Many aerial photography, photographic mosaic, and topographic map displays are made for the legal staff and have proven invaluable in condemnation suits. Such displays are also made for the Public Information Section.

CURRENT PHOTOGRAMMETRIC PRACTICES IN VIRGINIA

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Before photogrammetry can be utilized to its fullest extent, the user must recognize its limitations. Photogrammetry is not the highway engineering cure-all prophesied by so many during the past few years. It must be employed with discretion and with close quality control.

In Virginia, only equipment and materials known to consistently provide high quality results are used. Photography, for instance, is taken using only a stable base aerial film and an aerial camera with a distortion-free lens. Diapositives are printed only on glass plates ¼ in. thick. Map manuscripts are compiled using only a stable base drafting film on which control points are plotted by means of a precision coordinatograph.

Ground control for mapping by aerial methods is established with Tellurometers for distance measurement and Wild T-2 theodolites for angular measurement. Two masters and two remotes of the early model MRA/1 Tellurometer and the later addition of two units of the MRA/2 model provide three complete distance measuring systems.

For quality control, a test profile is measured routinely on the ground during establishment of ground control for each stereoscopic model from which a map is to be compiled. The profile data, however, are withheld from the stereoscopic instrument operator until after each stereoscopic model has been used in compiling the maps and making other essential measurements. An independent check is then made by a supervisor to determine completeness of planimetric detail and accuracy of the contour delineations or cross-section measurements. This check is made before the setup of each successive stereoscopic model is removed from the photogrammetric instrument.

The actual utilization of photogrammetric equipment for highway engineering in the State can be placed in two distinct areas: (a) route location stages, and (b) accumulation of survey data for use in highway design. In the route location stages, topographic mapping is accomplished at a scale of 200 ft to 1 in. with a 5-ft contour interval. For highway design, the maps are compiled at a scale of 50 ft to 1 in. with a 2-ft contour interval or cross-sections are measured photogrammetrically using stereoscopic models of the same scale.

Aerial photography is taken using a State-owned Aero Commander twin engine aircraft with a Wild RC-8 aerial camera. Both pilot and photographer are former survey party personnel who have other office duties within the highway location section when not actually engaged in flying.

A complete photographic laboratory is maintained for processing the exposed aerial film and printing photographs on paper and on glass as needed. Contact printing is accomplished through the use of an automatic electronic dodging printer and enlargements are made utilizing a Zeiss SEG-V Rectifier-Enlarger. Photographic mosaics are copied using an overhead-type Robertson copy camera. This camera is used for all departmental copy work, including road and bridge plans, maps, and sketches, and further doubles as a photographic enlarger.

All ground control for the route location topographic mapping (scale of 200 ft to 1 in. with a 5-ft contour interval) is accomplished by three survey parties equipped with Tellurometers, Wild T-2 theodolites, and Zeiss automatic self-leveling levels. Horizontal control for all such mapping is based on the Virginia State plane coordinate system and vertical control on sea level datum. All traverses for ground control are computed and adjusted by electronic computer. Because the photographic image of each horizontal control point is usually off the main traverse, the traverse program was written to include computation and adjustment of the supplemental measurements to these points.

Compilation of the topographic detail is accomplished utilizing five Kelsh stereoscopic plotting instruments. The compilation is made on an emulsion coated stable base drafting film in pencil after which the map is completed using scribe techniques. Each scribe sheet actually serves as a photographic negative from which copies of each completed map are produced photographically on stable base Cronaflex material. The only inking involved is in labeling the elevation of contours and identifying other map features. During the last fiscal year, approximately 173 sq mi of mapping were completed in addition to the other larger scale contour delineation and cross-section measuring accomplished by the mapping unit.

The topographic mapping serves as the basis for subsequent route location and as a means for reporting route alternatives and making recommendations. This phase is accomplished well in advance of design and subsequent location survey staking of the highway on the ground.

