AERIAL SURVEYS SPEED TURNPIKE LOCATION*

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PLANNING for an eastern extension of the Pennsylvania Turnpike from its present terminus west of Harrisburg to Philadelphia has advanced from preliminary studies to the design stage in a little over a year. In June, 1947, when the Pennsylvania Turnpike Commission asked Gannett Fleming Corddry & Carpenter, Inc. to make the necessary location studies for this 140 miles of superhighway through rugged country and closely built up suburban areas, it wanted the surveys completed in time to permit detailed design studies to begin in the spring of 1948.

It was of course immediately apparent that, unlike the existing 160-mile turnpike, this projected extension of almost equal length would be surveyed and designed in a period of engineering manpower shortage. To find the qualified field personnel necessary to make a ground topographic survey of such magnitude seemed almost impossible and would at best consume much valuable time. Similarly the office personnel necessary to translate that survey to paper was in short supply.

With the two chief elements of the conventional method of highway location surveys difficult to obtain, the alternative was to find another method. Accordingly, with the approval of the turnpike commission, it was decided to select the aerial survey as the method producing suitable topographic maps in the shortest length of time. It is believed that this decision instituted the largest application of aerial mapping to highway location work attempted to date.

Since the best results are obtained from aerial photography when foliage is off the trees, the staff concentrated on general route studies during the summer months of 1947. These studies were made from maps prepared by the U. S. Geological Survey, the Army Map Service, Pennsylvania Department of Highways, and other agencies, and formed the basis upon which the flight strip was selected.

Copies of tactical sheets of the Army Map Service were included in the contract documents. On these sheets the area to be mapped was shown in rectangular blocks that were coincident with the outline of the finished topographic map and numbered to match. The general route, although not totally restricted by the client, was indicated to a certain extent by the desire to avoid highly productive farm lands and congested populated areas.

One Square Mile per Day

Proposals based upon specifications prepared by the writer's firm were invited from the larger photogrammetric engineering organizations and were opened Oct. 14, 1947. Three bids were received, with Aero Service Corporation of Philadelphia submitting the successful one. The contract between Gannett Fleming Corddry & Carpenter, Inc., and this company was awarded on Oct. 15, 1947, and flying started immediately. It was specified that deliveries of completed topographic maps should be made during the course of the work, with final delivery required within 145 calendar days. This completion date indicated a rate of about one square mile of finished topography per day.

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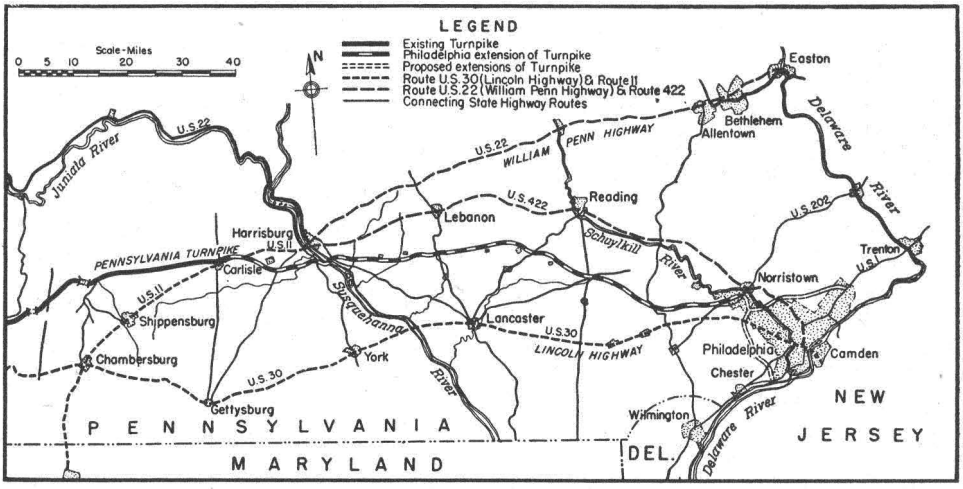
The end product specified consisted of an inked linen topographic drawing, complete in cultural detail, on a scale of 1 in. = 200 ft. and showing contours at 5-ft. intervals. The scale width of each finished sheet was one mile and the length covered a distance of 2.5 to 3.1 miles.

