contain a minimum amount of scale distortion. They are also used for compiling photomosaics and for photo interpretation (figs. 4-6, 8-13).

Oblique airphotos are taken with the optical axis of the camera at an angle less than 90 degrees to the earth's surface. There are two types of obliques--high and low. The adjectives, high and low, refer to the optical axis of the camera rather than to the altitude from which the photo was taken. When high obliques are taken, the camera is pointed high enough for the photo to include the horizon. Low obliques are taken with the camera axis pointing lower, or more nearly vertical, and the horizon does not show on the photo. High obliques are used more frequently than low obliques; therefore, the term oblique used without the adjective usually refers to high obliques.

Both high and low obliques are excellent as planning information devices because the viewer can readily see the relationship of one image to another. Low obliques are useful for some interpretation purposes, but high obliques are of very limited usefulness for interpretation because more images are obscured (see figs. 1 and 2). Another disadvantage of obliques is that it is extremely difficult to use them for measurement. Because of perspective, scale within the airphoto varies greatly; nearer objects appear much larger than more distant ones. Also, images of the nearer objects are quite distinct, but those in the distance may blend together so that it is impossible to differentiate one object from another.

FILM TYPES

A variety of film types are now available, but comparatively few are in general use. Panchromatic film (black and white) is used most often because it is adequate for many purposes (see figs. 1-14). A yellow filter (sometimes called a minus-blue filter) generally is used with panchromatic film to diminish the effects of haze. Panchromatic is the most useful film for planners. It is also the least expensive type of film.

Planners will find prints from infrared (black and white) films revealing and very useful for forest and other vegetation studies, and for certain soil and water studies (including water-course delineation, soil erosion, and water pollution studies). Infrared should not be used for other land-use studies because little or no detail in shadows is discernible, and because differences in atmospheric humidity produce misleading changes in greyness. Various combinations of filters with panchromatic and infrared films are useful for special studies.

Use of color photography has been rather limited. Until recently the slow film speed (requiring full sunlight for correct exposure) and the high cost of aerial color films virtually precluded their use except for experiments. Now, the speed of aerial color film is the same as that of ordinary aerial panchromatic film; therefore, exposures of color film can be made under the same conditions as panchromatic film. The difficulties of handling color transparencies rather than prints, the difficulties and high cost of making color prints, and the high cost of color film itself continue to make it impractical at present for airphoto coverage of large areas. Planners should, however, be aware of the advantages of color photography, which may make it worth the difficulties and additional expense for special-purpose coverage of areas of limited size. Also, it is probable that technological changes, together with increased use of aerial color film, will result in lower cost of both film and prints within the next few years.

Color reversal film (which after processing is a transparency like the color slides made by amateur photographers) and prints from color reversal film are easier to interpret than prints from black-and-white film, because the viewer is accustomed to seeing features in color and also because characteristics not visible on black and white photographs are apparent on color photographs. Landforms, cultural features, vegetation, variation in soil types, variation in water depths, drainage patterns, and other images often are recognized and studied most easily on color photographs.

Other films are presently of limited usefulness to planners. However, two are useful for special-purpose studies. Orthochromatic film (black and white) would be useful to show underwater obstructions in harbors, rivers, and along shorelines. Camouflage detection film, a color reversal film, is sensitive to infrared radiation and shows differences in infrared reflectance in false-color rather than in black and white. For example, green vegetation appears as a reddish hue, and objects painted green to camouflage them as vegetation appear as purple, blue, or gray. Recently, the Forest Service has been cooperating with a film manufacturer to improve the infrared detection qualities of camouflage film. The new infrared aerial color film is being tested to determine its potential applications for detecting differences between healthy and diseased or insect-infested trees. It seems probable that additional applications of this new film will be found. [5]

FORMAT

Most aerial cameras make photos having a square format, usually 9 inches, although increasing use is being made of larger square formats. Because distortion increases toward the edges of the photo area, it is easy and not excessively expensive to reduce distortion by using a 9- by 9-inch square from the center of a 12- or 18-inch square negative. The reduction of distortion is especially important for vertical airphotos used for mapping and measurement, because distortion causes inaccuracy.

At any given scale, obliques having a rectangular format of 9 by 18 inches would sometimes be more useful to planners than obliques of 9 by 9. Relationships between the rural-urban fringe and the city center, for example, could be more readily shown on the wider and larger format.

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[5] Infrared color and regular color photographs illustrate city planning problems. Sweep of Creative Power. In LIFE 59 (26): 70-91, Dec. 24, 1965.

PRINT TYPES

Aerial photographs usually are printed on photographic paper. Two thicknesses, or weights, of paper are used: single-weight and double-weight. Single-weight paper is thin and some kinds are easily cracked or torn. Prints on single-weight, low-shrink paper are usually used in compiling mosaics because it is easier to cut than double-weight and does not buckle, but double-weight is preferred if shrinkable paper is used. Mosaics generally are printed on single-weight paper. Double-weight paper is better than single-weight for prints that will be handled a great deal--such as those used in fieldwork. Enlargements of individual photos also are printed on double-weight paper. Improvements in plastics, and decreasing costs, have made it feasible to print aerial photographs on a polyester base. Prints on polyester are waterproof and do not tear easily; they are excellent for fieldwork. At present, only contact prints are available on polyester, and their cost is about 50 percent higher than the cost of contact prints on double-weight paper.

Photographs may have a shiny or dull surface. The former are called glossy prints; the latter are matte or semimatte prints. Single-weight paper used for aerial photographs may have a glossy, semimatte, or matte finish. Double-weight paper used for aerial photographs usually has a matte or semimatte finish. Prints on most polyester bases are semimatte in appearance. Images on glossy prints appear sharper than those on matte prints; this factor makes glossies more suitable for interpretation and for reproduction than matte prints. Matte- or semimatte-textured prints, however, are easier to mark with ink, colored pencil, or soft drawing pencil than are glossies, on which only special inks and grease pencil adhere reasonably well.

AIRPHOTO SCALES

The scale of photography is generally expressed in one of two principal ways: (1) as a ratio or a fractional scale, or (2) in feet or miles per inch.

The scale of airphoto negatives generally is expressed as a fractional scale, in which 1 inch on the airphoto is equal to a certain number of inches on the ground. This scale sometimes is shown as a fraction, e.g., 1/20,000, but usually is shown as a ratio, e.g., 1:20,000. The scale of negatives is determined by the lens focal length and the altitude of the camera above ground level.

The scale of contact prints[6] is sometimes expressed as a ratio or fraction, but the feet-per-inch scale is used more often. For example, although the negative scale of a photo is given as 1:20,000, usually the contact print scale is expressed as 1" = 1,667'. The scale of enlargements made from airphoto negatives also is expressed in feet per inch.

Mosaic and photo-index scales are shown in either fractional scales or miles per inch. Scales and their equivalents in feet per inch, inches per mile, miles per inch, acres per square inch, square inches per acre, and square miles per square inch are shown in appendix table 3.

If the type of film used, the altitude at which photography is flown, and other pertinent factors remain constant, the ground resolution or amount of detail shown in aerial photographs usually increases with the increase in the diameter and focal length of the lens used. An exception to this is the high-resolution, wide-angle lens recently developed by several firms. Focal lengths frequently used are 6, 8 1/4, 12, 24, and 36 inches. A 6-inch focal length lens is often used for topographic mapping. An 8 1/4-inch focal length lens is used for medium-altitude photography such as that used for Department of Agriculture land-use (1:20,000) and forest (1:15,840) studies. Lenses having a 12-inch or longer focal length are used for large-scale work requiring little relief distortion and displacement, such as photography of urban areas or rural areas having variable topography.

The negative scale of the photograph, the quality and focal length of the lens, and the type of film used are the principal factors determining the degree of enlargement feasible from a negative. The negative scale of the photographs should be suited to the use for which the photography is intended, whether it is stock bought from a firm or agency, or new photography flown for a specific planning project.

With each succeeding larger scale, more airphotos are needed to cover any given area. Thus, if all other factors are equal, the cost of coverage increases as the scale increases. Using a scale that is smaller than is needed results in less accurate work; a scale that is larger than necessary causes

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[6] Contact prints are made with the negative in direct contact with the printing paper and are the same size as the negative, usually 9 inches square.

unjustified expense and also additional work in using the extra airphotos.

Airphoto negative scales used for city planning range from about 1:1,200 to 1:4,800 (1'' = 100' to 1'' = 400') for studies in which detail is needed. Scales of 1:7,920 to 1:20,000 (1'' = 660' to 1'' = 1,667') usually are adequate for many larger area land-use studies. And scales of 1:36,000 (1'' = 3,000'), 1:63,360 (1'' = 1 mile), or even smaller scales are preferable for mapping and are also quite useful for many types of county, regional, or State planning studies. More information about the scales useful to planners, the purposes for which these scales are suitable, and the type of detail discernible at the various scales is shown in table 1.

Table 1.--Approximate airphoto scale ranges useful for planning and planning-related studies

Example of uses[1]	Level of detail discernible[2]
Scale 1:250,000	
Studies of land forms Studies of gross land use	Natural features: Mountain ranges Valleys Lakes Rivers Urban areas. Rural areas: Forests Farmland
Scale 1:96,000-1:126,720	
Studies of land forms Studies of gross land use	Includes all discernible at preceding scale Urban areas: Subdivisions Rural areas: Villages Reservoirs Transportation and communication: Airports Railroad yards Expressways and interchanges
Scale 1:62,500-1:70,000	
General land-use studies at State and regional levels Studies of watershed drainage patterns Studies of road and street patterns. Studies of rate of rural to urban land use change Preliminary site selection studies for new towns	Detail discernible at preceding scale. Natural features: Streams, Flood plains Ponds, Beaches Potholes, Rapids Swamps Urban land uses: Residential areas Industrial areas

See footnotes at end of table.

Table 1.--Approximate airphoto scale ranges useful for planning and planning-related studies--continued

Example of uses[1]	Level of detail discernible[2]
Scale 1:62,500-1:70,000	
Selection of possible sites for State or county parks Preliminary site selection studies for new highways	Urban land uses (continued): Commercial areas Parks and recreation areas Race tracks Rural land uses: Woodlots Cultivated fields Pasture or idle land Industrial complexes Transportation and communication: High-voltage electric transmission towers Pipelines Gas and oil storage tank farms
Scale 1:25,000-1:50,000	
Natural resources inventory Studies for reservoir site selection Study of potential water power	Detail discernible at preceding scale. Transportation: Railroads Highways Docks Shipyards Urban land uses: Subdivisions Shopping centers Mobile home parks Central business districts Drive-in theaters Stadiums Golf courses Rural land uses: Farms Nurseries Greenhouses Cemeteries
Scale 1:12,000-1:20,000	
Detailed land-use studies Mapping the distribution of one crop Housing market analyses Shopping center location studies Studies for selection of dam sites School site selection Farm land-use planning Erosion control studies	Detail discernible at preceding scale. Urban land uses: Residential Houses--single, duplex, row Apartment buildings Institutional Hospitals Churches

See footnotes at end of table.

Table 1.--Approximate airphoto scale ranges useful for planning and planning-related studies--continued

Scale 1:12,000-1:20,000	
Example of uses[1]	Level of detail discernible[2]

Soil mapping
Forest classification
Forest inventory
	Community facilities
	  Schools
	Commercial
	  Shopping areas
	  Gasoline stations
	Industrial
	  Factories
	  Warehouses
	Vacant land
	Rural land uses:
	  Nonfarm residential
	  Farmsteads
	    Houses
	    Barns
	  Cropland
	    Row crops
	    Close-grown crops
	    Pasture
	    Orchards
	    Vineyards
	  Idle land
	  Irrigation and drainage ditches
	Natural features:
	  Rivers
	  Sandbars
	  Streams
	  Ponds
	  Swamps, marshes
	Transportation and communication:
	  Roundhouses
	  Lanes
	  Streets
	  Parking lots
	  Bridges
	  Airports
	    Runways
	    Hangars
	    Administration buildings
	    Control towers
	  Pipelines
	    Pumping stations
	    Oil storage tanks
	    Gasometers
	    Water storage tanks
	Recreation areas:
	  Football fields
	  Baseball diamonds
	  Campgrounds
	  Swimming pools
	  Picnic grounds

See footnotes at end of table.

Table 1.--Approximate airphoto scale ranges useful for planning and planning-related studies--continued

Example of uses[1]	Level of detail discernible[2]
Scale 1:7,920	
Classification and inventory of buildings Count buildings Count railroad cars on a siding Highway route selection	Detail discernible at preceding scale
Scale 1:5,280	
Measure size of buildings Identify individual heavy industries	Detail discernible at preceding scale
Scale 1:2,400	
Measure size of railroad cars and automobiles	Detail discernible at preceding scale

[1] Information concerning the uses of various scales is based on interviews and on the author's own use of airphotos.