After a highway survey and design project is advanced to the location survey stage where the centerline is to be staked on the ground, a combination of techniques is employed involving both photogrammetric and conventional field surveying practices. Where ground cover is so tall and dense that accurate measurements cannot be made by use of aerial photography, ground survey methods are used exclusively. On some projects only the cross-sections are measured and contours for interchanges are delineated by photogrammetric methods. On other projects all planimetric detail is also delineated (generally referred to as topography). On some projects a topographic map is compiled of the entire project, measuring and delineating the contours on a 2-ft interval. More recently the photogrammetric methods have been confined to measurement of cross-sections using a Benson-Lehner Terrain Data Translator coupled to a Kelsh stereoscopic plotter. The cross-section data in digital form are punched directly into cards.

The preferred approach in making this type of survey is to first establish a survey baseline on the ground, tie the centerline into the State plane coordinate system and then measure on the ground the profile of this baseline. The baseline is then targeted at 500-ft intervals. An attempt is made to target the centerline or baseline for all location-type surveys involving the photogrammetric measurement of cross-sections. Where there are likely to be few natural ground image points, such as in wooded areas, cultivated fields and meadows, additional targets are placed near the outer limits of the area to be photographed for use as stereoscopic model leveling points.

Targets are printed in the form of a cross on 45-in. squares of white muslin cloth and are fastened at the corners by gutter spikes 7 in. long (Fig. 8). These printed targets cost approximately $0.30 each and are extremely easy to transport and place on the ground. In wooded areas where the targets are somewhat difficult to identify, two strips of white muslin cloth, 9 in. wide and 10 ft long, are first placed over the points in the form of a cross and the small target is placed in the center to provide contrast.

After all targets are placed on the ground and the photography mission is completed, photographic prints are furnished the ground control survey parties for use in identifying all visible targets and in establishing vertical control along or near the outer limits of the photography. Where targets have been destroyed by animals, cattle, deer, and the like, sharply defined natural images are selected to serve as control points.

The plane coordinate computed centerline or baseline is plotted on stable base drafting film using the Aristo coordinatograph and the targeted horizontal control points. The electronic computer traverse program automatically computes the plane coordinates in increments of 500 ft, greatly facilitating the plotting of centerlines on the manuscript, particularly where curves are involved.

The actual photogrammetric instrumentation work is accomplished by means of an electronic digital measuring and recording system. The Terrain Data Translator

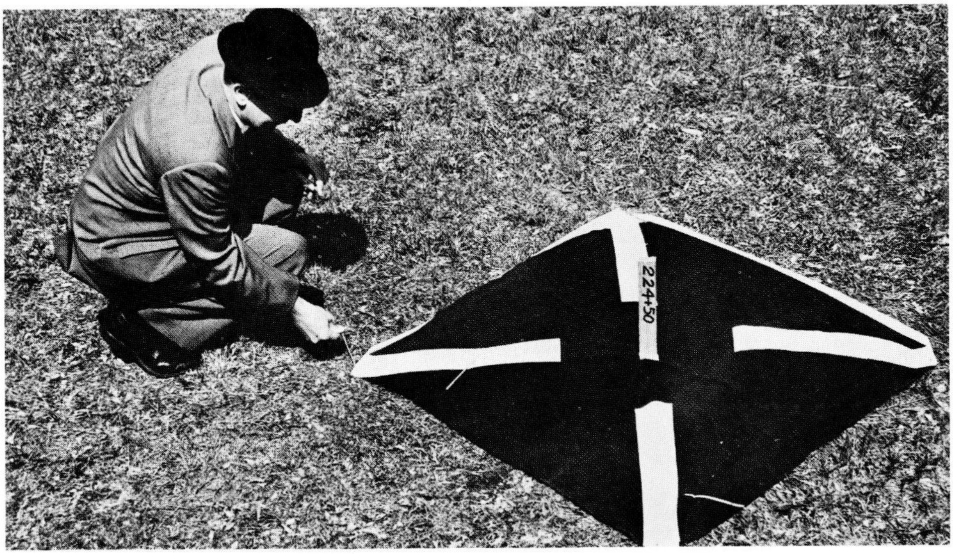

Figure 8. Target for aerial surveys.

