

mark. The field crews surveying vertical control use Zeiss self-leveling levels and K & E yard rods with foot-strips on the side for accuracy check.

The horizontal control surveying crews use Bilby aluminum towers, Tellurometer, and T-2 theodolites. The geodetic marker surveying program was planned for setting station markers along approximately 1,276 mi of the primary highway system.

Most aerial photogrammetric projects are targeted, using opaque white plastic material, except on sand bars where black is used. The material comes in 36-in. widths at \$0.23/yd and is not retrieved because of the low cost. Specifications for setting targets, as well as for the complete photogrammetric work of each highway location and design project, from planning to the contract construction stage, are described in "Photogrammetry and Data Processing in Mississippi" by I. W. Brown, as prepared for the Committee on Electronics at the 47th Annual Meeting of AASHO, Denver, Colo., Oct. 1961.

A topographic map for highway location and/or design, at an appropriate scale, should be considered just as necessary for making an optimum location as any of the other tools now being used. The key to this concept is the word optimum. There is no doubt good highway locations can be, and are being made, without using large-scale topographic maps. Such a map, however, is a tool which, in the hands of an experienced engineer, provides an opportunity to determine and compare, in detail an almost limitless number of feasible locations at practically no additional cost, resulting in a highway that will be cheaper to build, cheaper to maintain, and provides the best possible traffic services.

PHOTOGRAMMETRIC ACTIVITIES OF THE PENNSYLVANIA DEPARTMENT OF HIGHWAYS

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Aerial survey methods, including photographic interpretation and photogrammetry, are utilized by the Pennsylvania Department of Highways in all appropriate phases of highway location and design. Utilization of these methods, however, is progressing cautiously due to some inaccuracies and unsatisfactory results encountered by the Department on early mapping projects. Adequate specifications and supervision of projects by professional photogrammetric engineering personnel have materially aided in attaining better accuracy in mapping for highway engineering purposes during the past several years and in developing more advanced techniques.

The initial significant expression of interest in photogrammetric methods, as an internal function of the Department of Highways, was purchase of a Kelsh stereoscopic plotter in 1955. Due to lack of trained photogrammetric personnel, little developed from this first step until January 1958 when the present organization came into being. The Photogrammetric Unit is currently organized in the Bureau of Design and reports to the Assistant Chief Engineer in charge of that Bureau.

Photography

The Department contracts with commercial photogrammetric firms on a negotiated basis for aerial photography. An aerial camera has recently been acquired to obtain oblique photography for planning purposes and for evaluating construction progress. The Department contracts for the use of an airplane and pilot, but the aerial photographer is a member of the Department's photographic staff.

Aerial photography to be used for mapping by photogrammetric methods is taken at scales of 1,000, 500, and 250 ft to 1 in. Specifications require the use of a distortion-free 6-in. focal length precision aerial camera. A contract with the U. S. Department

of Agriculture was recently completed for aerial vertical photography coverage of the 67 counties of Pennsylvania at a scale of 1:20,000. Photographic enlargements of this photography at a scale of 660 ft to 1 in. were also purchased. The contact prints and enlargements are being utilized for area reconnaissance surveys for general highway and county mapping for planning, and for photographic interpretation in soils research. Large-scale aerial photography, taken from low flight heights, is used for engineering soils studies.

The Department's photographic laboratory is a section under the direction of the Special Assistant to the Secretary of Highways. The laboratory is not equipped to handle 9- by 9-in. size aerial photography, but may be expanded at a later date should this be warranted.

Ground Control

In September of 1961, the U. S. Coast and Geodetic Survey, under supervision of the Photogrammetric Unit, established monumented permanent geodetic survey station markers along the proposed routes of the National System of Interstate and Defense Highways in the Commonwealth. Begun in March 1958, basic control surveying was completed under contract for 1,151 mi of the highway network. The total amount expended for this work was \$691,552.03, averaging about \$600 per highway mile.

The U. S. Coast and Geodetic Survey field party established horizontal positions for control survey monuments set at intervals of 2 to 5 mi and determined elevations for vertical control survey monuments set at a 1-mi interval. All control survey monuments were set at distances of 500 ft to 0.5 mi from the actual or proposed centerline for the highway and were position identified on aerial photography furnished by the Department. These aerial photographs have been furnished the U. S. Geological Survey for use in planning control networks for 1:24,000-scale topographic maps to be compiled on a quadrangle basis by photogrammetric methods.