[2] Some airphoto interpreters claim that greater detail is discernible in each category; others believe less is discernible. The level of detail shown in each group is that which the author has been able to identify. The images were checked on single airphotos or airphoto mosaics. Viewing stereopairs through a folding stereoscope should enable anyone who is familiar with the size, shape, texture, tone, and pattern of any of these images to identify them at the indicated scales.

PHOTO TYPES

There are several ways in which aerial photographs are taken: (1) as single, or individual, photographs, with a different area shown on each photograph; (2) as a series, with portions of the same geographic area shown on successive photographs so that adjacent pairs of photos in the same flight line may be viewed stereoscopically; and (3) as continuous strips in which one exposure of the film provides a single picture. For illustrations and other non-stereoscopic uses the continuous-strip photograph would be the width of the film (either 2 1/4 or 9 inches) and as much as 500 feet long. For stereoscopic use, two simultaneous continuous exposures are made; each is half the width of the film. Each type can be taken from vertical or from oblique angles. Table 2 indicates the types of aerial photography useful for various planning and planning-related studies.

Single photographs of places or objects of interest may be taken from any desired altitudes or angles by either professional or amateur photographers. Airphotos taken as single photos cannot be used for measurement because the scale is unknown, ground control is absent, and there are distortions caused by tip and tilt of the camera. Single airphotos, however, are useful for qualitative and illustrative purposes.

Aerial photographs of an area may be taken in one or more continuous strips. If the airphotos are to be comparable, they should be taken from the same altitude and with a common angle of tilt, the latter being as nearly vertical as possible. Some overlap of area covered by one photograph with that covered by the next photograph is needed.

Vertical photography for stereoscopic use in photogrammetry or photo interpretation should be flown at a constant altitude and angle. The minimum overlap needed for stereoscopic coverage is 50-percent

Table 2.--Types of aerial photography useful for planning and planning-related studies

Type	Uses
Photo-index sheets	Select airphotos needed for study
Photo-index sheets and other uncontrolled mosaics	Obtain general impression of topography Obtain general impression of types of land use change by comparing mosaics of same area made from photography of different years Preliminary site selection for parks, schools, and so forth, from mosaics of recent photography Obtain general impression of types of land use and patterns of land use
Semicontrolled mosaics	Same as for photo index sheets and other uncontrolled mosaics Land use studies of large areas, such as States and regions, for which precise measurements are not needed
Controlled mosaics	Same as for semicontrolled mosaics Inventories of natural resources Inventories of land uses Base for map compilation Land use studies requiring precise measurements
Vertical airphotos	Preparation of new planimetric or topographic maps Compilation of mosaics Provide data for updating maps Inventories of natural resources, land uses, buildings, and so forth Site selection Land use studies Traffic counts As base "maps" for farm planning, delineation of soil boundaries, and so forth
Oblique airphotos	Illustrate relationships between land uses

Note: Level of detail discernible varies with quality and scale of the mosaics and airphotos.

forward lap (60-percent usually is advisable) and 20- to 35-percent side lap with adjacent strips. For stereoscopic viewing, a print of each of two adjacent, overlapping photographs in a strip is used. These are called a stereoscopic pair (stereopair). When the areas of overlap are viewed through a stereoscope, a three-dimensional effect is easily obtained. The stereoscope also magnifies images so they can be studied more readily.

Uses of Airphotos in Planning

The two principal uses of airphotos in planning have already been mentioned briefly: Photo interpretation and photogrammetry (the latter includes both measurement and mapping). Airphotos also have many uses as public information and education devices.

INTERPRETATION

Interpretation of airphotos is dependent on the recognition or identification of objects shown as images on the airphotos. Information about the steps used in airphoto interpretation is given in the following chapter. Here, let us consider the types of objects or features whose images can be identified and the types of planning studies for which photo interpretation is a useful tool.

Identifiable Features and Objects

Both natural and manmade features can be identified on good aerial photographs of appropriate scale.

Many natural features are readily recognized on airphotos. These include mountains, valleys, and plains; rivers, lakes, streams, ponds, and swamps; natural surface cover (which includes bedrock, loose rock, sand, and bare soil); and natural vegetation cover.

Man-made or man-changed features identifiable on airphotos include agricultural and other rural land uses, urban land uses, and transportation and communications facilities. Forests and agricultural land uses such as fields, orchards, and farmsteads are easily recognized. Differentiating between row crops (such as corn) and close-grown crops (such as wheat or barley) is relatively simple. Distinguishing pasture from close-grown field crops often is difficult. Naturally reseeded wooded areas generally appear quite different from those where seedlings were planted by hand. Orchards are recognized by the shape and height of the trees as well as by the pattern in which the trees are planted. Usually there is more ground space visible between the fruit trees in an orchard than there is between trees grown for timber. Farmsteads, each with its house, yard, garden, barn, and other buildings, are readily recognized, although the individual farmstead's pattern varies by geographic region and by type of farm.

Many other manmade features located in rural areas can be identified on airphotos. These include industrial complexes and isolated factories; estates; extractive industries (including oil and gas fields, quarries, and strip and deep mines) and other excavations (such as borrow pits); and irrigation or drainage canals, dams, and water impoundments.

Cities and towns are easy to distinguish, even on airphotos of quite small scales. Gross urban land uses, such as industrial, commercial, or residential areas, are easy to identify.

Many individual features in urban or rural areas can be readily recognized; others can be identified only through interpretation of significant clues. This process sometimes is called photo deduction, because one makes conclusions about the identity of an image by reasoning from the details that are known.

For example, some institutions (such as general hospitals and schools) are easily recognized from their images, but others cannot be identified so readily. For instance, a photo might include images of two buildings similar in size, shape, and type of location. If building A has a relatively large parking lot, is adjacent to a highway, and has a railroad siding, it can be deduced that building A is a factory. If building B has an adjacent playground, and there are no other clues to the building use, it probably would be deduced that the building is a school. However, caution is necessary since photo deduction is more susceptible to error than photo recognition. Building B might be an orphanage or a children's convalescent home.

Figure 1.--Templeton, Carroll County, Iowa, November 1961.

Figure 2.--Bowie, Prince Georges County, Md., October 1962.

Figure 1 demonstrates the usefulness of high obliques to illustrate the relationships between land uses--in this case, the relation between a village and its rural hinterland. Notice also that the grain storage bins and houses in the middle ground obscure structures behind them.

Figure 2, a low oblique, shows an area changing from rural to urban land use. Notice the apparent difference in size between houses in the foreground and those in the background.

Figure 3.--Portion of a soil survey map for Lehigh County, Pa. Scale 1:15,840.

This portion of a soil survey map of the Allentown-Bethlehem urbanizing area shows the wealth of detail that may be seen when a photomosaic, rather than a blank sheet of paper, is used as a map base. Notice the airport, the fields, the cemetery, the drive-in theatre, and the new subdivision. On the soil maps published by SCS, the cultural symbols are printed in black and the soil symbols and boundary lines between soil types are printed in red.

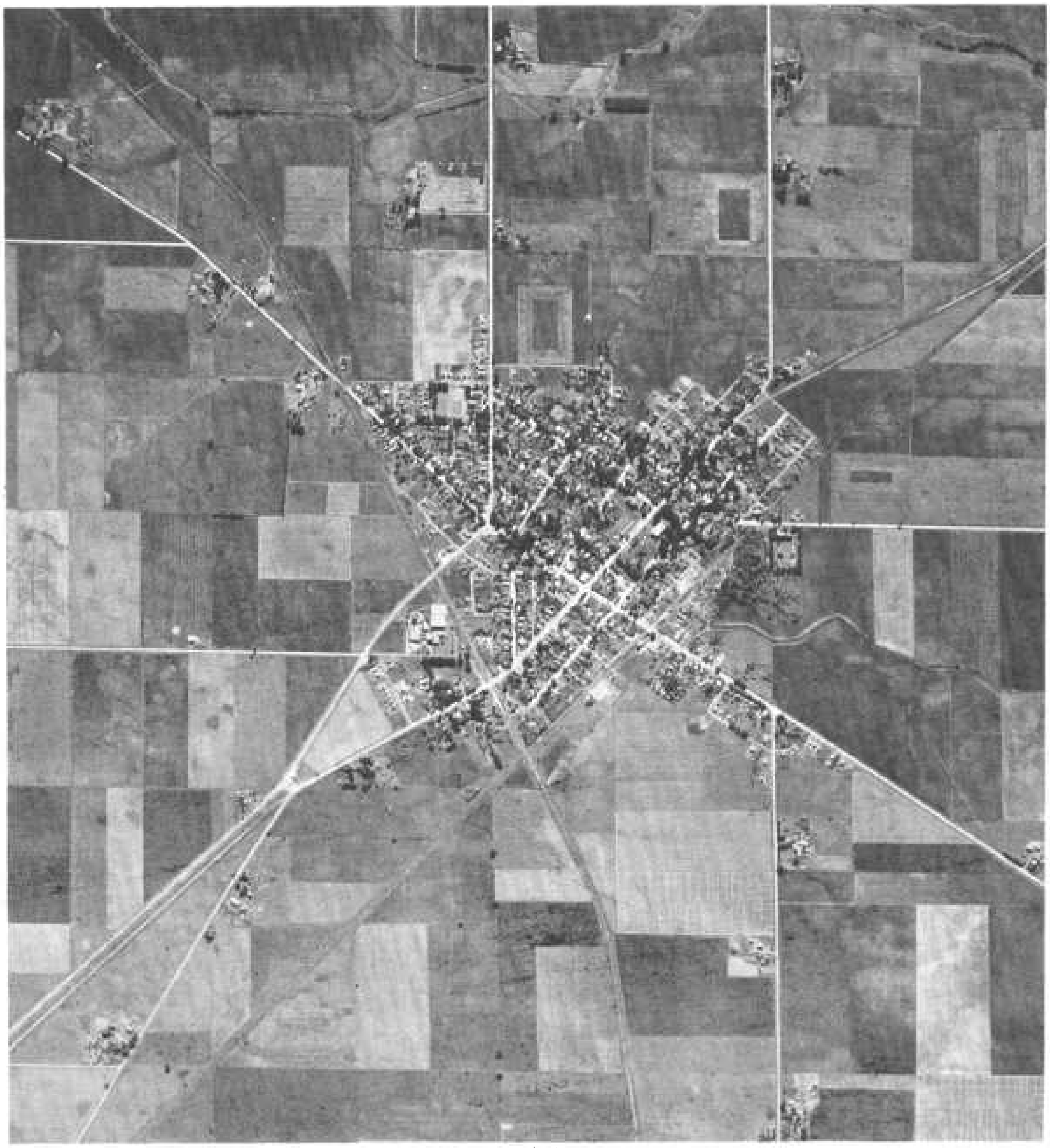

Figure 4.--Morton, Tazewell County, Ill., June 1939. Scale 1:20,000.

The patterns of land use in a small town and the rural area adjacent to it are clearly seen in this vertical photo. The population of Morton in 1940 was 2,241. The arrow on this and the following figures indicates the way the photo should be held so that shadows fall toward the viewer.

Figure 5.--Morton, Tazewell County, Ill., August 1957. Scale 1:20,000.

Airphotos show the great changes in land use that occurred on the fringe of Morton between 1939 and 1957. Development followed the main roads, and only one small subdivision (lower left corner) leapfrogged beyond the built-up area. Population in Morton was 3,693 in 1950 and 5,325 in 1960.