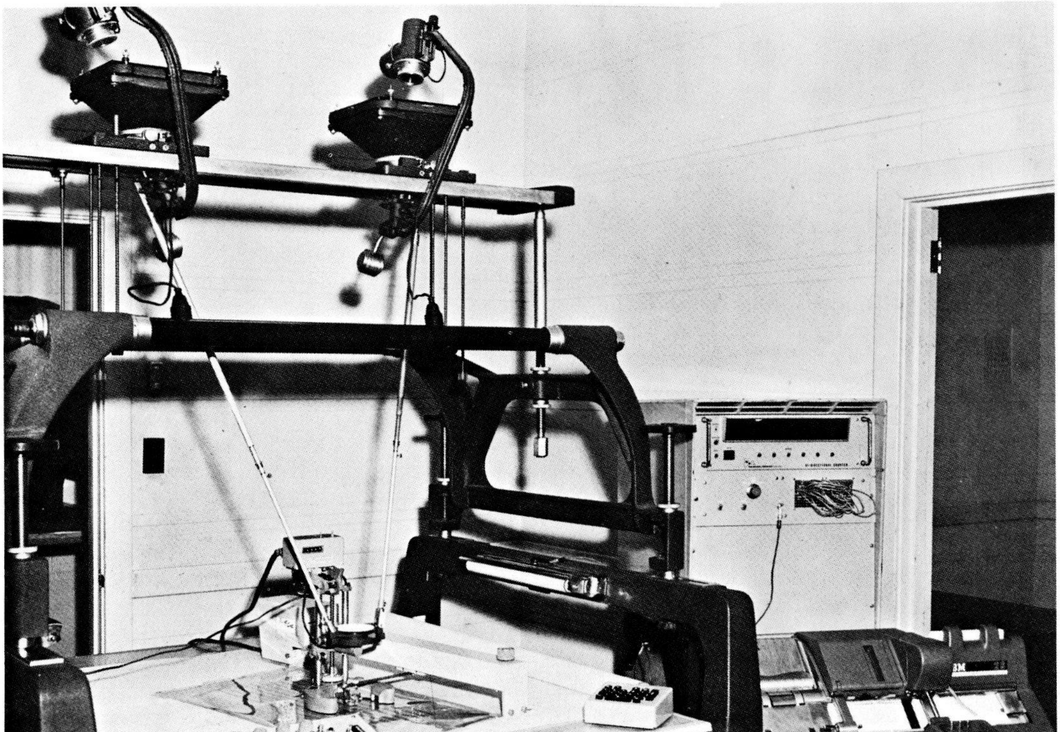

Figure 9. Benson-Lehner Terrain Data Translator.

(Fig. 9) being used for this work is the transistorized or solid state model with the Nixie Tube display for horizontal distance. The photogrammetric instrument operator by means of a horizontal scaler makes a cross-section point measurement at each 20-ft increment plus all breaks in the ground line. To maintain the 20-ft increment, the operator needs only to glance at a transparent overlay consisting of several parallel 24-in. long scales and used for horizontal alignment of the scaler.

As originally designed, the horizontal scaler had to be moved and re-aligned at right angles to the survey line for each cross-section measured. The arm that attaches to the chuck of the Kelsh tracing table has been lengthened and small holes drilled on centers 1 in. apart. The tracing table can now be moved from hole to hole, each of which is equal to the ground distance of 50 ft at stereoscopic model scale and provides seven cross-section positioning lines for tangents without moving the horizontal scaler.

Improvements have been made in the method by which digital data are transferred to punched cards. Star wheels were added to the key punch program card to (a) automatically enter the fixed data, (b) advance the card numbering relay at the end of each card, and (c) light a lamp on the control unit to indicate that the digital data are being entered in the proper position in the card. In addition, a switch was added to the TDT control unit to record the measured centerline elevation from the control unit rather than from the Kelsh tracing table. This switch also zeros the horizontal distance on the TDT display and transfers the information to the IBM card when crossing centerline. After the station number and centerline elevation are set into the control unit, the operator has only to concentrate on making the successive point measurements for each cross-section, regardless of the number of cards for each cross-sectioning station. On completion of the measurements for a cross-section, the instrument operator sets station number and centerline elevation for the next cross-section and zeros his card counter. Then he rejects the last card containing the previous cross-section data and the new fixed data are entered automatically.