Other details of the specifications provided for identification of dwellings by symbol, spot elevation at road and railroad intersections, summits, depressions and saddles, and a coordinate system to be shown at 1,000-ft. intervals. Buildings with any side equal to 60 ft. or more had to be shown in correct outline but others were indicated by a 25×25 ft. square. The symbols for streams, swamps, quarries, etc. conformed closely to standard practice.



Topographic maps for extension of the Pennsylvania Turnpike 140 miles to Philadelphia were made in 145 days.

The entire project required 51 map sheets all of uniform width but varying in length from 5 to 7 ft.

Results Found Accurate

Field checks were made on each map by our own field parties to determine its conformity with the specifications—which provided that 90 per cent of all elevations be correct within one-half contour interval, or $2\frac{1}{2}$ ft., and that the remaining 10 per cent were not to be in error by more than one contour interval. A profile 3,000 to 5,000 ft. in length, run in the field, was compared to a profile plotted from the contour map covering an identical line. The accuracy of horizontal dimensions was determined by spot check in the field by actually measuring the distance between certain well defined cultural features.

With the exception of an occasional minor omission, a not unusual result of high speed in the drafting room, the maps were found to conform to the specifications. The important features—vertical and horizontal accuracy—were well within the requirements.

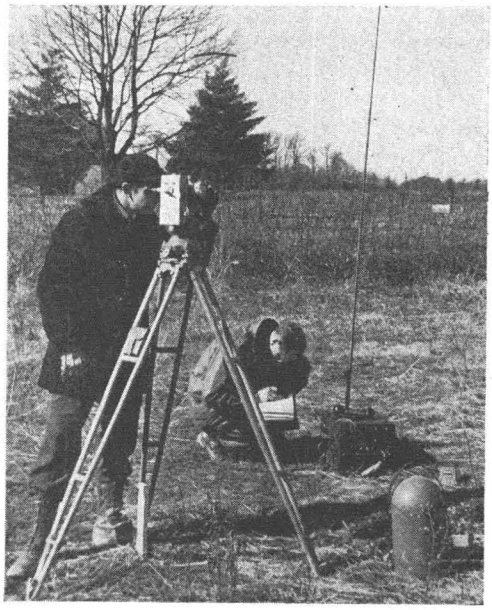
In addition to the topographic map sheets the contract provided for delivery of collateral photographic information to increase the usefulness of the maps. These included photo mosaics at a scale of 1 in. = 400 ft., corresponding to the topographic maps in boundaries, a set of contact prints from the mapping negatives at 1 in. = 1,000 ft., a set of enlargements at a scale of 1 in. = 400 ft., an assembled photo index for all photography completed and a tabulation describing the elevations and coordinates of the aerial mappers control points.

Economical Mapping

To those engineers struggling with rising cost problems coupled with reduced productivity of sub-professional help, the aerial survey presents at least a moderate form of relief. It is not intended to imply that the application of photogrammetry to all survey and mapping problems will result in the ending of all such problems. Neither is it implied that the method, as at present developed, will enable the engineer to put his transit and tape in storage. The leading firms in the field of photogrammetry are most emphatic in pointing out its limits of usefulness and maxima of application.

However, for the particular problem discussed here it is felt that in comparison with conventional ground topographic surveys the topographic map resulting from an aerial survey is as accurate, is considerably more complete, is produced faster, risks less human error, and is by far more economical.

On this last point, consider making by stadia survey or any other ground method, a complete topographic map over an area one mile wide by 141 miles long, showing 5-ft. contours and all cultural features and covering a range of topographic types from rugged, wooded hill country to the solidly built up suburbs of metropolitan Philadelphia, for less than $1.00 per acre. Consider further that this operation required 145 calendar days during the wrong end of the calendar for ground surveying in Pennsylvania, Nov. 1 to March 25.