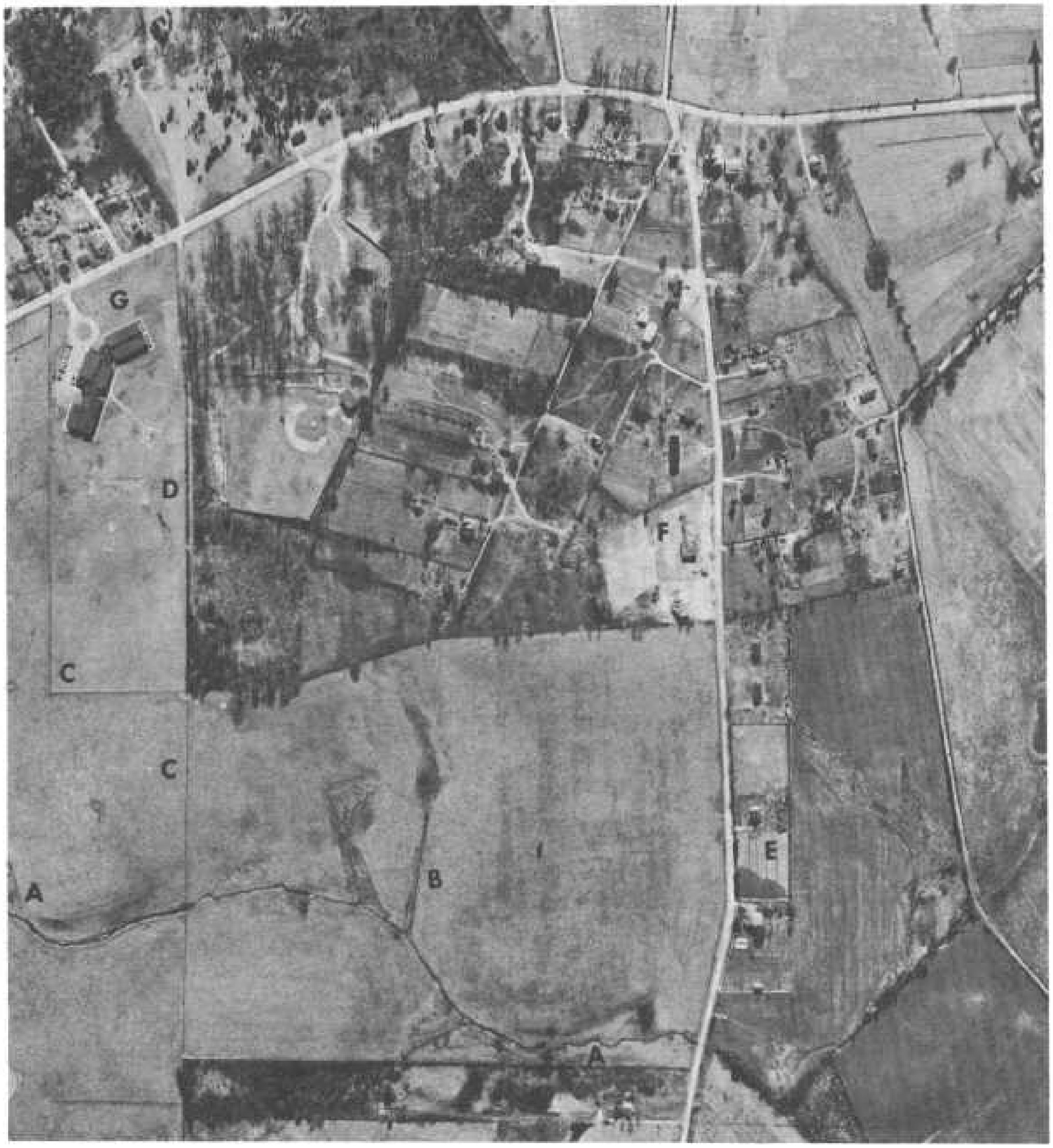

Figure 6.--Rock Creek Watershed, Montgomery County, Md., March 1957. Scale 1:6,000.

Many natural and manmade features are easy to recognize on this vertical airphoto of a portion of the Washington, D.C. rural-urban fringe. Annotated features are identified in text.

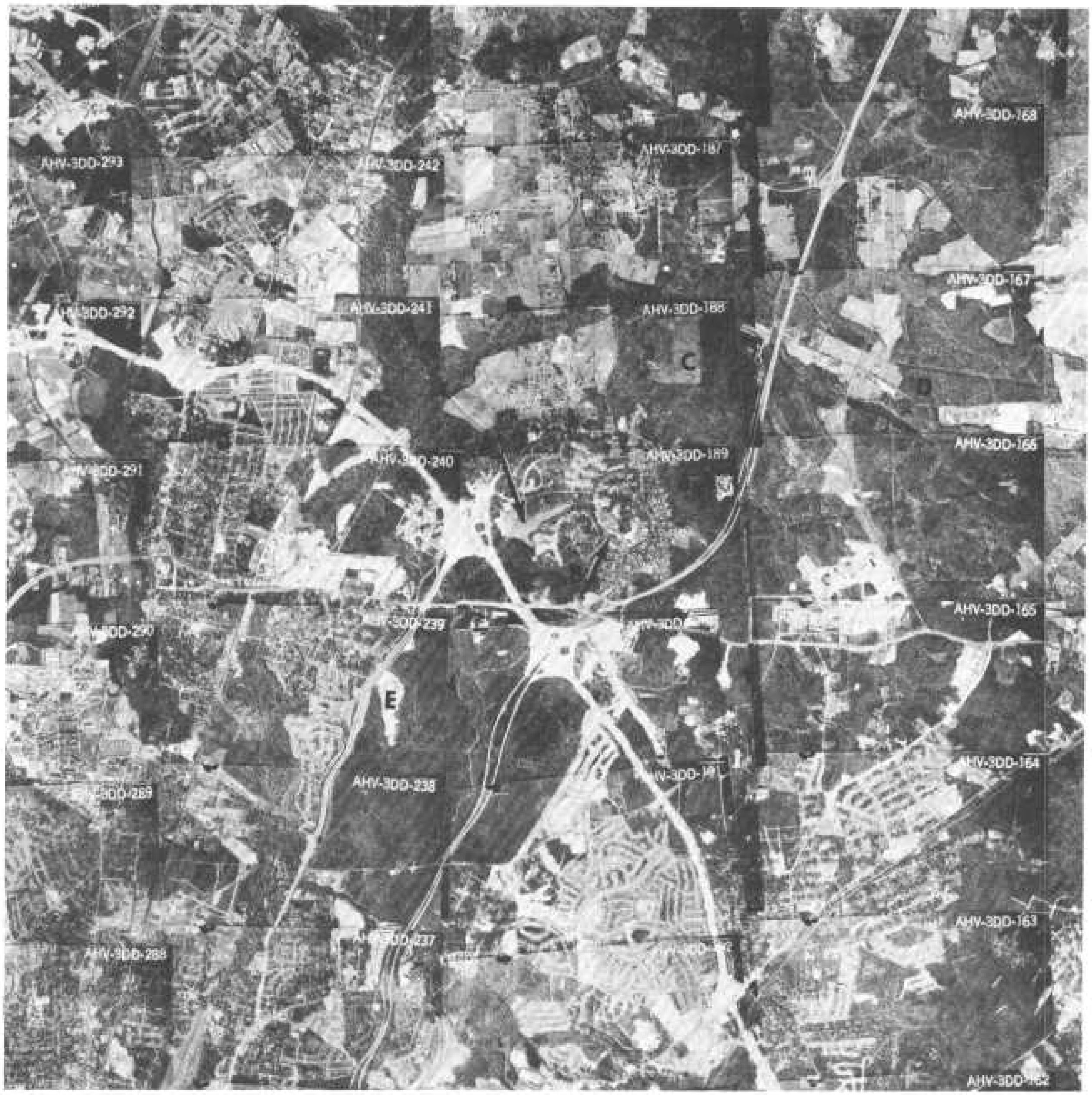

Figure 7.--Portion of a photo-index sheet for Prince Georges County, Md., October 1963. Scale 1:63,360.

Urban, rural, and transportation patterns of land use can be readily recognized at this scale. Annotated features are discussed in text on pages 40, 42, and 45. Photo-index sheets, a type of uncontrolled photomosaic, are used principally as an index to a collection of airphotos. The area covered by each individual airphoto is easy to identify (see p. 31).

Figure 8.--Greenbelt, Prince Georges County, Md., October 1952. Scale 1:20,000.

Woods, fields, lake, recreation area, buildings, highways, and streets are identifiable at this scale. Notice the curved clearing through the wooded area in the lower right corner.

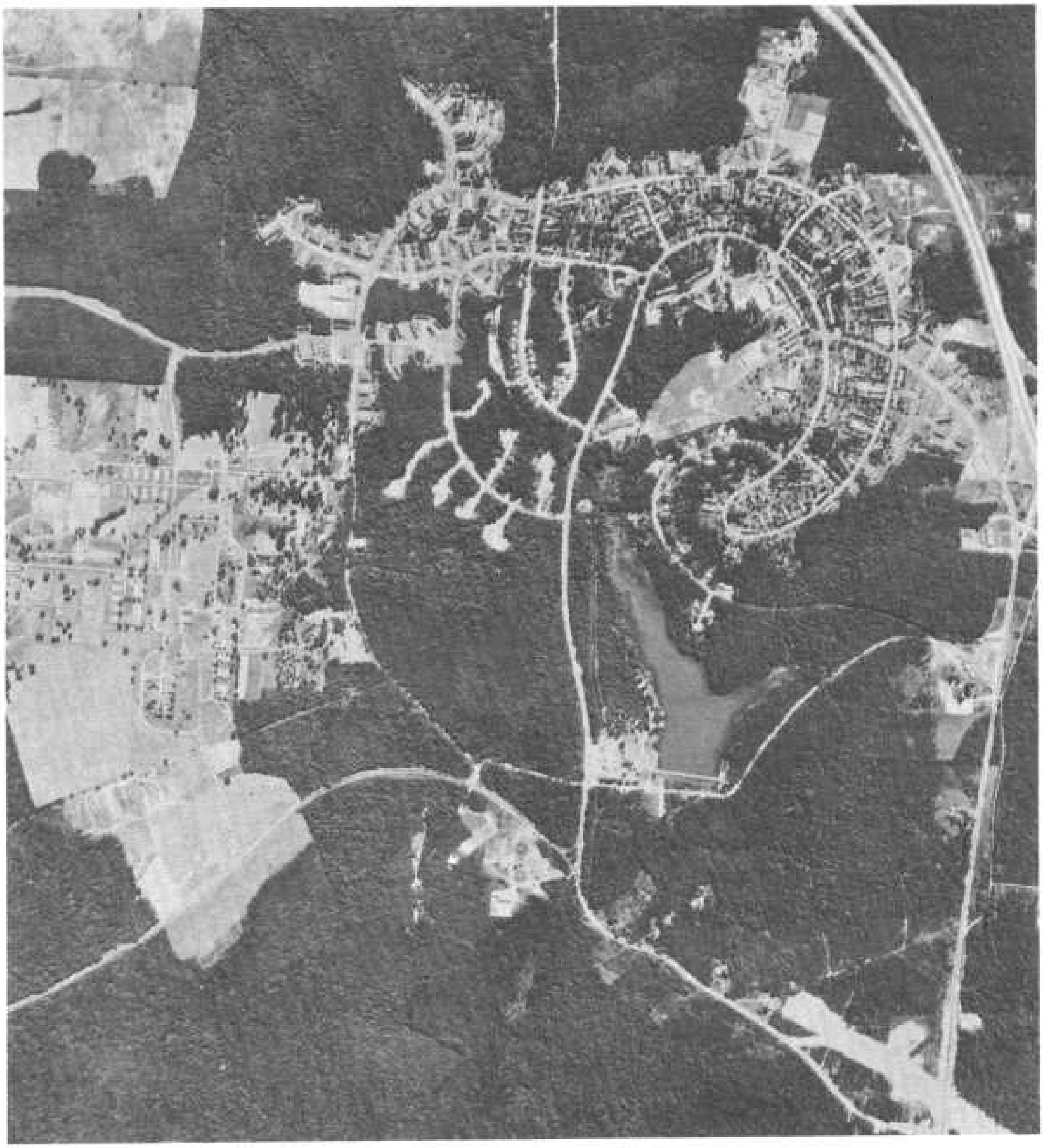

Figure 9.--Greenbelt, Prince Georges County, Md., June 1957. Scale 1:20,000.

The patterns made by Greenbelt and the fields and buildings of the agricultural research center at Beltsville show clearly on this airphoto because of the tonal contrast with the wooded areas. The trees are darker shades of gray in this photo than they are in figures 8 and 10 because dark green leaves reflect less light than is reflected by the yellow, light red, and light brown leaves of autumn. Notice the change in the lower right corner from a clearing in 1952 to a parkway in 1957. Also note the new clearing in the lower left corner and the clearings for new streets in the woods between the lake and Beltsville.

