PHOTOGRAMMETRY AS APPLIED BY FEDERAL HIGHWAY PROJECTS OFFICE, REGION 9, U. S. BUREAU OF PUBLIC ROADS

The Federal Highway Projects office in Region 9, located in Denver, Colo., is responsible for the location, design, and construction of Federal Domain Highways in Colorado, New Mexico, South Dakota, North Dakota, Texas, Utah, and Wyoming. In administering Forest Highway funds, the region's responsibility is similar to that of a State highway department. Using highway funds administered by other organizations, such as the National Park Service, Bureau of Indian Affairs, and others, the Federal Highway Projects office serves as the road building agency.

The large area encompassed by the seven States, with their varied types of topography, weather conditions, and vegetational coverage, offers a real challenge to the progressive highway engineer in highway location, design, materials investigations, and construction. The wide latitude in climatic conditions presents an almost year-round opportunity to implement photogrammetry, electronics, and other advanced techniques. The remoteness of many of the highway projects within these States and manpower limitations makes the use of photogrammetry and electronics almost mandatory.

The Aerial Surveys Branch of the U. S. Bureau of Public Roads began training limited numbers of the Region 9 Federal Highway Projects personnel in aerial surveys and photogrammetry in 1950. Emphasis was placed on the effectiveness of aerial surveys and photogrammetry in reconnaissance surveys and in preliminary survey and design.

Between 1957 and 1959 personnel were trained in operating precision stereoscopic instruments, equipment was obtained, and preliminary surveys were made for highway location purposes by aerial survey instead of ground survey methods. Currently the full-time employees are one photogrammetric engineer, one Kelsh instrument operator, and four field survey parties, each consisting of a party chief and five to eight members. In addition, part-time engineering technicians prepare manuscripts for compiling maps, compute plane coordinates, and file photographs.

Aerial vertical photographs, in scales from 1:12,000 to 1:30,000, are used for each reconnaissance survey to assist in determining and comparing the feasible route alternatives, in selecting the best route corridor for large-scale topographic mapping, and in measuring drainage areas. These photographs are usually available from other Government agencies at reasonable unit prices.

The photography for large-scale topographic mapping of each selected route is purchased by contract negotiated with commercial firms. An aerial camera, having a distortion-free 6-in. focal length lens, is specified, as well as scale stable base film. Photography scale ranges from 1:4,800 to 1:12,000, depending on scale specified for map compilation.

The aerial photography specifications are patterned after the "Reference Guide Outline, Specifications for Aerial Surveys and Mapping by Photogrammetric Methods for Highways, 1958." The contractor is required to furnish two sets of contact prints and one photographic index of the aerial photography. In addition to black and white photography, aerial color photography is generally included, either at a scale of 1:6,000 or 1:12,000. This color photography has been used primarily by photographic interpretation for locating sources of suitable construction materials and as an aid in photogrammetric compilation of the map manuscripts.

Ground survey control work is performed by trained U. S. Bureau of Public Roads personnel. Placement of targets on the ground centered on markers of horizontal control points, at vertical control points in or near the corners of each stereoscopic model, and on property corners is completed before photographing each highway route. Normally, this targeting is adequate for the required mapping, but in some instances supplemental vertical control has to be measured to natural image points for short segments of each highway route. Although a variety of targeting materials has been used, white lime and white centerline striping paint have been most effective. Cross-type targets in which the center one-third of each leg is black, centered on the station marker of each control point, provide the contrast necessary for accuracy in orienting each stereoscopic model. The majority of surveys are incorporated in the State plane coordinate system by triangulation originating and closing on geodetic survey monuments for which the State plane coordinate positions are known or can be computed.

The State plane coordinates are adjusted for each survey project to a datum where differences between distances determined from plane coordinates on the maps and distances measured horizontally on the ground will not be larger than permissible by accuracies required in the basic control surveys, as 1:5,000 or 1:10,000.

The survey control traverse is measured by use of T-2 theodolites, 12-ft subtense bars, and electronic measuring devices. The elevation of stereoscopic model leveling points is measured by spirit levels in closed circuits or by measurement of vertical angles, using the subtense bar to obtain essential horizontal distances. Traverse azimuths, distances, and plane coordinates are computed by an IBM program written specifically for theodolite-subtense bar measured traverses.

Map manuscripts are compiled either by commercial firms under negotiated contract or by Region 9 personnel and equipment. Map manuscripts are normally compiled on a scale stable base polyester film, surface treated for drafting purposes. The plane coordinate grid is traced from a master coordinate grid sheet. For design purposes, compilation scale of the topographic maps is usually 100 ft to 1 in., with a contour interval ranging from 2 ft where the topography is nearly level to 10 ft where the topography is rugged. Areas presenting special design problems, such as bridge sites, are mapped at a scale of 50 ft to 1 in., whereas areas containing several feasible highway routes are mapped at a scale of 200 ft to 1 in.

