

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-

ed map. The Photogrammetry Section is directly responsible to the Chief Engineer of Highway Design and derives its authority through his delegation of duties. In recent months the section has undergone considerable expansion and improvement in anticipation of an even more complete utilization of aerial surveys by highway designers and planners within the organization.

### Maps Compiled by Department

The Texas Highway Department, through careful deliberation of the subject, has not found it necessary to obtain aerial film negatives through the use of State-owned equipment and personnel. This phase of the total operation has been assigned to prequalified aerial photographic firms on a proposal basis under a set of standard specifications. No serious difficulties have been encountered under this system and it is expected the procedure will continue until a reevaluation demands use of an alternative method.

The Photogrammetry Section employs three Kelsh stereoplotters in the map compilation process. Scribing is used almost exclusively, and all plane coordinate grid systems are based, directly or indirectly, on the State plane coordinate system. The slotted template method of extending horizontal control has been used to a limited extent in mapping for the determination of drainage areas and other types of mapping projects where a low order of accuracy is acceptable. A sketchmaster instrument is usually used in the transfer of essential planimetric information from the photographs to the map compilation sheets.

Plans are being formulated toward the acquisition of an electronic measuring and digital recording instrument to be attached to the stereoscopic plotter as an aid in cross-section measurement and recording work. At present, this work is accomplished manually from the determination of elevations by the stereoscopic plotter operator to punching of the electronic computer cards.

In certain instances, where the size or importance of a project will allow, U. S. Department of Commerce photography has been used in the compilation of topographic maps. This has proved particularly valuable in reconnaissance or route location surveys that demand a flight height too large to produce a map suitable for use in the preliminary survey and design, and construction stages.

The varied nature of Texas topography and vegetation permits, in certain regions, topographic maps to be compiled from photography taken during the summer months. This advantage is utilized in photographing projects in these regions during this normally slack season.

Aerial photography flights from which only planimetric maps are to be compiled are made during any season and supplemented by field survey work where and if required. The setting of photographic targets on the ground over station markers of survey control points before photographing a highway survey project is desired, but in some cases basic horizontal control is established after the photography flying is completed.

All photographic processing, other than the aerial film negatives and the two sets of contact prints furnished by the contractor, is accomplished in the State's reproduction section. This section is fully equipped to handle all phases of the work, including the making of diapositive plates, enlargements of the photographs (both rectified and nonrectified), photographic mosaics (controlled and uncontrolled), reduction of map manuscripts (screened fully or partially) printed on plan-profile sheets or right-of-way plan sheets, and other related products.

In the past, basic field control has been established by each affected District office with the advice and assistance of a member of the Photogrammetry Section. On receipt of an Electrotape instrument recently ordered from the Cubic Corporation of California, a three-man field party, fully equipped for high order basic control surveying work, will be assigned this duty. Because a majority of the maps for highway design are compiled at a scale of 40 ft to 1 in., the electronic surveying device will be utilized to establish reference monuments approximately 1 mi apart that will be used as closure stations for transit-tape survey in staking the designed centerline of the highway. The transit-tape survey crew will set the photographic targets on points every 300 to 400 ft apart wherever photography of 200 ft to 1 in. scale is used and adjust the

error of closure in the ground surveyed position of these points, if necessary, to each control survey station the Electrotape has occupied. The elevation of vertical control points near the corner of each stereomodel, and elsewhere as required, will be determined in the usual survey manner on the ground.

The District offices perform a field check and test profile analysis of the topographic maps as prints of the maps are delivered and inform the Photogrammetry Section of the results.

### Maps Compiled by Photogrammetric Firms

In the event a highway project survey is to be developed by contract, proposals are requested from photogrammetric firms which have been prequalified by the State as to their abilities and facilities. The request is accompanied by a set of standard specifications pertaining to the acceptable quality of photogrammetric work in general and a set of special specifications setting forth conditions and standards applicable to the particular project.

The contractor is responsible for the photography, all compilation products, and the field control. The Photogrammetry Section checks the manuscripts on a stereoscopic plotter while the District field offices conduct a separate on-the-ground evaluation as delivery is made. The District field office is informed as to the results of the stereoscopic plotter checking and either returns the map sheets to the contractor for correction or accepts them as meeting the requirements of the specifications.

### Special Projects

A procedure has been established in obtaining detailed right-of-way information from maps compiled photogrammetrically at the large scale of 20 ft to 1 in.<sup>1</sup>

Research is being conducted into the possibility of utilizing a six-projector Kelsh stereoscopic plotter instrument in bridging horizontal control. The recent delivery of a three-projector Kelsh instrument should facilitate this research.

A system of reducing the aerial photographic image to 35-mm strip film and the projection of a three-dimensional image on a screen through the use of two projectors remotely controlled from a single source is being studied both for design use and for demonstrations at public hearings.

Color photography has been examined to a limited extent for feasibility in differentiating soil conditions, geological formations, types of ground cover, etc. No definite program for its general use has been established.

An attempt is presently being made to design an image projecting machine, manually operated, that will determine the azimuth and degree of tilt, scale, and crab of a photograph through the use of opaque templates.

## PHOTOGRAMMETRY IN ARIZONA HIGHWAY DEPARTMENT

The Photogrammetric Division of the Arizona Highway Department was inaugurated in October 1957 with a staff of six men selected from existing personnel with varying experience in utilization of photogrammetric methods. Equipment consisted of a KEK plotter, two vertical sketchmasters, a slotted template cutter and an assortment of used drafting tables. The initial purpose of the new division was revision and modernization of the small-scale county maps which had been made a number of years previously and were incomplete and inadequate.

<sup>1</sup>Henry, H. A., "Development of Photogrammetric Methods for Right-of-Way Operations in Texas." HRB Bull. 283, pp. 39-48 (1961).