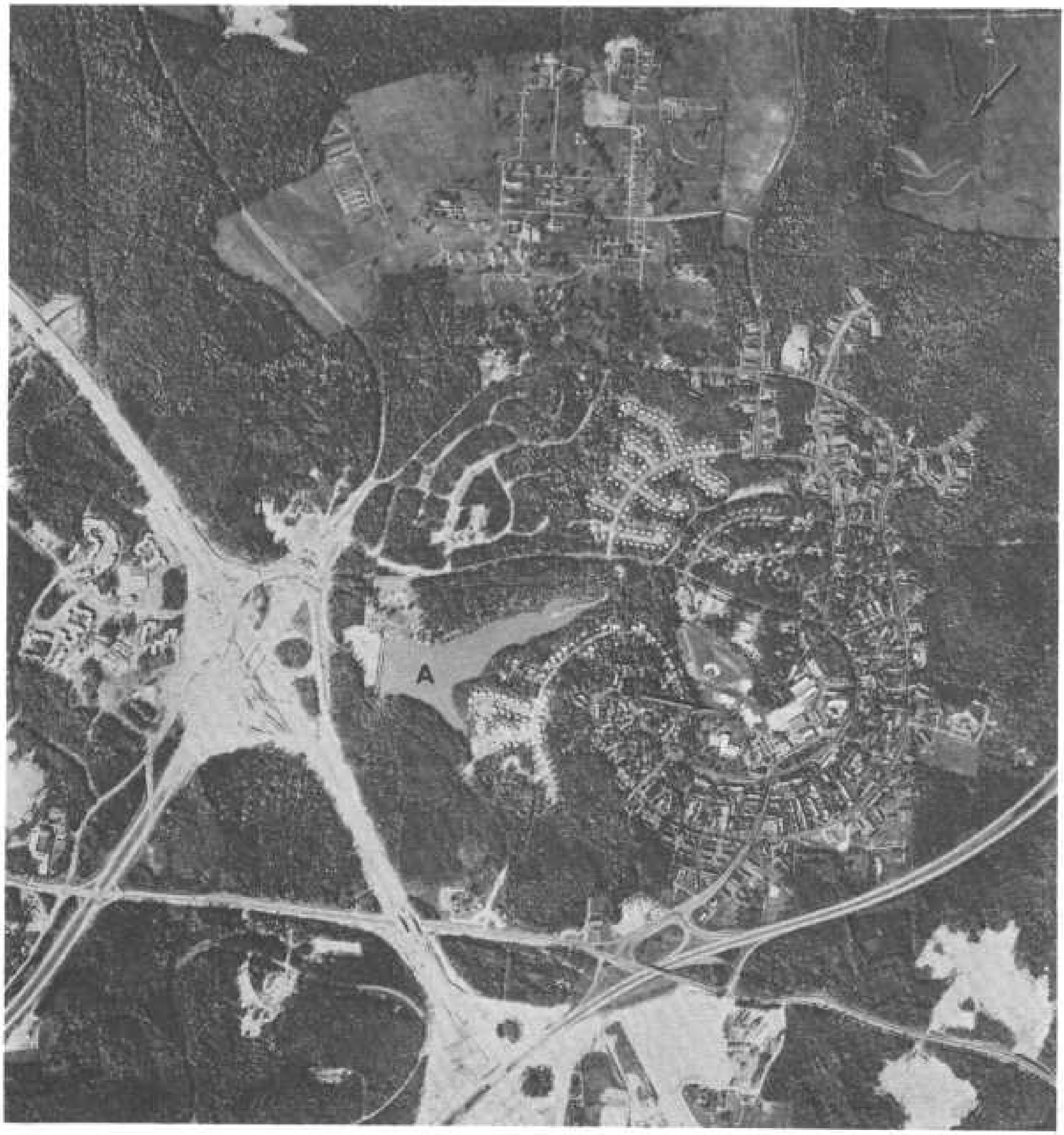

Figure 10.--Greenbelt, Prince Georges County, Md., October 1963. Scale 1:20,000.

The usefulness of a time series of airphotos of a developing area is shown by comparing this airphoto with figures 8 and 9. Notice in the lower left corner that the clearing made in 1957 now contains a divided highway that will connect with the highway under construction. Time has brought other changes. Notice the new garden apartments to the left of the interchange. Compare the development around the Greenbelt lake in figures 8, 9, and 10. Obviously, the greatest change was between 1957 and 1963. In this airphoto the pattern of new clearings in the woods between the lake and Beltsville indicates additional land would soon be in residential use.

Figure 11.--Greenbelt, Prince Georges County, Md., October 1963. Scale 1:12,000.

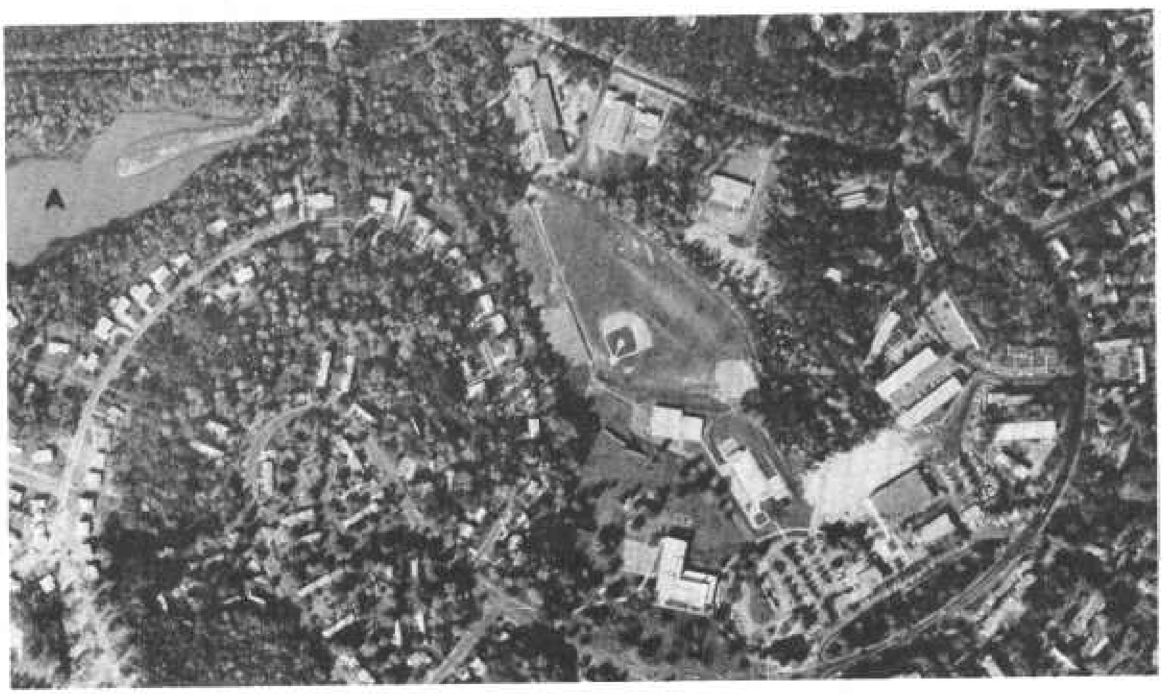

Figure 12.--Greenbelt, Prince Georges County, Md., October 1963. Scale 1:7,200.

Differences in the amount of detail discernible at various scales are easily seen by comparing figures 11 and 12 with figures 7, 10, and 13.

Figure 13.--Greenbelt, Prince Georges County, Md., October 1963. Scale 1:4,800.

At this scale even the relatively narrow lines marking the tennis courts (to left of baseball diamond) are easily seen. The shopping center (A), pool (C), and school (D) are easy to identify at this scale. A count of vehicles parked on-street and on parking lots could be made, although tree shadows partially obscure some cars and may completely obscure others. Notice the tonal differences between the asphalt streets and concrete sidewalks and driveways.

Figure 14.--Greenbelt, Prince Georges County, Md., October 1963. Semicontrolled photomosaic, scale 1:15,840.

This is a portion of Sheet 8-13 of a semicontrolled photomosaic of Prince Georges County. In constructing the mosaic only the center parts of the airphotos for this area of Prince Georges County were used in order to lessen errors in scale. This portion of the mosaic was made from the airphoto shown in figure 10 and the photos adjacent to it. Notice that much less of the interchanges and of Beltsville can be seen than are shown in Figure 10, because of the differences in scale.

Recreation areas such as golf courses, baseball diamonds, and tennis courts usually are easy to recognize because they have distinctive patterns. Conversely, recognizing the image of a park is not always possible because it may not be sufficiently different from that of a forest. In that event, one would try photo deduction and search for clues such as a paved access road, a parking lot, or picnic area. Although the presence of one or more such clues would suggest that the area is a park, the apparent absence of them would not necessarily be proof the area is not a park.

Dams and impoundments are readily recognized. Water purification plants also are easy to recognize. Sewage disposal plants and refuse dumps may require photo deduction.

Many types of transportation and communication facilities can be recognized easily. These include airports, expressways, parkways, streets, and alleys; bridges; harbors, canals, and locks; high-voltage power lines; and radio and television transmitting and relay towers.

Highways, roads, and railroads often are easy to recognize, but sometimes photo deduction must be employed in distinguishing between a road and a railroad. A railroad, of course, has more gentle curves than are necessary for highways and roads, which frequently have 90-degree angle intersections. Heliports often are difficult to recognize because they are quite small.

Some pipelines are easily recognized because of the difference between the soil or vegetation covering them and that adjacent to their trenches. Other pipelines are not recognizable; pumping stations may be the only clues to their location.

Telephone lines and low-voltage electric lines may be recognized, but distinguishing between them usually is impossible.

Photo Interpretation as a Useful Tool for Planning Studies

The physical form and the structure of neighborhoods, cities, and geographic regions are easily observed because airphotos clearly show many land forms and land uses. The form of large areas is, of course, seen best on small-scale airphotos or on mosaics; therefore, these are helpful in regional, State, metropolitan, and county planning studies. Conversely, large-scale airphotos are needed for study of neighborhoods. The use of airphotos also facilitates the comprehension of relationships between the different features shown; between town and countryside, for example, or between the various buildings in a neighborhood.

Specific types of planning-oriented studies for which airphotos are useful include those concerning traffic counts, parking surveys, identification of present land uses, determination of rate of land-use changes; identification of sources of air and water pollution, inventory of recreation and other open-space uses, estimation of public utilities and services needed in a developing area, inventory of real property for tax assessment purposes, determination of extent of flood damage, erosion control studies, condemnation and renewal of urban areas, determining route locations for highways, watershed drainage surveys, inventory of new structures not shown on tax maps, and selection of sites for schools, parks, and other community facilities.

What planning information can be gained from airphotos? As illustrations, let us consider four of the types of studies mentioned above.

Traffic and Parking.--Airphotos are an accurate source of data for use in traffic and parking surveys. This is a special use of airphotos and usually requires a special flight. Both the moving and the parked vehicles are "frozen" in time (such as at 4:00 p.m. on Wednesday, September 15, 1965); therefore, cars, buses, and trucks in sample areas or in a central business district or other area can be counted on the airphotos at any time. Pedestrian counts also can be made. An extra advantage inherent in using airphotos for transportation surveys is that there is less likelihood of duplication than there is with surface counting procedures, and the counts made on the airphotos can be verified readily.

Rate of Land-Use Change.--Planners can make good use of old airphotos, for they are an excellent, and sometimes the only, source of accurate data on previous land uses. Airphotos show the direction, type, and density of development in a changing area. The rate of urbanization of a survey area can be determined quickly and accurately by comparing a time sequence of airphotos. For example, see figures 4 and 5, which demonstrate this clearly. This procedure can provide the information on past and present rates of land-use change that is needed as a base for reliable resource-needs projections.

Air and Water Pollution.--Some sources of air and water pollution can be seen on airphotos. Clouds of dense, black smoke from an apartment house, for example, show clearly. Industrial and municipal wastes discharged into and discoloring streams or rivers sometimes may be observed on ordinary airphotos taken on panchromatic film; wastes discharged into streams may be seen clearly on color or infrared airphotos.

Recreation.--Airphotos are a useful source of data needed to classify and inventory present park and recreation areas. The airphotos can also be used to classify, inventory, and evaluate the recreation potential of undeveloped land and water resources.

MAPPING

As mentioned earlier, maps of many types are essential tools used in planning. A base map, showing at least the area of the jurisdiction being planned; the major water courses; and the railroads, highways, and streets should be prepared if one is not already available. Airphotos are useful in preparing new base maps or bringing old ones up to date. They are also very useful for preparing many other types of maps, including resource maps, land-use maps, and ownership maps.

Base Maps

If an up-to-date, accurate base map of adequate scale is not available, a new base map should be made. Also, if the area being studied is one of great change--such as an urbanizing county--it may be quicker and less expensive to have a new base map prepared than to bring an old base map up to date. Airphotos can be used as the primary source, or even the only source, of data for the preparation of base maps. Skilled photogrammetrists use stereoscopic airphotos and stereo-plotting machines to make the base manuscripts needed for both topographic and planimetric maps. If adequate recent photography is available, the final cost of new maps would be reduced by using it. If available photography is inadequate or not sufficiently up to date, new photography should be made. The cost of the airphotos, even if new ones are needed, is only a small part of the total cost of mapping.

If new photography is needed, the steps are:

1. Determine purpose for which the map will be used and the type of map needed;
2. Review the area to be photographed, using existing map sources;
3. Determine approximate flight lines and altitude, selecting optimal combination of available camera types, lens focal lengths, and film and filter types to provide the scale and type of photography needed;
4. Photograph;
5. Develop and print;
6. Establish ground control after analysis of developed photo strips;[7]
7. Prepare map manuscript by photogrammetric means; and
8. Print map.

The most satisfactory results are obtained when one firm is given the responsibility of both making the photography and preparing the maps. If base maps are available that are somewhat outdated but otherwise adequate, they can be brought up to date quickly and at relatively low cost by transferring to them data obtained from the latest available aerial photography.