For trial projection and design of the highway centerline on the topographically mapped route, ozalid prints from the map compilation manuscripts are used. The position of the centerline is plotted accurately on the compilation manuscripts using plane coordinates of its accurately computed PI, P.O.T., and curve points. Cross-section lines at 50-ft stations and intermediate points at right angles to the designed centerline are penciled on the reverse side of the transparent map manuscripts for ease in determining where dimensional measurements should be made.

The cross-sections are measured photogrammetrically on the stereoscopic models either by commerical firms engaged by negotiated contract, or by the photogrammetric unit of Region 9, using a Kelsh stereoscopic plotter and an Auto-trol digital scaler. Terrain measurement data obtained by contract are paid for on a mileage basis requiring an average of not less than a specific number of cross-sections per mile. With the Auto-trol scaler, the terrain data are electronically transferred successively from the stereoscopic model and punched into IBM cards in one operation. The punched cards are edited through an extensive IBM program to highlight any obvious human or machine errors. The corrected digital data are then tabulated for use in design.

In addition to using aerial photography for highway location and design, enlarged photographs (scale 100 ft to 1 in.) and semicontrolled photographic mosaics are used to advantage in the acquisition of rights-of-way and in condemnation hearings. One 3-dimensional model, constructed of styrofoam, has been used to choose the bridge site best fulfilling esthetic objectives.

The photogrammetric facilities and procedures are supplemented by:

1. Electronic measuring equipment (one set), delivered August 1, 1962.
2. A second Kelsh stereoscopic plotter for specialized mapping and training purposes.
3. Adoption and use of aerial color film negative photography on scale stable base. From this photography both black and white and color prints are made, thus eliminating need for the black and white film negative photography.

To date, the purchase of an airplane equipped with an aerial camera cannot be economically justified because (a) favorable weather and other conditions limit aerial photography throughout the greater portion of Region 9 to early spring and early fall, (b) the services of local commercial firms equipped for this type of work are readily available at economical prices, and (c) only about 175 mi/yr of highway surveys are made.

In using modern photogrammetric equipment and methods, junior engineers have excellent opportunities for training in efficient and effective surveying and design procedures and methods. This training is given in cooperation with the fully equipped electronic section, now part of the design section, and is supplemented by a complete program in all phases of highway location and design.

With approximately 400 mi of highway surveys completed by aerial methods, Region 9 personnel are aware of the numerous benefits obtainable from aerial surveys, including reduced survey costs, more complete and accurate data for design, and achievement of better highway locations for the construction funds available.

MICHIGAN STATE HIGHWAY DEPARTMENT PHOTOGRAMMETRIC ACTIVITIES

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The evolution of aerial surveying and photogrammetry within the Michigan State Highway Department has progressed at a slow steady, and fruitful pace throughout the past 10 yr.

In 1951 a Photogrammetric Section was established by the Department as a section of the Route Location Division. Early in 1961, the Photogrammetry Section was transferred to the Design and Survey Division.

Photography

The Department maintains up-to-date files of aerial photography covering the entire State. This photography was purchased from the U. S. Department of Agriculture and is at scales of 1:20,000 and 1:15,840. This coverage is used for area reconnaissance surveys and for preliminary route location purposes. The Soils Division also uses this photography quite extensively in photographic interpretation search for possible borrow pits. In addition, many miles of special photography has been obtained for specific purposes.

Photography for photographic mosaics to be used in route location studies and for photogrammetrically compiling large-scale maps for highway design is obtained from commercial firms on a negotiated contract basis. Each project flown and photographed is rigidly inspected and all photography is thoroughly checked for compliance with specifications based on those prepared by the Photogrammetry for Highways Committee, jointly sponsored by The American Society of Photogrammetry and The American Congress on Surveying and Mapping.

Photography flown for reconnaissance survey and photographic mosaic preparation purposes is generally accomplished with either an 8¼- or a 12-in. focal length cartographic camera at a scale of 800 ft to 1 in. All photography for design mapping purposes is obtained with a 6-in. focal length precision cartographic camera equipped with distortion-free lens, at scales of 250, 330, or 500 ft to 1 in., depending on type and nature of highway improvement for which a survey is required.

Michigan's weather is an important factor to be considered when planning aerial photography for the design-mapping program. In the lower peninsula, fall is not well suited to aerial photography for design mapping even though leaves are gone from the deciduous trees, because weeds, grass and corn present a problem by obscuring the ground. Spring is the ideal period for taking aerial photographs. Snow generally disappears in late April and trees are again in full bloom in late May. About 30 days are, therefore, available in which to accomplish all large-scale mapping photography, and of these, perhaps only 5 to 6 days present suitable aerial photography conditions.