tion, from location survey staking to roadway surfacing, was accomplished in cooperation with the U. S. Bureau of Public Roads using this arrangement.

Cross-Sections Measured Photogrammetrically

In 1958, aerial photography was taken over a section of highway approximately 12 mi long for experimentally measuring cross-sections by photogrammetric methods. District survey crews under the guidance of the consultant established all horizontal and vertical control necessary for the project. Cross-sections at every 100-ft station and at breaks in grade and ground slope were measured for about a 350-ft width across centerline and digital information was furnished in punch card form for subsequent input to an electronic data plotter. More work of this nature is planned.

Past experience using consultants for aerial surveys and mapping has led to present plans to continue negotiating engineering contracts for this type of service.

AERIAL SURVEYS AND USES OF PHOTOGRAMMETRY FOR HIGHWAYS

Aerial Surveys Branch, U. S. Bureau of Public Roads
Washington, D. C.

The Aerial Surveys Branch was officially established in 1952. This was not the beginning, however, of the actual use of aerial surveys by the U. S. Bureau of Public Roads. Instead, it was the culmination of more than two decades of use by a few employees of the Bureau of aerial photography for highway engineering purposes. The uses began elementally and were gradually increased in detail, precision, and scope. Creation of the Branch followed directly the successful completion of a comprehensive aerial survey to locate feasible highway routes through a 90,000 sq mi area in the central United States. Previously aerial surveys had been utilized advantageously on numerous projects for route location and design purposes. Among the significant project examples are:

1. George Washington Memorial Parkway, 1928,
2. Pioneer Road for the Alaska Highway in Canada and Alaska, 1942;
3. Inter-American Highway, 1947-48; and
4. Mississippi River Parkway (now Great River Road), 1950-52.

The principal responsibilities of the Branch are to:

1. Promote better design through use of aerial surveys;
2. Develop, improve, and disseminate information on methods, standards and practices;
3. Exercise leadership in writing specifications for aerial surveys;
4. Perform liaison and consultation services;
5. Conduct conferences and schools in aerial surveying for highway engineering purposes; and
6. Serve as a central source of information.

Aerial surveys for highways comprise taking and using aerial photographs, regardless of their type or scale and manner of use, while accomplishing the essential photographic interpretation (including photogrammetry and electronic computer applications) and requisite ground control surveys.

Reconnaissance Surveys

Reconnaissance surveys for determining feasible routes and comparing them to select the best route have been completed and reports have been prepared for highway projects of diversified traffic requirements and various construction standards in re-

gions of Africa, Hawaii, continental and United States. In addition, route locations for numerous high-standard sections of the Interstate Highway System have been determined. All reconnaissance surveys are made by small-scale existing photography obtained from many different sources, supplemented by use of small-scale topographic and/or planimetric maps when available except around or through metropolitan areas where recent photography is required. Parallax measurements are made to locate the routes on gradients not exceeding the maximum established by the class of highway to be located. Photographic interpretation is employed in sufficient detail and scope to ascertain the qualitative controls of highway route location resulting from land use, topography, soil and ground conditions, and drainage. The feasible routes are delineated on the aerial photographs so that each segment is in steroscopic correspondence with the topography when the photographs are examined stereoscopically.

Reconnaissance survey reports are written according to the specific requirements of each survey. Some reports contain only brief narrative comments pertaining to route position and length and to general topographic conditions and the significant land uses, which combined with topography have controlling influence on the feasible route alternatives. Other reports include detailed route descriptions, soil conditions and analyses, sources of construction materials, estimated construction quantities for all principal items of highway construction, right-of-way and severance damages, alignment standards attainable, anticipated maintenance costs, and historic, archaeologic, and scenic or recreational areas served.

By way of illustration, the reconnaissance survey for the large route-location project previously mentioned involved the elemental measurement of parallax and computation of grades and horizontal curvature without benefit of ground control for photogrammetric use and photographic interpretation by stereoscopic examination of about 30,000 aerial photographs covering the entire 90,000-sq mi area. The final report included delineation on maps and evaluation of each feasible route and estimates of probable costs of right-of-way and construction for each 2,000-mi route of the 10,000 mi of route alternatives across 246 counties in ten States. The total survey cost was $140,000, averaging $14.00 per route mile, based on the total length of all alternatives. Such economic advantages alone justify utilizing aerial survey methods in the reconnaissance survey stages. An added bonus is better located and engineered highways, providing safety and service far exceeding that usually attained whenever the reconnaissance surveys are made on the ground only.