Land-Use Maps

Planning the development of any area requires in addition to socio-economic data, knowledge of the area's topography, underlying physical structure, and the natural resources. Airphotos and photogrammetric procedures are used for the preparation of topographic maps, such as those made by the U.S. Geological Survey (USGS), which show contours of the land, water courses and their drainage systems, wetlands, forests, and numerous cultural features. Airphotos, together with field surveys, also can be used to map soils, geologic structure, and mineral deposits.

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[7] "Ground control is the conventional ground control surveys--horizontal or vertical--that are needed to establish scale; to determine the factors needed in the rectification of aerial photographs; and to provide a network of control points for mosaicking, compilation of planimetric and topographic maps, and the orientation of stereoscopic models as may be necessary in the various stereoplotting devices." Charles W. Koechley, Director, Cartographic Division, SCS.

Meaningful plans cannot be made unless the types of present land uses, the percentage of land covered by buildings, the acreage in the various land uses, and the areal distribution of these land uses are known. The land-use map is the simplest means of presenting these and other needed data in useful form.

On airphotos, general land uses may be identified, classified, measured, and delineated. The land-use data can then be transferred to a copy of the base map or to an airphoto mosaic.

For more detailed land-use surveys, supplemental data not shown on airphotos should be gathered through field checks. This is in addition to the field checks that always should be made of all images about which there is any question concerning identification. Enlargements of airphotos are excellent for use as field worksheets. For rural areas, enlargements of 1" = 600'; 1" = 700'; or even 1" = 800' are adequate. For cities, towns, and villages, enlargements of 1" = 200' are better.[8]

MEASUREMENT

Many kinds of measurements needed for planning studies can be made from controlled airphoto mosaics or from single airphotos; still others can best be made from stereopairs of airphotos. Their relative accuracies vary, so the type of airphoto and the method of measurement will depend on the precision needed for each particular job.

Many measurements that can be made on planimetric maps can also be made from controlled mosaics. Approximate sizes and distances can be measured on semicontrolled mosaics, but they cannot be used for accurate measurements. For example, only the <u>approximate</u> acreage in the wooded area, A, and the approximate length of the dam at Greenbelt Lake can be determined in figure 14.

Most airphotos are of a much larger scale than airphoto mosaics and therefore are more useful for measuring smaller features and objects. The approximate acreage of water surface in Greenbelt Lake can easily be measured on figure 10, (scale 1:20,000). At the larger scale on figure 13 (1:4,800), the size of the swimming pool and the shopping center can be determined.

Viewing a stereopair of airphotos such as that of Greenbelt (AHV-3DD-188 and -189 shown in the photo-index, fig. 7) one could measure the heights of buildings or trees and the overhead clearance of various highway underpasses provided some vertical standard, such as a building of known height, is viewable on the photographs.

Various devices have been invented to aid in making quick, accurate measurements from airphotos. A photograph of a special direct-reading plastic scale for measuring lengths is shown in appendix figure 15. Areas can be measured with a planimeter, or with a dot or circle grid (appendix figs. 15 and 16). Height can be measured with a parallax bar or a stereoscopic viewer utilizing a "floating dot."

INFORMATION AND EDUCATION

Airphotos are a useful tool for information and education. Statistics, words, maps, and ordinary ground-level photographs may be used to inform the inhabitants of a city that its population growth has been accompanied by urban sprawl, but a set of vertical airphotos of the city over time (in 1950, 1955, 1960, and 1965, for example) gives a clear, quick idea of the rate and expansion of urban area (figs. 4 and 5).

Oblique airphotos are especially useful information devices. For example, an oblique taken in 1955 of the waterfront along the river in Detroit or along the channel in Washington, D.C., would show the hodge-podge of uses that was characteristic of unplanned growth. Oblique airphotos of the same areas in 1965 would show the sharp contrasts brought about through urban redevelopment.

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[8] ASCS enlarges 1:20,000 negatives to a scale of 1" = 330' for areas where fields are small and to a scale of 1" = 660' where fields are large to determine for each individual field the acreage of land in certain crops; FS uses contact prints at 1:15,840 for stereoscopic study to assist in the determination of timber types, volumes, and so forth; and SCS generally uses stereopairs at a scale of 1:15,840 for study in the office, then uses single, alternate airphotos in the field as a base on which to delineate data.

As mentioned earlier, some images on airphotos are relatively simple to recognize and identify, while others are extremely difficult. The appearance of an image can vary with the type of film used; the season and time of day the photo was made; the scale and clarity of the print; the shape, size, pattern, texture, and tone of the object; and the background of the interpreter. The more significant characteristics and the problems they pose are discussed below.

PATTERN

The outline or pattern of objects shown on the airphotos is one of the most important characteristics in photo interpretation for planning studies. Manmade objects generally are characterized by straight lines or smooth curves, while natural features are characterized by irregular outlines. This dichotomy of outline or pattern facilitates image identification.

Let us consider an example. It might be important for a planner to know whether the image bisecting an area that appears to be a good potential recreation site is a stream or an unimproved, winding road. Either might appear as a dark or a light, curved line. If the line is irregular, the image is that of a natural object. If the image is regular in outline, it is man made. Notice in the lower left quarter of figure 6 the dark, irregular outline of the stream, A. Notice also that B, while similar to A in tone, is a straight line; because it is straight, we are sure this line is man made. Other characteristics lead us to infer that it is a drainage ditch. The straight lines shown at C and D are similar in some respects to the drainage ditch, B. These lines, however, obviously are fence rows, because shadows of the fence posts are visible on the original airphoto.

Pattern, in addition to its usefulness in helping one distinguish between natural and man-made features, also enables easy identification of certain objects or groups of objects. For example, the baseball diamond in the upper left quarter of figure 6 and the pond in the lower right quarter are easily recognized because of their typical patterns. Orchards, golf courses, railroad yards, drive-in movie theaters, residential subdivisions, industrial areas, and even towns and cities are identified on airphotos primarily by the patterns of their component parts.

SHAPE AND SIZE

The shape and size of objects provide important clues for their identification. Some objects, such as airport landing strips, and highway cloverleafs, easily can be identified solely by their shape. Other objects can be identified primarily because of their size in relation to the size of other objects; for example, a four-lane highway in a rural area can easily be distinguished from a two-lane rural road although surfacing, width of shoulders, and other features may be similar. For other objects, the clues of both shape and size are needed.

Shadows of an object often indicate the shape and the dimensions of an image. This is particularly important in vertical airphotos, where the roof of a building or top of some other object may blend so well with the background that it could not be identified except for the shadow it casts. Where shadow interpretation is important, airphotos should be held so that the shadows fall toward the viewer, as they do in figure 6. If airphotos are held so that shadows point away from the viewer, serious misinterpretations may result. For example, hills may seem to be valleys or gravel pits may seem to be piles of gravel.

The shadows of trees along the fence row in figure 6 show that the trees differ in both size and shape. The V-shaped shadow of building E, in the lower right quarter, shows that the building has a pitched roof; the shadow of building F, in the right center, shows that the building has a flat roof; and the shadow of building G, in the upper left quarter, indicate that the roof has an irregular shape, with the center section of the roof being lower than that of either side.

Comparison of the sizes of the various buildings provides clues to their possible use. Building G, quite the largest object shown in this airphoto, probably is either a school or a small factory. The buses in the parking lot would lead us to deduce this is a school. Building F, larger than most houses shown in the airphoto, might be a residence but is more likely to be in commercial or light industrial use. Judging by its size and shape, building E appears to be either a house or a small barn. The building probably is a house; it lacks the barnyard, irregular paths to it, and lanes to nearby fields that probably would be evident if it were a barn.

TEXTURE

All materials and, therefore, all features and objects, have texture. In airphotos, only rather gross textures are discernible, but those greatly assist in the identification of images.

Texture differences are especially useful in distinguishing among types of vegetation. Even a novice can distinguish between wooded land, which has a nubby texture, and open land, which appears smooth or fine-grained (figs. 7, 8, and 9). Distinguishing between woods and brush and between pasture and cultivated land is more difficult. Cultivated fields often have a fine-line texture; the lines may be straight or curved. Pasture, idle land, and marsh also have distinctive textures. Determining the types of crops in cultivated fields is a task for only highly skilled photo interpreters who have a good knowledge of the characteristics distinguishing various crops at different seasons.

Knowledge of cover characteristics of a tract of land may often be useful in land-use planning. For example, if in selecting the site for a new airport, 10 sites are found that appear equally good, it would save time and money to scan the newest available photo-index sheets of those areas to determine the type of vegetative cover at each site. In considering total costs of developing the airport, the cost of clearing a wooded site (less the value of any wood sold) would necessarily have to be added to the land cost. On the other hand, if the wooded land was only on the periphery of a site, the trees would be an asset because they would absorb some of the noise today's planes create.

Knowledge of cover characteristics also is of importance in selecting sites for many other special uses, such as highways, parks and recreation areas, and schools. For example, if other aspects of various possible school sites are comparable, selecting a site that has a bit of woodland or marsh would provide children and teachers with the added advantage of an easily accessible nature laboratory.

TONE

The variations in tone (in black and white photos) or the differences in color (in color photos) assist in image identification. In black and white photos the tone, or shade of gray, varies according to the amount of light reflected from each object. In general, light-colored objects reflect a lot of light; this results in a white or light-gray image on the photo. Conversely, dark objects reflect little light, thus producing a black or dark gray image on the photo.

Tone, then, depends upon the amount of light reflected from an object (which varies according to the surface texture of the image) and the amount of this reflected light which strikes the film in the camera (which varies with the filters used and with the angle of the camera to the reflected light.) The tone of an object also may vary due to such factors as the weather conditions at the time the photographs were taken and the developing and printing methods employed. In addition, tone may vary according to the angle from which light is reflected to the camera. For example, on two succeeding airphotos of a lake, the water may appear as a dense black tone on one airphoto and as white or light gray on the other.

Notice the variations in tone of the wooded areas in figures 8, 9, and 10. Each of the three airphotos was taken at approximately the same altitude on panchromatic film with a minus-blue filter using a camera with an 8 1/4-inch focal length lens. The wooded areas in figure 9 (airphoto taken in June) are darker than those in figures 8 and 10 (October) because green leaves reflect less light than yellow or red leaves reflect.

SIZE AND SCALE

For airphoto recognition, identification, and interpretation, the size of the feature or object photographed and the scale of the print are to a degree linked. As an example, very large features such as mountain ranges can be recognized on prints of the very small-scale photos taken and transmitted from weather satellites. At nearly the other extreme, one automobile can be distinguished from another in a parking lot, and the automobiles can be counted, on a single airphoto having a scale of 1:6,000 (1" = 500').

(See fig. 6; there are buses and cars in the parking lot.) If one uses a stereopair of airphotos and a stereoscope, vehicles can be counted on airphotos of even smaller scales.

Ease of recognition varies with the size of the feature or object and the scale of photography. The lake shown in figures 7, 10, 11, and 12 is an image many people can easily recognize as being a lake, but notice how much easier it is to recognize on figure 10, at a scale of 1:20,000 (1" = 1,667'), than it is on figure 7 at a scale of 1:63,360 (1" = 1 mile). Observe, also, that the additional increases in scale in figures 11 and 12 over that of figure 10 add little if anything to one's ability to recognize the lake. On the other hand, look again at figure 10 and notice image B. Then look at image B on figures 11 through 13. Because the object itself is relatively small, few people will be able to recognize the image on figure 10, some will recognize it on figure 11, and others may not do so until they look at figures 12, or even 13. It is not distinguishable at all on figure 7.

SPECIAL KNOWLEDGE

Knowledge in many disciplines is necessary for detailed, accurate interpretation of all land uses shown in airphotos. Fortunately, a more general fund of information often is adequate for identification or interpretation of images of many objects in which planners are most interested. When general knowledge is inadequate, photo interpreters skilled in various specialties should be consulted concerning specific photo-interpretation problems.

Let us consider a few examples. Almost anyone should recognize the image of a tree on an airphoto of adequate scale--because it is an object with which we are thoroughly familiar, even though we are not accustomed to seeing it from the air. Identifying the species of the tree is more difficult and requires special knowledge. Many people might be able to identify the tree as being of a deciduous or coniferous type; relatively few would be able to say whether a deciduous tree is an oak rather than a maple, because this identification depends upon knowledge of ecology and forest types.

Most people should be able to identify a building on an airphoto of adequate scale. Identifying the use for which the building was designed often depends upon special knowledge. Many people might be able to identify a gasoline station because it is a distinctive object (or combination of objects) with which we are familiar, but the same people might have difficulty in identifying a store, a school, or a stable because they may not be familiar with the distinguishing characteristics of each of these building types. Planners, geographers, architects, builders, and others with special knowledge of building types could identify many buildings as being residences, hospitals, stores, or schools.