Department surveying personnel, in most cases, establish horizontal and vertical control for commercial photogrammetric firms when the mapping is for use by Department design personnel. All such control is extended from, and closed on, monuments established by the U. S. Coast and Geodetic Survey. Horizontal control positions are computed on the State plane coordinate system based on the Lambert Conformal Conic Projection. The Department has an IBM 650 electronic data processing unit for the reduction and adjustment of surveying data.

On consultant engineering contracts for location or design, the required mapping is usually the direct responsibility of the consultant. Some consultants will establish the necessary mapping control, but generally commercial photogrammetric firms will complete all phases of the mapping program, including the essential control surveying as well as photography and compilation of maps by photogrammetric methods. All contracts written with the mapping clause, however, are subject to standard Department of Highways specifications for photogrammetric services and are closely supervised and inspected by Department photogrammetric engineering personnel. These personnel advise and assist the consultant engineering firms on photogrammetric procedures and methods and make available location descriptions and geodetic values of all newly established control survey monuments.

In rural or wooded area projects, photographic targets of white muslin cloth are set on the ground before photography flights. For 1:12,000-scale aerial photography targets are 3 by 10 ft, and for 1:3,000-scale aerial photography they are 1.5 by 5 ft. The targets are anchored to the ground with wood stakes and are retrieved for future use. Targets are set at an interval equal to one-fifth the specified photography flight height and on all existing permanently monumented triangulation stations and bench marks within the limits of photographic coverage. In densely wooded or steeply sloped areas, the points for the usual distribution of vertical control for map compilation by photogrammetric methods may also be targeted.

Personnel and Equipment

Current personnel include eight Kelsh stereoscopic plotter instrument operators and shift supervisors, three draftsmen, three survey computists, and four supervisors.

The unit is equipped with three Kelsh stereoscopic plotters. All are 5:1 projection ratio instruments with two projectors. Consideration is now being given to the feasibility of purchasing a three-projector model.

In March 1958, the Department purchased a MRA-1/cw Tellurometer and later a Model 4a Geodimeter for making distance measurements in control surveys. There are also a Wild T-1 and two Wild T-2 theodolites with complete essential accessories for making angular measurements, for polaris observations, and for night operations. The Department has Zeiss N1 2 levels in each district office and in the photogrammetric unit for establishing vertical control.

Mapping for Design

Topographic maps for preliminary design are normally compiled at a scale of 200 ft to 1 in. with a contour interval of 5 ft. A scale of 100 ft to 1 in. for planimetric or topographic mapping with a contour interval of 2 ft is sometimes utilized in urban areas. Site mapping for bridge location and design and for drainage structure design is usually accomplished at a scale of 100 ft to 1 in. with a contour interval of 2 ft. An overlay depicting engineering soils classifications will probably be prepared for some of these projects. Maps for design and preparation of construction plans in rural areas are normally compiled to a scale of 50 ft to 1 in. with a contour interval of 1 or 2 ft. In urban areas a scale of 40 ft or 25 ft to 1 in. may be used for such design, depending on the complexity of the engineering problems.

Photogrammetric measurement of cross-sections has been authorized on a limited number of projects in lieu of delineating contours. The results thus far have been quite satisfactory. On one Interstate project, the cross-sections and earthwork quantities determined by this method have been accepted by the contractor for construction purposes.

Summary

During 1960, contracts were initiated on 25 projects totaling 253 mi of highway alignment. During 1961, contracts were initiated for aerial photography and printing of glass plate transparencies for Department mapping with Kelsh stereoscopic plotters on ten projects. Contracts have also been executed with several commercial photogrammetric firms for aerial survey work on a total of 123 highway miles.

During the 1962 spring season mapping was accomplished on eight projects for a total of 50 mi. During the 1962 fall program, aerial survey work was done on 17 projects totaling some 135.3 mi and including 45.2 mi of aerial photography at various scales, 14.5 mi of topographic mapping by photogrammetric methods at a scale of 50 ft to 1 in., and 75.6 mi at a scale of 200 ft to 1 in.

Contracts for these projects do not include topographic mapping or aerial photography requirements of the prime engineering contracts let separately for other work to consultant engineering firms for which surveys are also required.

FUNCTION AND TECHNIQUES OF THE PHOTOGRAMMETRY SECTION, TEXAS HIGHWAY DEPARTMENT

The Texas Highway Department recognized the value of photogrammetry as a tool in the location, design, construction, and maintenance of highway facilities during the early stages of the science's development and established a definite program of utilizing the various advantageous phases of photogrammetry. Since that time the program has developed into the creation of a separate section within the Highway Design Division, the employment of specialized personnel, and the procurement of equipment necessary for the completion of a highway project survey from the aerial photograph to the finish-