PHOTOGRAMMETRY IN AN ENGINEERING FIRM*

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Introduction

IN CHOOSING the subject for this paper, it occurred to me that many of you would be interested in knowing of the scope and variety of the photogrammetric activities of our firm, particularly as related to engineering projects. During my short association in this company I have continually encountered basically old methods and procedures applied to problems that were new to me. So I decided that there would be a rather large part of this audience engaged in a field of activity similar to that of mine a few months back, and that you would be interested in the scope of applications I had recently observed with so much interest. So I have chosen to tell you about the nature of our firm and its work and of the applications it has found for photogrammetry. I hope that you will find these of interest as have I during the past few months.

The Firm and Photogrammetry

The firm of Lockwood, Kessler and Bartlett, Inc., as it is presently constituted, dates from its incorporation in 1934 under the presidency of Ford Bartlett. This firm was a direct outgrowth of the practise of a group of engineers that goes back to 1889 and included Mr. Bartlett's father. During the later portion of the practise of the elder Bartlett, he was associated with Messrs. Lockwood and Kessler, whose names still appear in the firm although they are no longer active. The early practise of the group was conducted largely in the New York City area and embraced such works as highways, docks, shore protection, sewers, utilities, and concrete structures.

The addition of photogrammetric methods to the firm's facilities stems directly from a project which was worked on in 1942. In that year the firm was engaged on route location for "the big-inch" oil line which brought crude oil from the fields of the southwest to the New York area. During a portion of the work, a field office was located in Little Rock, Arkansas and it was there that Mr. Bartlett first had an opportunity to see photogrammetric equipment in operation. That was the Multiplex equipment in use in that city by the Corps of Engineers' district office. As a result of his problems in pipe line location work, Mr. Bartlett was quick to recognize the advantages of the photogrammetric method, and determined there and then that photogrammetric equipment must be added to his engineering tools. However, we were involved in a war at that time and photogrammetric equipment was unobtainable for civilian purposes. This situation continued until the end of the war but at the earliest opportunity thereafter, Mr. Bartlett followed through on his decision. By 1947, he had his first equipment, a Wild Autograph A-6, installed and ready for work.

As a result of the relatively large capacity of photogrammetric equipment, it was found early that it could not be kept busy in conjunction with only the engineering operations of the firm. So in addition to the work on the firms engineering projects, the equipment has been used on others. These have divided themselves into two general categories. The first is for those clients who call upon the firm to prepare topographic maps, the map itself being the end product required. The second is where the firm works with other engineers in an over-all project with our operations being involved with the surveys and maps required for design purposes. With these two additional categories there has been a sufficient work load to justify a considerable expansion of photogrammetric facilities. This work now constitutes approximately one-third of the firm's total operations. I will discuss today only the portion of the work that is more directly involved in engineering operations, as I believe it is the portion about which less is known and probably will be of greater interest to you.

Today the photogrammetric facilities of the firm include, in addition to the original A-6, one Wild Autograph A-5, three Kelsh

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plotters with projectors for six-inch Metrogon photography; fifteen wide-angle Bausch and Lomb commercial type Multiplex projectors; one nine-projector Multiplex frame and table, and three three-projector Multiplex frames and tables. Our Bausch and Lomb Multiplex reduction printer is of the nominal ratio of 153/30 and is matched to the Metrogon lens. The Wild A-5 reduction printer is likewise matched to six-inch Metrogon photography. The A-6 is equipped with corrector plates for use with diapositives prepared by contact from six-inch Metrogon negatives. All aerial cameras for photogrammetric work are six-inch Metrogon cameras, one being a Fairchild Cartographic and the other two being K-17's which have been rebuilt for precision work. In the photographic laboratory is a Saltzman enlarger with a tilting lens and easel for rectification work. The lab and office also provide the usual miscellaneous equipment associated with photographic and photogrammetric work. For flying for aerial photography, we have at present three airplanes, a stagger-wing Beechcraft, a Cessna 195 and a Ventura PV-1. Our personnel provides fifteen operators for the plotting instruments and another twenty-five engaged in flying, laboratory and drafting operations.

No mention of photogrammetric facilities would really be complete without brief reference to the facilities for field control surveys which are so necessary in the projects undertaken. Just as much attention has been given to equipping the survey parties. In addition to the more usual survey equipment with which they are provided, they have available such items as T-2 theodolites, two-way radios, subtense bars, altimeters and the Zeiss automatic level.

Pipe Lines and Photogrammetry

Now I will describe some of the photogrammetric work our firm has performed in connection with engineering projects. It is appropriate that the first description be of pipe line projects since it was on such a project that the advantages of aerial photogrammetry were first recognized. Our part in these projects has been to determine the final line location within the bands prescribed as a result of earlier reconnaissance, to prepare the necessary maps of the line and adjacent territory, and to lay out and stake the line for construction.

Usually the earlier reconnaissance has narrowed the line location to a relatively narrow band so that it may be covered with a single flight of aerial photographs. The flight height for such photographs depends upon several factors which may vary from project to project but generally is in the order of 10,000 feet. The photographs then become the chief source of information for determination of the line location. By stereoscopic study, an engineer is able to lay out on the photographs a location for the line that is subject to relatively little change as a result of conditions encountered in the field.

After the line location has been laid out on the photographs, a strip map is prepared from the photographs by use of the photogrammetric equipment. This mapping may be only planimetric or it may also include the hypsography depending upon the nature of the terrain and its importance relative to line location. The proposed line is next transferred to this strip map which is then ready for the application of property lines, results of further field investigations and the application of all other survey data resulting from actual line "stake out." The elevations for determining the profile of the line may result from photogrammetric work depending upon the nature of the conditions encountered and the accuracy required. In Figure 1 is shown a sample portion of a strip map prepared for a recent project in Michigan. The top portion illustrates the map prepared from the aerial photographs with the line location as planned. The lower portion is of the same area and shows the line as actually laid out, together with the data collected by field survey.