When is a specialist's help needed? For many planning studies, no outside help should be needed. But for other studies, even a large and diversified planning staff may have inadequate skills. Both the quantity and the quality of information that can be obtained from airphotos depend upon the background of the person using them. If the background, training, and experience of the staff acting as photo interpreters is not directly related to the topic of the study, it would be advisable to have the interpretation done by someone who is qualified in that subject. False interpretation may be far more costly than hiring consultants or letting a contract for the work.

Electronic printers are among recent developments that have made it possible to obtain better quality prints from airphoto negatives than was possible with earlier types of contact printing equipment. Similarly, research now underway will lead to the development of sophisticated electronic devices and techniques for automatic identification, counting, measuring, and mapping of many land uses. These techniques and devices should be very useful to planners. Forerunners of these--the Model T's of the electronic age--already are in use. It is probable that landforms, vegetation, lakes and streams, roads and railways, and urban and industrial agglomerations will soon be identified by automated photo scanning and comparison devices. However, it is unlikely that machines will replace skilled photo interpreters who can differentiate, for example, the uses of various buildings in an urban area. Just as automated mapping procedures have helped rather than replaced skilled cartographers, automated photo identification procedures will provide planners with much useful data but will not provide all the details that can be obtained through photo interpretation.

Steps in Uses of Airphotos for Interpretation

A great amount of information can be obtained by studying photo-index sheets, mosaics, and single airphotos with the unaided eye or with a single magnifying lens. More detail can be seen by studying stereopairs of airphotos with the aid of a lens or mirror stereoscope. For special studies, airphotos taken with cameras using certain kinds of film and filter combinations may be needed to maximize the tone contrast of the objects of interest.

Areas to be studied may be selected by methodically scanning photo-index sheets or mosaics. For example, if one were looking for undeveloped land for a park site near Washington, D.C., in the Washington-Baltimore corridor, one would scan the index sheet or sheets of the latest available photography of that area. A portion of one index sheet covering the area is shown in figure 7.

When one scans figure 7 for a site for a park having a minimum of 500 acres of undeveloped land, it is apparent that the only possible sites within the area shown are at locations C, and D, and E. The three areas to be studied would be marked on the photo index sheet or on a transparent overlay. If field checks of the areas showed that residential or other development had not occurred since the airphotos were flown, airphotos that include the three areas would be selected and ordered for detailed study.

A transparent piece of plastic on which has been marked a square the size of one airphoto at the scale of the photo-index sheet (in this case, a square 2.8" x 2.8") is useful in determining the area covered by each individual airphoto. The plastic is held so that the upper right-hand corner of the square coincides with the upper right-hand corner of each of the airphotos on which the area of interest appears. Airphotos AHV-3DD-187, -188, -189, and -190 would be ordered for stereoscopic study of site C; airphotos AHV-3DD-166, -167, and -168 would be ordered to study site D; and airphotos AHV-3DD-191, -238, -239, and -240 would be ordered for study of site E. Airphotos AHV-3DD-189 and -190 would be used to study site E as well as site C.

Inspection of a topographic map of these possible sites may be made before the airphotos are ordered or may be made in conjunction with interpretation of the airphotos. The boundaries marked on the photo-index sheet should also be marked on the airphotos and on the map.

Analysis of the selected areas would be made by viewing the stereopairs of airphotos through a stereoscope. An inexpensive folding stereoscope designed for field use provides adequate magnification for this and many other types of planning studies.

a. The first step in the analysis is to look for readily identifiable images that are undesirable in a park site because these would quickly eliminate the need for further study of the area. To prevent optical illusions, airphotos should be held so the shadows fall toward the observer.

b. Methodical scanning of airphotos, like methodical scanning of a book, is quicker and more accurate than haphazard scanning.

c. All images of interest for a particular study should be marked and annotated on one of each pair of airphotos. Ink, soft colored pencils, and soft drawing pencils can be used to mark directly on semimatte airphotos; ink and grease pencils can be used to mark directly on glossy airphotos. This is quicker and cheaper than marking on nonshrink overlay materials and offers fewer opportunities to confuse or lose needed data. However, photos that must be cleaned to use again should be marked only with grease pencil or acetone-soluble ink. When preliminary study of the airphotos has been made, data can be transferred to overlays; grease pencil marks can be wiped off the airphotos with a bit of cotton dampened with carbon tetrachloride, and acetone-soluble ink can be removed with acetone-dampened cotton. Grease pencil and soft drawing pencil marks sometimes can be removed with a gum eraser without damaging the surface of the print.

   Caution: Fumes from all grease solvents are toxic. Use these solvents only with adequate ventilation. Some solvents are also flammable. Read the label and follow carefully any precautions listed.

d. Images that are not easily recognized should be carefully studied for clues that may help the viewer deduce enough additional information to identify the image. If the image still is not identified, then one must seek still other clues in the area adjacent to it, synthesize all the bits of information concerning the image, and make an inference about its possible identity. Field checks should be made to verify the identification.

e. Delineating images to be transferred to a map base can often be done most easily while viewing the images through the stereoscope. Generally, it is preferable to mark on the right-hand print of the stereopair.

f. When all images of interest have been identified, annotated, and delineated, transferring data to a map base will be facilitated if the images are classified into various categories, and images in the first category are mapped first, images in the second category mapped second, and so forth. If images from more than one pair of airphotos are to be mapped, it may be quicker and easier to transfer all the data from one pair of airphotos and then transfer data from a second set of airphotos rather than mapping, first, for example, streams shown on all airphotos, and then mapping all roads. Establishing standard procedures for transferring data will lessen chances of error. Use of standardized classifications and standardized mapping symbols also is helpful.[9]

Detailed information concerning the various steps in airphoto interpretation is given in the Manual of Photographic Interpretation (2). Especially worthwhile for planners are the chapters on the Fundamentals of Photo Interpretation, Photo Interpretation of Soils, Photo Interpretation in Agriculture, Photo Interpretation in Urban Area Analysis, and Photo Interpretation in Geography.

Availability of Airphotos

After a planner has determined the type of aerial photography required, how and where can it be ordered? Airphoto coverage of almost all of the United States is available; the area of interest probably has been photographed a number of times. Various Federal and some State, county, and city agencies, and commercial firms may have available the types of photography needed. If any of these are suitable, it usually is quicker, easier, and cheaper to buy prints of the existing coverage than to order new photography.

The Map Information Office, U.S. Geological Survey (USGS), Washington, D.C., 20242, publishes an index map on the Status of Aerial Photography which indicates the Federal or local government agencies, or commercial firms, holding negatives of recent photography best for most uses. The Map Information Office also publishes a map showing the Status of Aerial Mosaics. It indicates areas for which mosaics are available and the agencies from which they may be ordered.

Most of the available photographic coverage of the United States has been taken for Federal government agencies, and of this, the majority of the photography has been made for the Department of Agriculture. Within the Department the greatest coverage has been made for ASCS. Numerous areas of the United States have been photographed for SCS. The Forest Service has airphotos of areas where National Forests are located.

In the Department of the Interior, the U.S. Geological Survey has coverage of many parts of the Nation.

The Coast and Geodetic Survey (C&GS), Department of Commerce, has coverage of the coastal areas and navigable rivers.

More aerial photography is available for many areas of the United States than is generally realized. An example of the types of major vertical aerial photographic coverage available for one area is shown in appendix table 4, which indicates recent coverage of Fairfax County, Va.; data include the area covered, year photography was flown, lens focal length, negative and contact print scales, scales of enlargements available, and the source of the airphotos. Similar details about mosaics are shown in appendix table 5. Information about available photo index coverage is shown in appendix table 6. In addition to large-area coverage, there is a great quantity of strip and spot vertical photography and oblique

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[9] For suggested land-use classifications see the Standard Land Use Coding Manual, prepared by the Urban Renewal Administration, Housing and Home Finance Agency (now the Dept. of Housing and Urban Development), and the Bureau of Public Roads, U.S. Dept. of Commerce, Jan. 1965. Available from the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402, $0.50 per copy.

photography flown for cities, highway departments, land developers, builders, and others.

Amassing data on regional, State, county, or city coverage is tedious and time-consuming work; however, when such data have been compiled for a planning department, it takes relatively little time and effort to keep them current. The difficulty of compiling such information is far outweighed by its usefulness.

How to Obtain Aerial Photography

The Geological Survey's index maps on the Status of Aerial Photography and the Status of Aerial Mosaics show the names and addresses of the firms and the Federal, State, and local agencies from which the general-purpose photography indicated on the maps can be ordered. Some agencies, upon request, will provide maps or lists indicating the specific areas their photography covers, the negative scale or contact print scale of the photography, and the number of graphic-index sheets or photo-index sheets (if available) that cover each county or other area. Price lists, usually separate from the status maps or lists, show the scales of photo-index sheets, contact prints, and enlargements available and give detailed instructions for ordering photography.

Requests for these maps or lists and for all photography should indicate the exact area of interest, including State, county, and map coordinates. When prints are ordered, an accurate sketch, marked map, or other description would help the firm or agency select the photographs needed, if identification symbols and roll and print numbers are not known. If prints of a number of airphotos are needed, the photo-index sheet or index map should be ordered first to use in making the selections. Other required data include the type and approximate scale of photos required, whether stereoscopic coverage is needed, and whether prints should have glossy or matte finish. If prints at an accurate scale are needed, state this on the order, specifying the scale desired.

If available photography for a large area is to be ordered, the photo-index sheets should be checked carefully. Some contract specifications require that strips of below-standard photographs be reflown; the replacement photography generally is reflown at the contractor's convenience, and may be done as much as 6 months after the original photography was flown. The result is unsatisfactory for some planning purposes. For example, if the original flight for coverage of an urbanizing county was in June and the replacement flight was in September, a great amount of construction may have occurred in the rural-urban fringe. Because of this, the data on present land use derived from the photography would be somewhat misleading, statistics on land-use change made by comparing this photography with an earlier set of photographs also would be misleading, and traffic counts for the entire area could not be made.

FROM U.S. DEPARTMENT OF AGRICULTURE

Maps of each State for which they have photographic coverage are available free of charge from ASCS, FS, and SCS. These maps indicate the area covered, the year the latest photographs were taken, the negative scale of the photography, the focal length of the lens used, and the type of film used. Areas under contract for new photography also are indicated. Photo-index sheets for areas served by the local offices of ASCS, FS, and SCS may be viewed at those offices.

Requests for the ASCS maps, requests for information about earlier ASCS photographic coverage available, and orders for ASCS photo index sheets and aerial photography in Eastern States should be addressed to: [10]

Eastern Laboratory
Aerial Photography Division, ASCS
U.S. Department of Agriculture
45 South French Broad Avenue
Asheville, N.C. 28801

[10] Photography is held at Asheville for the following States: Alabama, Connecticut, Delaware, Florida, Georgia, Illinois, Indiana, Iowa, Kentucky, Maine, Maryland, Massachusetts, Michigan, Mississippi, Missouri, New Hampshire, New Jersey, New York, North Carolina, Ohio, Pennsylvania, Rhode Island, South Carolina, Tennessee, Virginia, and Wisconsin. ASCS does not have photography of Vermont; for USDA's airphotos of Vermont, contact the Forest Service.

Orders for photo-index sheets and photography for Western States should be sent to:[11]

Western Laboratory
Aerial Photography Division, ASCS
U.S. Department of Agriculture
2505 Parley's Way
Salt Lake City, Utah 84109

Requests for information about SCS photo index sheets, airphotos, mosaics, and orders for them, should be addressed to:

Cartographic Unit
Soil Conservation Service
Federal Center Building
Hyattsville, Md. 20781

The Forest Service has photography of the National Forests and National Grasslands; the office in Washington, D.C., holds negatives and index prints for its photography in the eastern United States and for Alaska. Airphotos for western States are available from the Service's regional offices. Inquiries concerning all FS photography may be sent to:

Division of Engineering, Forest Service
U.S. Department of Agriculture
Washington, D.C. 20250

Most ASCS coverage made on nitrate film from 1936 through 1941 has been transferred to a fireproof room at the National Archives because this type of film is highly flammable. All SCS photography taken before 1940, and nitrate coverage taken in 1941 and 1942 which is not shown on current SCS aerial photography status maps, has been transferred to the National Archives. Information about coverage at National Archives should be addressed to:

National Archives and Records Service
Cartographic Branch
General Services Administration
Washington, D.C. 20408

[11] Photography is held at Salt Lake City for the following States: Arizona, Arkansas, California, Colorado, Hawaii, Idaho, Kansas, Louisiana, Minnesota, Montana, Nebraska, Nevada, New Mexico, North Dakota, Oklahoma, Oregon, South Dakota, Texas, Utah Washington, and Wyoming. ASCS does not have photography of Alaska; FS has photos of part of the State.