Once the stereoscopic model is set up and the TDT coupled to the tracing table, instrument operators have been measuring around 500 cross-section points per hour. Under ideal conditions, however, where there is very little ground cover, they can measure about 700 cross-section points per hour. Before the instrument modifications were made, the instrument operators were averaging around 250 to 300 points per hour, 50 to 100 points per hour more than when the measurements were made and recorded entirely by manual methods. These rates do not, however, reflect the time required for making each stereoscopic model setup.

The TDT with the special modifications is capable of re-cycling at such a rate as to permit visual observation and automatic recording of the measurements of 1,700 points per hour, but this is allowing no time for change of station number and elevation or for re-alignment of the horizontal scaler at right angles to the centerline.

Perhaps another factor contributing to the increased productivity of the electronic system is the ability of each photogrammetric instrument operator to hold his stereoscopic vision, particularly in wooded areas and where the ground slopes are steep. With the electronic system, the instrument operator can keep his eyes constantly on the stereoscopic model, but when using manual methods he was constantly glancing away from the stereoscopic model to view and mark the tracing table distance from centerline and would momentarily lose his vision of the streoscopic model.

The TDT can be used to the best advantage with two separate Kelsh stereoscopic plotters. The digital measurement and recording of cross-section data are accomplished from one photogrammetric instrument while a stereoscopic model is being set up in the other. On completion of measurements and recording with the first instrument, the TDT is coupled to the next instrument.

Areas where heavy foliage obscures the ground still require conventional ground survey procedures and later punching of the measurements into cards by manual methods.

After all cross-section measurements are punched for each location survey project, they are sent through the IBM checking program. This checking program verifies the centerline elevation from card to card, checks for vertical differences of 50 ft or greater between adjacent cross-sections at the centerline point and also indicates where no centerline point is recorded. It further indicates where horizontal distances between adjacent cross-sections are not decreasing from left to center or increasing from center to the right and when there is a vertical difference of 20 ft or more between adjacent points on each cross-section. It also indicates when the photogrammetrically or otherwise measured elevation at the center of the cross-section does not agree with the elevation measured by spirit levels for centerline stationing points.

The designers seem to welcome projects where the cross-sections have been measured by photogrammetric methods. When they encounter unusual problems in design and need additional information, cross-sections or contours can usually be furnished from the stereoscopic models in a matter of hours, in contrast to the several days or weeks required to obtain additional survey information from the field when surveys are made by conventional methods on the ground.

Photographic mosaics and enlargements of aerial photographs are utilized in most phases of route location, traffic analysis, geologic and soil analysis, preparation of right-of-way cost estimates, and drainage studies.

When highway projects are advanced to the design stage, the first thing the designers generally request is a set of aerial photographs. Photographic enlargements are generally requested during the early stages of design. After the highway construction plans are advanced to the procurement of rights-of-way, photographic enlargements are furnished for appraisal work and are frequently furnished for use in condemnation cases.

It is felt that photographic mosaics prepared by orthophotographic methods will have a very definite place in the highway engineering program. Orthophotographs will provide a means whereby the aerial photography images can be accurately portrayed on highway plan sheets, thus greatly enhancing the usefulness of photography in all phases of highway engineering. An instrument called the orthophotoscope has been developed by the U. S. Geological Survey which compensates for the image displacement due to relief height. It provides a photographic map from which distances can be accurately scaled between features and eliminates the need for much symbolization to indicate land uses, topographic features, vegetation, etc.

Photogrammetry and photogrammetry united with electronics for measuring and digital recording of specific measurements have provided the means for greatly increasing engineering productivity in Virginia.