Preliminary Surveys

Preliminary survey mapping is usually done at the large scales of 100 ft and 50 or 40 ft to 1 in. on a joint research and project survey basis. The contour interval, usually ranging from 5 to 2 ft, is selected according to topography ruggedness and design requirements. All mapping is on datum of the State plane coordinate system adjusted so differences between map distances, as determined from the plane coordinates, and distances measured horizontally on the ground will be less than 1:5,000 or 1:10,000, according to the accuracy required in the basic control and in the mapping.

Survey projects initiated by regional offices of the U. S. Bureau of Public Roads are thoroughly examined through use of available small-scale aerial vertical photographs and topographic maps to determine the conventional procedure most expedient and economical for adequately accomplishing the required mapping. The procedure thus determined is then analyzed for adaptation or development of a new approach so as to produce either better accuracy, a more quickly accomplished survey, savings in survey costs, or a combination of the three. Materials and photogrammetric instumentation techniques are also analyzed and varied in order to reduce incidential expenses and improve procedures.

In preliminary survey mapping, new photography is designed and taken for each survey project. The photography is compatible with the inherent characteristics of the stereophotogrammetric instruments used for map compilation. Considerable planning is done to keep within the instrumental relief-height to flight-height ratios and to avoid photography scales exceeding practical working limits in map compilation with the available, double projection, photogrammetric instruments.

Work of the Aerial Surveys Branch seldom continues beyond the mapping phases of the preliminary survey stage of highway engineering into the detail design phases. Usually its activities are confined to specialized fields of using and advising in use of photogrammetry and aerial surveys for accomplishing essential work in highway engineering. The design work is done in other offices, adequately staffed to perform these duties.

Special Services and Research

Special services are a continual and important function of the Branch. Requests originate from many different sources, such as other Federal agencies, State governments, colleges and universities, regional offices of the Bureau, governments of other countries, and commercial firms. Some requests are merely questions pertaining to scales and types of aerial photography desirable for certain purposes. Other requests are for extensive review and analyses of aerial photography to determine soil conditions along a highway route and to locate sites for borrow of suitable construction materials.

The Branch has fulfilled three requests for specialists to go out of the country on short assignments: one to Ethiopia, one to Costa Rica, and one to Peru. In Ethiopia the work was to determine locations for possible highway routes; in Costa Rica the assignment was to review highway route location work performed by Costa Rican engineers and to make recommendations regarding the relative merits of the various route alternatives, in Peru, the assignment was to train Peruvian engineers in the principles and use of aerial surveys for highway engineering purposes. In addition, using aerial photographs furnished by the requesting agency, numerous miles of highway route alternatives have been located, delineated on the photographs stereoscopically, and compared; the most feasible route has been recommended throughout many States and other countries.

In response to requests, numerous trips have been made to regional and division offices of the Bureau to perform a consultant engineering service, especially in obtaining aerial survey services by contract for highway engineering survey and design purposes.

Since 1947, aerial survey training has been given to highway engineers, administrative personnel, junior engineers, and materials engineers of the United States and other countries. According to individual needs, length of training varies from 3 hr to 3 mo or more and includes basic principles and procedures, instrumentation and instrument operation, photographic interpretation, and basic and supplemental control surveys, as well as their applications in each stage of highway engineering. In response to specific requests, there has been an average of more than two aerial survey schools conducted each year for the past 12 years for engineers from all regions of the Bureau, from nearly every State, and from other countries.

Numerous articles have been written for publication by the Highway Research Board, the American Society of Photogrammetry, American Congress on Surveying and Mapping, American Society of Civil Engineers, the International Society for Photogrammetry, the U. S. Bureau of Public Roads, and the Pan American Highway Congress.

To achieve positive identification of ground control survey markers, special studies have been made to evaluate material, dimensions, and spacing for photographic targets.

As survey project work is done, research is accomplished to determine accuracies of bridging horizontal control by use of radial stereotemplets prepared and assembled from aerial photographs of different scales.

To determine the differences in measurement of earthwork pay quantities by both aerial and ground survey methods, cross-sections are being measured on one highway project in a rough mountainous area where clearing of the route was necessary before photography. The original ground cross-sections and the constructed highway cross-sections, measured separately by ground survey and aerial photogrammetric methods, will be used to compute the earthwork volumes and to compare them on a difference basis according to each method of measurement.

Data on survey costs relative to all types of highway surveys are compiled and revised on a continuing basis to keep cost records current and available to answer requests for information.