FROM U.S. DEPARTMENT OF COMMERCE

Photographic coverage held by the U.S. Coast & Geodetic Survey is shown on ozalid copies of index maps. Each map shows the date of photography (month, date, and year), scale of negatives, type of film, flight lines, and photograph exposure numbers. Requests for information, and orders for index maps and airphotos, should be addressed to:

Director, Coast & Geodetic Survey
Attn.: Photogrammetry Division
Washington Science Center
Rockville, Md. 20852

FROM U.S. DEPARTMENT OF THE INTERIOR

Maps of each State showing photographic coverage flown for the U.S. Geological Survey are available free of charge from the Map Information Office.

Map Information Office
U.S. Geological Survey
Washington, D.C. 20242

These maps indicate the areas covered, the year the photography was flown, the negative scale of the photography, the focal length of the lens used, and the identification code of each project. The maps also show longitude and latitude, county boundaries and names, and indicate outlines of topographic quadrangle maps, each of which covers either 15 or $7\frac{1}{2}$ minutes of longitude and latitude.

Photo-index sheets for USGS photography follow the same outlines as the quadrangle maps and cover either 15 or $7\frac{1}{2}$ minutes of longitude and latitude. Price lists and other information needed for ordering airphotos or photo-index sheets are also available from USGS.

ORDERING NEW PHOTOGRAPHY

If existing airphoto coverage is not suitable, then the planner will need to contract with a commercial aerial photography firm to fly the required photography. Before ordering, it is helpful to compile a list of all uses the aerial photography is intended to serve and to group these uses according to both priority of need and probable time of use. Have a clear notion of how the photography will fit both present needs and the future work program.

Consider the types of qualitative data needed and the kinds of measurement and levels of accuracy that will be needed. Decide in advance whether a high level of accuracy is necessary. After photography is flown for use in providing only qualitative information, it will be too late to decide that, on second thought, a new planimetric map of the area is needed within the year or that a controlled mosaic is needed immediately. Why will it be too late? Because the type of camera used, the lens focal length selected, the altitude at which the plane is flown, the amount of tip and tilt allowed in the negatives, the way the flight lines are laid out, the requirements for ground control for the photography, and even the type of plane used are quite different for photography made for qualitative information than for photography needed for mapping and accurate measurement. Unless the contractor knows exactly what uses are expected to be made of the photography, it will be impossible to get the maximum benefit for each dollar spent on this very versatile tool.

Many factors determine the quality of the photography and, consequently, its usefulness to the planner. For example, if the pilot of the plane or helicopter is not sufficiently skilled in flying for the purpose of taking aerial photographs, the airphotos might contain distortions that would make them difficult or impossible to use for either map or measurement purposes.

Comparatively few people know aerial photographic equipment, films, filters, and so forth, well enough to write the specifications for a contract without assistance. For this reason, planners' needs will best be met and the public interest will best be served if the planner consults several reputable firms concerning his specific aerial photography needs before bids are asked for or a contract is written.

Airphoto contract specifications prepared by various agencies are good guidelines. One excellent publication is the Reference Guide Outline Specifications for Aerial Surveys and Mapping by Photogrammetric Methods for Highways (8). Detailed information about technical specifications for contracts is given in the Manual of Photogrammetry (1).

Names and addresses of reputable firms specializing in aerial photography can be obtained in several ways. The Map Information Office, U.S. Geological Survey, provides the names and addresses of commercial firms whose photography is indicated on the Status of Aerial Photography map. The photo-index sheets available from ASCS, FS, and SCS show the name and address of the firm which made the photography. Additional information about commercial aerial photography firms may be found in advertisements in Photogrammetric Engineering, the journal of the American Society of Photogrammetry. State highway departments may be very helpful in providing information about contract specifications and firms. Planning departments known to have ordered new photography should be an excellent source of information about firms. Discussions with persons in other planning departments also provide the opportunity to gather, informally, opinions on the cooperativeness and reliability of various aerial photography firms.

Consultations with other groups that might need airphotos for their work also offer the possibility of coordinating two or more orders for new photography. If several agencies in one area can use airphotos of the same type and same negative scale, a joint contract for flying the photography can save each agency money since each would pay only a part of the total cost of the negatives. Both might also save money on the prints ordered, because the cost per print usually decreases in proportion to the number of prints ordered from each negative.

Even if photography of different areas or different scales is needed, it is desirable for agencies to put their individual contracts together as a package for submission to prospective contractors. There are several advantages: (1) By grouping orders for photography, the overall order is larger; the cost per square mile for photography of large areas often is less than the cost for small areas. (2) Aerial photography can be flown on relatively few days each month (because of cloud cover, haze, rain, and so forth) and during only a few months of the year for certain photogrammetric or photo interpretation uses.[12] The better aerial photography firms are busy; therefore, it may be impossible to get one of these firms to do the work unless the contract is large enough to be attractive. (3) The more experienced firms are more likely to produce airphotos of the necessary high quality and accuracy.

Coordinating requirements for aerial photography also prevents needless and costly overlaps in orders. This is especially important in orders for new airphoto negatives, for photogrammetric work to prepare new maps or update old ones, and for compilation of airphoto mosaics. Preventing an overlap in ordering any one of these could save thousands of dollars.

Selected References

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1960. Aerial Photos in Geologic Interpretation and Mapping. U.S. Geol. Survey Prof. Paper 373, 230 pp., illus.

(10) U.S. Soil Conservation Service.
1966. Aerial-Photo Interpretation in Classifying and Mapping Soils. U.S. Dept. Agr. Handb. 294, illus.

(11) Whitmore, George D.
1941. Elements of Photogrammetry. 136 pp., illus. International Textbook Company, Scranton, Pa.

[12] For urban planning, mapping of both rural and urban areas, and many engineering studies, it is better to have photography flown in either early spring or late fall because objects are not obscured by snow or by foliage of deciduous trees. On the other hand, photography to be used for studies of agricultural land use (such as acreage in various crops) should be flown during the season when most crops can best be seen (for most crops this would be summer). The photography needed for forest surveys varies with the species of trees in the area and with the specific type of study to be made.

Appendix Figures

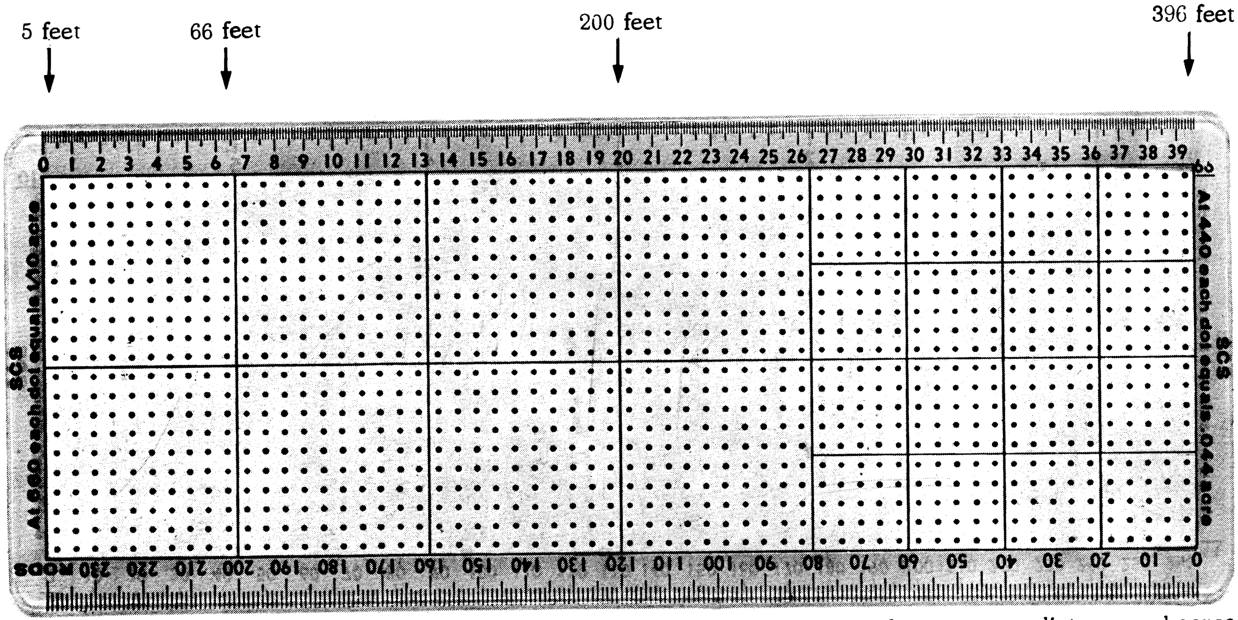

Figure 15.--Photograph of a device used by Soil Conservation Service personnel to measure distance and acreage on airphotos. The dots and grid lines have been printed on a piece of clear plastic. A white opaque coating around the edge of the plastic permits printing of 4 direct-reading scales. On the front, at top, measurements from 1 to 396 feet can be read directly from airphotos having a scale of 1:7,920. The eight large squares on the left are used to measure acreage on photos having a scale of 1:7,920 (1" = 660'); each dot equals .10 acre and each square equals 10 acres. At 1:15,840 (1" = 1,320') each dot equals .20 acre and each square equals 20 acres. The four squares on the right, subdivided into four squares each, are used to measure acreage on photos having a scale of 1:5,280 (1" = 440'); each dot equals .044 acre, each small square equals 1.11 acres, and each large square equals 4.44 acres.

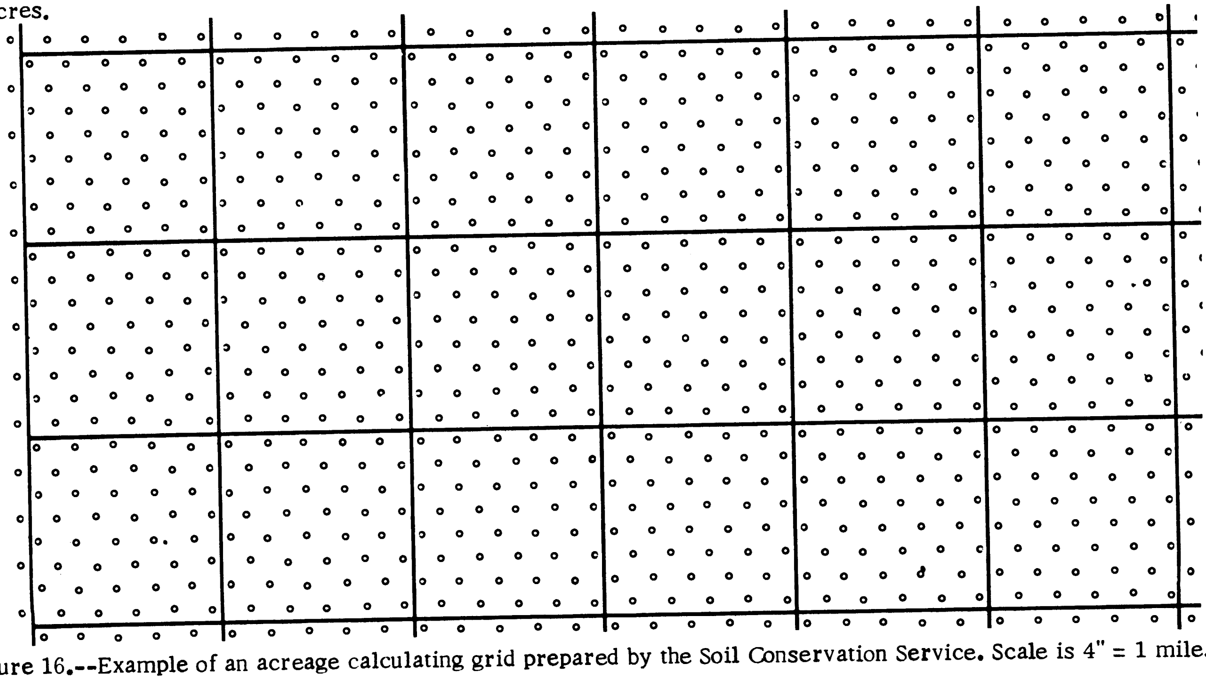

Figure 16.--Example of an acreage calculating grid prepared by the Soil Conservation Service. Scale is 4" = 1 mile.

The original grid is printed on clear plastic. Similar circle or dot grids for various scales can be made quite easily on any dimensionally stable plastic.