Field surveyors, using a precision theodolite and a radio transceiver, established the necessary horizontal and vertical controls for aerial work.

It is an extremely conservative estimate that, if the necessary qualified personnel had been available, to produce an end product of comparable completeness and accuracy would have required a time period five times longer and an expenditure five times larger.

Photogrammetric Procedures

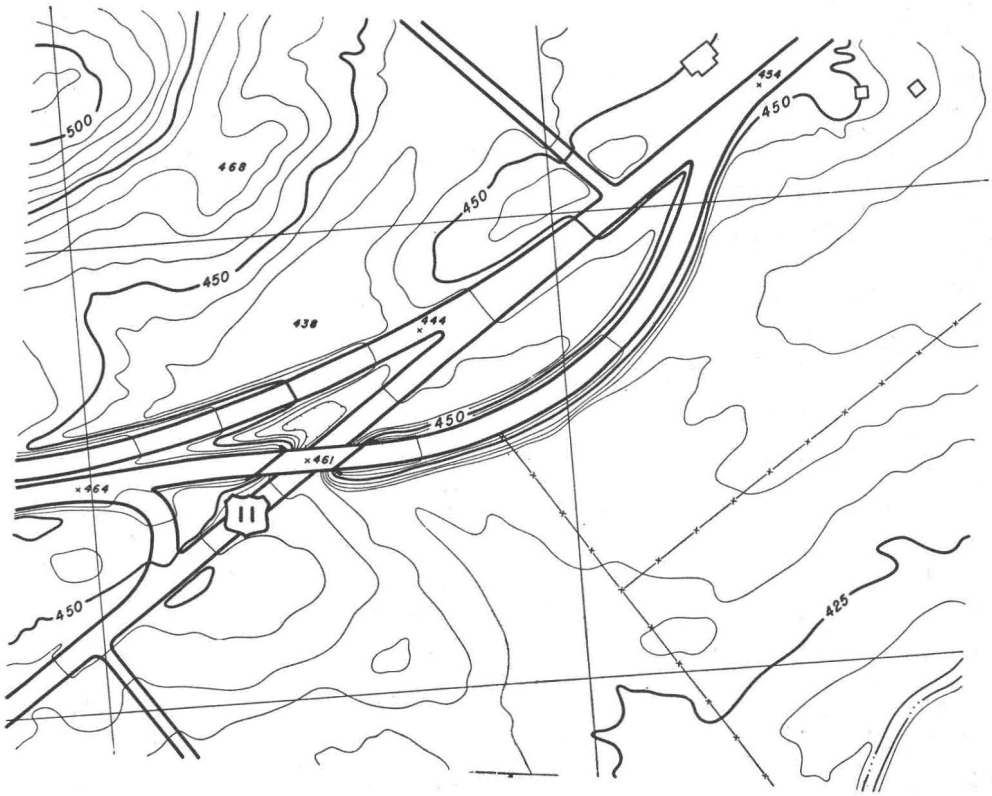
The Aero Service Corporation used a single-engine light plane of good range and stability, assigning a veteran pilot-photographer team to the job. Flying at an altitude of more than a mile above the selected route, the aerial camera photographed the area on glass-plate negatives. (Glass plates were used rather than film because of the greater dimensional stability of the glass plates in processing and handling.) The photographer exposed a plate at intervals of about 20 seconds, and the negatives were flown daily to the aerial surveyor's main laboratories at Philadelphia for processing.

After prints were made, a set was turned over to the field surveyors, who established the necessary horizontal and vertical control data. These crews are trained in the use of new precision theodolites, combining traverse and bench leveling. The method eliminated the far slower chaining and spirit-level methods,

at no sacrifice in accuracy. Horizontal closures ranged from 1 foot/10,000 to 1 foot/80,000 with 1 foot/30,000 the average. The average error of vertical closure of level measurement was .004 ft. per mile.

In general, a time saving of 20 to 50 per cent over older methods for this work is effected with this technique. Radio communication was used to speed the necessary ground survey work. On traverse work, with an average distance of a mile between working parties, it was found that visual signals often were not clear. The survey crews then were equipped with compact radio transceivers—short-wave radio receiving and broadcasting units powered by self-contained battery units, which have a line-of-sight range of a few miles. Field parties using these units could quickly coordinate their basic control. All of the control was tied into control points of the Coast and Geodetic Survey for both the horizontal and vertical positions.

With the field survey data at hand, the compilation of the topographic map from the aerial photos was accomplished with photogrammetric equipment. The technical aspects of this process are quite interesting. The aerial photographs are exposed so that full stereoscopic coverage for the area is obtained. Basically, the method employs the same principle as the old parlor stereopticon, but the modern aerial photos are made with precision cameras and lenses, then processed through precision measuring and contouring equipment so that true elevations may be obtained.



Topographic map of the present eastern terminus of the Pennsylvania Turnpike. This is a direct reproduction of a section of one of the topographic maps for the whole route by aerial methods.

Each photographic plate has a forward overlap of 55 per cent, as well as a considerable overlap at the sides. These stereo photos are taken about one-half mile apart, at an altitude of more than a mile, giving a gigantic separation and increased stereoscopic depth to the view. After field survey parties have established control points for the areas photographed and the plates are rectified for tilt, contouring begins. Using very precise mapping equipment operating on a principle similar to the military range finder, the stereometer operator measures exactly the ground elevations from these stereo views. He is able to draw contours on the photograph to within one-half contour interval two and one-half feet in this instance.

In addition to the topographic features, all the wealth of planimetric detail appearing on the aerial photos is added to the topo maps. Roads to their proper width, buildings, streams, wooded areas, transmission lines and other important data are revealed to the stereometer operator for recording on the map sheets.

A point not to be overlooked in a project of this type and size involves the problem of gathering the necessary information without divulging the proposed location, at an early stage, to land speculators. This particular route was flown and photographed in about two working days without powdering the landscape with surveyors. It should be noted here that the strict confidence in which all data were held by the employes of both the aerial surveyors and the consulting engineers almost approached the phenomenal. Until the Governor of Pennsylvania formally announced the location, the local press had failed to name any major point within seven miles of the actual line.

Design Details Not Fixed

Although final design has not appreciably advanced at this stage, certain departures from the design of the existing Pennsylvania Turnpike are under consideration. Notably among these will be a maximum grade of two per cent and a maximum curvature of three degrees. Tangents between reversed curves will be held to a minimum of 1,000 ft. and between curves in the same direction will be held to a minimum of 2,500 ft. The country in general is not as rugged as the present line across the Allegheny Mountains and will require no tunnels, but a major structure of about 4,000 ft. in length will be required to cross the Susquehanna River near Harrisburg.

Transitional spirals and superelevation will be applied to curves for a design speed of 70 miles per hour.

The extension traverses a more highly developed country and consequently will intersect more roads and railroads. As all rail lines and highways are separated, the frequency of structures increases from 1.8 per mile on the original turnpike to about 2.4 per mile on the extension. This factor alone will act as a deterrent to the desire to increase the width of the divisor strip, which is 10 ft. on the completed portion. To increase the span or width of over 200 bridges would add no mean amount to the total construction cost.

The location of interchanges must await the completion of the traffic analysis now under way, but it can be estimated that about nine will be required. As all turnpike traffic must be channeled to a toll booth for exit and entrance, no change in fundamental features is contemplated. However, where space and economics permit, the minimum radius on the various ramps will be increased to ease the flow of leaving and entering traffic.

Within the past few weeks a group of four large banking houses offered to underwrite $70,000,000 in bonds of the Pennsylvania Turnpike Commission for this extension.