Appendix Tables

TABLE 3.--VERTICAL AIRPHOTO SCALES AND EQUIVALENTS

Scale	Feet per inch	Inches per mile	Miles per inch	Acres per square inch	Square inches per acre	Square miles per square inch
1:500	41.667	126.720	0.008	0.0399	25.0906	0.00006
1:600	50.000	105.600	0.009	0.0574	17.4240	0.00009
1:800	66.667	79.200	0.013	0.1020	9.8010	0.00016
1:1000	83.333	63.360	0.016	0.1594	6.2726	0.00025
1:1200	100.000	52.800	0.019	0.2296	4.3560	0.00036
1:1500	125.000	42.240	0.024	0.3587	2.7878	0.00056
1:2000	166.667	31.680	0.032	0.6377	1.5682	0.00100
1:2400	200.000	26.400	0.038	0.9183	1.0890	0.00143
1:2500	208.333	25.344	0.039	0.9964	1.0036	0.00155
1:3000	250.000	21.120	0.047	1.4348	0.6970	0.00224
1:3600	300.000	17.600	0.057	2.0661	0.4840	0.00323
1:4000	333.333	15.840	0.063	2.5508	0.3920	0.00398
1:4800	400.000	13.200	0.076	3.6731	0.2723	0.00574
1:5000	416.667	12.672	0.079	3.9856	0.2509	0.00624
1:5280	440.000	12.000	0.0833	4.4444	0.225	0.00694
1:6000	500.000	10.560	0.095	5.7392	0.1742	0.00897
1:6500	541.667	9.748	0.103	6.7356	0.1485	0.01054
1:7000	583.333	9.051	0.110	7.8117	0.1280	0.01219
1:7200	600.000	8.800	0.114	8.2645	0.1210	0.01291
1:7920	660.000	8.000	0.125	10.0000	0.1000	0.01563
1:8000	666.667	7.920	0.126	10.2030	0.0980	0.01596
1:8400	700.000	7.543	0.133	11.2489	0.0889	0.01758
1:9000	750.000	7.040	0.142	12.9132	0.0774	0.02018
1:9600	800.000	6.600	0.152	14.6924	0.0681	0.02296
1:10000	833.333	6.336	0.158	15.9423	0.0627	0.02489
1:10800	900.000	5.867	0.170	18.5950	0.0538	0.02905
1:12000	1000.000	5.280	0.189	22.9568	0.0436	0.03587
1:13200	1100.000	4.800	0.208	27.7778	0.0360	0.04340
1:14400	1200.000	4.400	0.227	33.0579	0.0303	0.05165
1:15000	1250.000	4.224	0.237	35.8701	0.0279	0.05605
1:15600	1300.000	4.062	0.246	38.7971	0.0258	0.06062
1:15840	1320.000	4.000	0.250	40.0000	0.0250	0.06250
1:16000	1333.333	3.960	0.253	40.8122	0.0245	0.06374
1:16800	1400.000	3.771	0.265	44.9954	0.0222	0.07031
1:18000	1500.000	3.520	0.284	51.6529	0.0194	0.08071
1:19000	1583.333	3.335	0.300	57.5515	0.0174	0.08989
1:19200	1600.000	3.300	0.303	58.7695	0.0170	0.09183
1:20000	1666.667	3.168	0.316	63.7690	0.0157	0.09968
1:20400	1700.000	3.106	0.322	66.3453	0.0151	0.10366
1:21120	1760.000	3.000	0.333	71.1111	0.0141	0.11111
1:21600	1800.000	2.933	0.341	74.3802	0.0134	0.11622
1:22200	1850.000	2.854	0.350	78.5698	0.0127	0.12277
1:22800	1900.000	2.779	0.360	82.8742	0.0121	0.12949
1:24000	2000.000	2.640	0.379	91.8274	0.0109	0.14348
1:25000	2083.333	2.534	0.395	99.6391	0.0100	0.15564
1:31680	2640.000	2.000	0.500	160.0000	0.0063	0.25000
1:36000	3000.000	1.760	0.568	206.6116	0.0048	0.32283
1:40000	3333.333	1.584	0.631	255.0760	0.0039	0.39484
1:48000	4000.000	1.320	0.758	367.3095	0.0027	0.57392
1:50000	4166.667	1.267	0.789	398.5563	0.0025	0.62284
1:60000	5000.000	1.056	0.947	573.9210	0.0017	0.89675
1:62500	5208.333	1.014	0.986	622.7442	0.0016	0.97291
1:63360	5280.000	1.000	1.000	640.0000	0.0016	1.00000
1:70000	5833.333	0.905	1.105	781.1703	0.0013	1.22044
1:96000	8000.000	0.660	1.515	1469.2378	0.0007	2.29568
1:120000	10000.000	0.528	1.894	2295.6841	0.0004	3.58700
1:125000	10416.667	0.507	1.973	2490.9800	0.0004	3.89165
1:126720	10560.000	0.500	2.000	2560.0000	0.0004	4.00000
1:144000	12000.000	0.440	2.273	3305.7851	0.0003	5.16529
1:250000	20833.333	0.253	3.946	9963.9070	0.0001	15.56811
Formulas[1]	$\frac{\text{Scale}}{12}$	$\frac{63360}{\text{Scale}}$	$\frac{\text{Scale}}{63360}$	$\frac{(\text{Scale})^2}{43560 \times 144}$	$\frac{43560 \times 144}{(\text{Scale})^2}$	$\frac{(\text{Ft. per In.})}{(5280)^2}$

[1] Scale is the relation between distance on an airphoto and distance on the ground. It is expressed as a ratio as shown here (1:20,000; that is, 1" on an airphoto equals 20,000" on the ground) or as a fraction (1/20,000). Scale of vertical airphotos is derived by dividing the altitude of the camera above ground (not sea) level by the focal length of the camera, and multiplying the quotient by 12.

TABLE 4.--MAJOR VERTICAL AERIAL PHOTOGRAPHIC COVERAGE FOR FAIRFAX CO., VA., 1950-1965

Area covered	Year flown	Approximate negative scale	Camera focal length	Approximate contact print scale	Approximate scale of enlargements	Prints available from[1]
Entire area......	Summer 1965	1:36,000	6"	1"=3,000'	Up to 1"=750'	Air Photographics
Most of area.....	Oct. 1964	1:24,000	6"	1"=2,000'	Up to 1"=500'	U.S. Geological Survey
Entire area......	Feb. - Mar. 1964	1:12,000	6"	1"=1,000'	Up to 1"=250'	Air Photographics
Entire area......	Mar.-May 1963	1:36,000	6"	1"=3,000'	Up to 1"=750'	Aero Service
Most of area.....	April 1963	1:36,000	6"	1"=3,000'	Up to 1"=750'	U.S. Geological Survey
Entire area......	1963-1964	1:24,000	6"	1"=2,000'	Up to 1"=500'	U.S. Geological Survey
Part of area.....	Dec. 1962	1:24,000	6"	1"=2,000'	Up to 1"=500'	Air Photographics
Entire area......	1962	1:20,000	8 1/4"	1"=1,667'	Up to 1"=400'	Agriculture Stabilization and Conservation Service
Part of area.....	May 1962	1:12,000	6"	1"=1,000'	Up to 1"=250'	Air Photographics
Entire area......	March 1962	1:12,000	6"	1"=1,000'	Up to 1"=250'	Air Photographics
Part of area.....	May 1961	1:18,000	6"	1"=1,500'	Up to 1"=375'	Air Photographics
Entire area......	March 1960	1:12,000	6"	1"=1,000'	Up to 1"=250'	Air Photographics
Entire area......	1959-60	1:60,000	6"	1"=5,000'	Up to 1"=1250'	U.S. Geological Survey (Army Map Service Photos)
Part of area.....	1959	1:120,000	3 1/4"	1: 10,000'[2]	Up to 1"=2500'	Aero Service
Part of area.....	July 1957	1:6,000	6"	1"=500'	Up to 1"=125'	Air Photographics
Entire area......	1954	1:20,000	8 1/4"	1"=1,667'	Up to 1"=400'	Soil Conservation Serv.
Entire area......	1951	1:36,000	6"	1"=3,000'	Up to 1"=750'	U.S. Coast & Geodetic Survey

[1] Aero Service, Air Photographics, U.S. Coast & Geodetic Survey, and Soil Conservation Service will make enlargements of portions of negatives up to 10 times the contact print scale. Maximum size enlargement is 40" x 40"; enlargements greater than those indicated in the table would have to be in more than one section.

In addition to major coverage listed above, coverage for Fairfax and Alexandria cities is available from several firms. American Air Surveys, Inc., has coverage of city of Fairfax and vicinity, March 1960, 1:6,000, enlargements up to 1"=100'; city of Alexandria and vicinity, April 1963, 1:18,000, enlargements up to 1"=300' and 1:24,000, with enlargements up to 1"=400'; western 2/3 of city of Alexandria, April 1964, 1:6,000, enlargements up to 1"=100'. Mention of aerial photographic firms is for information only and does not imply the Department's endorsement of certain firms to the detriment of other firms, or that those mentioned include all such firms.

TABLE 5.--AIRPHOTO MOSAICS AVAILABLE FOR FAIRFAX CO., VA., 1950-1965

Area covered	Date photos taken	Date mosaic compiled	Type	Negative scale of mosaic	No. of mosaic sheets to cover area	Source of mosaic
Most of area.......	Nov. 1963	1964	Semicontrolled	1:24,000 (1"=2000')	1	Air Photographics[1]
Entire area........	1954	1957	Controlled	1:63,360 (1"=5280')	3	Soil Conservation Service
Entire area........	1954	1957	Controlled	1:20,000 (1"=1667')	21	Soil Conservation Service

[1] Mention of an aerial photographic firm is for information only, and does not imply the Department's endorsement of certain firms to the detriment of others.

TABLE 6.--AIRPHOTO INDEX COVERAGE AVAILABLE FOR FAIRFAX CO., VA., 1950-1965

Area covered	Date photos taken	Approximate scale of photos	Approximate scale of index	No. index sheets needed to cover area	Source of index[1]
Most of area......	Oct. 1964	1:24,000	1:62,500	7	U.S. Geological Survey
Entire area.......	Feb.-Mar. 1964	1:12,000	1:24,000	12	Air Photographics
Entire area.......	Mar.-May 1963	1:36,000	1:144,000	[2] 1	Aero Service
Most of area......	April 1963	1:36,000	1:125,000	4	U.S. Geological Survey
Entire area.......	1963-64	1:24,000	1:62,500	12	U.S. Geological Survey
Part of area......	May 1962	1:12,000	1:24,000	12	Air Photographics
Entire area.......	May-July 1962	1:20,000	1:63,360	4	Agriculture Stabilization and Conservation Service
Entire area.......	March 1960	1:12,000	1:24,000	12	Air Photographics
Entire area.......	1954	1:20,000	1:63,360	3	Soil Conservation Service
Entire area.......	1951	1:36,000	1:250,000	1	U.S. Coast & Geodetic Survey

[1] Mention of aerial photographic firms is for information only, and does not imply the Department's endorsement of certain firms to the detriment of other firms, or that those mentioned include all such firms.
[2] Included on one photo index sheet are all of Washington, D.C.; part of Montgomery Co., and all of Prince Georges Co., Md.; all of Arlington and Fairfax Counties, most of Prince William Co., and part of Loudoun Co., Va.

TABLE 7.--SOURCES OF ILLUSTRATIONS

Figure number	Identification number	Type; Scale, if any	Place	Date	Source
Cover, upper half...	Pa.-79,782	Low oblique	Chester Co., Pa.	Sept. 1950	SCS
Cover, lower half...	40,905	High oblique	Philadelphia, Pa.	April 1963	SCS
1......	SCS-Ia-2758	High oblique	Templeton, Carroll Co., Iowa	Nov. 1961	Inf. USDA
2......	MD. 30383	Low oblique	Belair, Prince Georges Co., Md.	Oct. 1962	Inf. USDA
3......	Lehigh Co., Pa., Sheet No. 21	Soil map, 1:15,840	Lehigh Co., Pa.	1962	SCS
4......	BXI-1-12	Vertical, 1:20,000	Morton, Tazewell Co., Ill.	June 1939	National Archives (ASCS photo)
5......	BXI-1T-41	Vertical 1:20,000	Morton, Tazewell Co., Ill.	Aug. 1957	ASCS
6......	MD-RC-1-85	Vertical 1:6,000	Rock Creek Watershed, Montgomery Co., Md.	Mar. 1957	SCS
7......	Photo-Index Sheet No. 2, Prince Georges Co., Md.	Photo Index, 1:63,360	Prince Georges Co., Md.	Photos, Oct. 1963	ASCS
8......	AHV-7K-12	Vertical, 1:20,000	Prince Georges Co., Md.	Oct. 1952	ASCS
9......	AHV-2T-12	Vertical, 1:20,000	Prince Georges Co., Md.	June 1957	ASCS
10.....	AHV-3DD-188	Vertical, 1:20,000	Prince Georges Co., Md.	Oct. 1963	ASCS
11.....	AHV-3DD-188	Vertical, 1:12,000	Prince Georges Co., Md.	Oct. 1963	ASCS
12.....	AHV-3DD-188	Vertical, 1:7,200	Prince Georges Co., Md.	Oct. 1963	ASCS
13.....	AHV-3DD-188	Vertical, 1:4,800	Prince Georges Co., Md.	Oct. 1963	ASCS
14.....	Photomosaic sheet 8-13, Prince Georges Co., Md.	Semicontrolled mosaic, 1:15,840	Prince Georges Co., Md.	Photos, Oct. 1963 Mosaic, 1964	(ASCS) SCS

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