The very brief explanation I have given of the pipeline projects indicates that they follow the same general sequence of operations as other route locations. In general, these all have a first broad reconnaissance phase in which one or more bands are determined. These bands then usually require fairly large scale mapping and it is at this stage that we usually see photogrammetric methods applied. The last operation is usually that of a detailed ground survey to finalize the line.

My brief explanation did not bring out the great advantage that aerial photographs and photogrammetry have brought

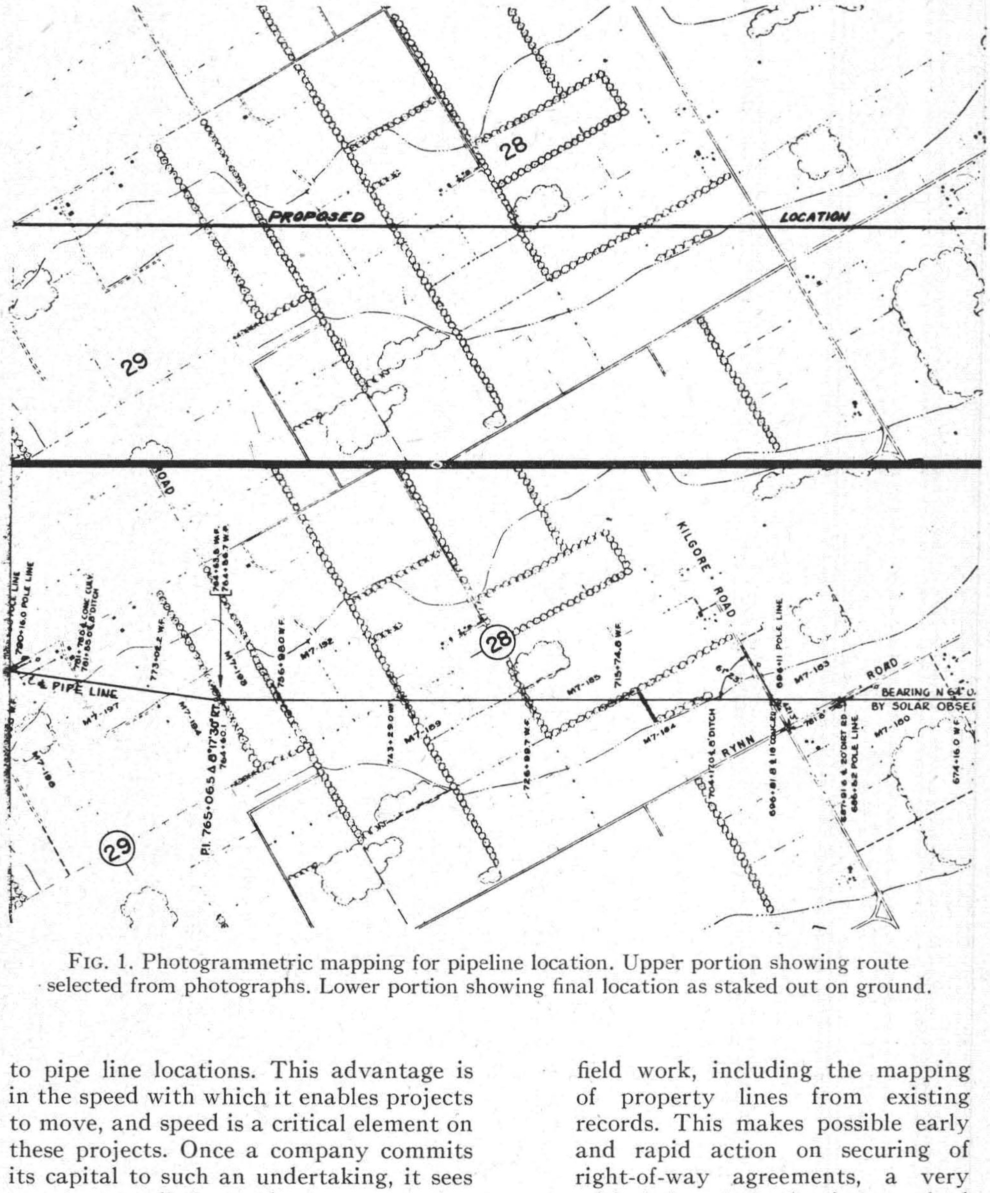

FIG. 1. Photogrammetric mapping for pipeline location. Upper portion showing route selected from photographs. Lower portion showing final location as staked out on ground.

to pipe line locations. This advantage is in the speed with which it enables projects to move, and speed is a critical element on these projects. Once a company commits its capital to such an undertaking, it sees no return until the products start moving through the line, and hence is always interested in the greatest possible speed. Photographs and photogrammetry contribute to this speed in the following respects:

(a) They reduce the effort, and hence the time, required in field reconnaissance.

(b) They usually result in a better location being selected, thus reducing the cost and time required in construction.

(c) They permit mapping to precede field work, including the mapping of property lines from existing records. This makes possible early and rapid action on securing of right-of-way agreements, a very critical element in the time required on a project.

(d) They provide the stake-out parties with a map. Taken to the field, the map enables the parties to do their survey work with a minimum of effort. Parties can be started on such work simultaneously at various points along the line, with the assurance that their various line sections will join up properly and without costly and time consuming reruns.

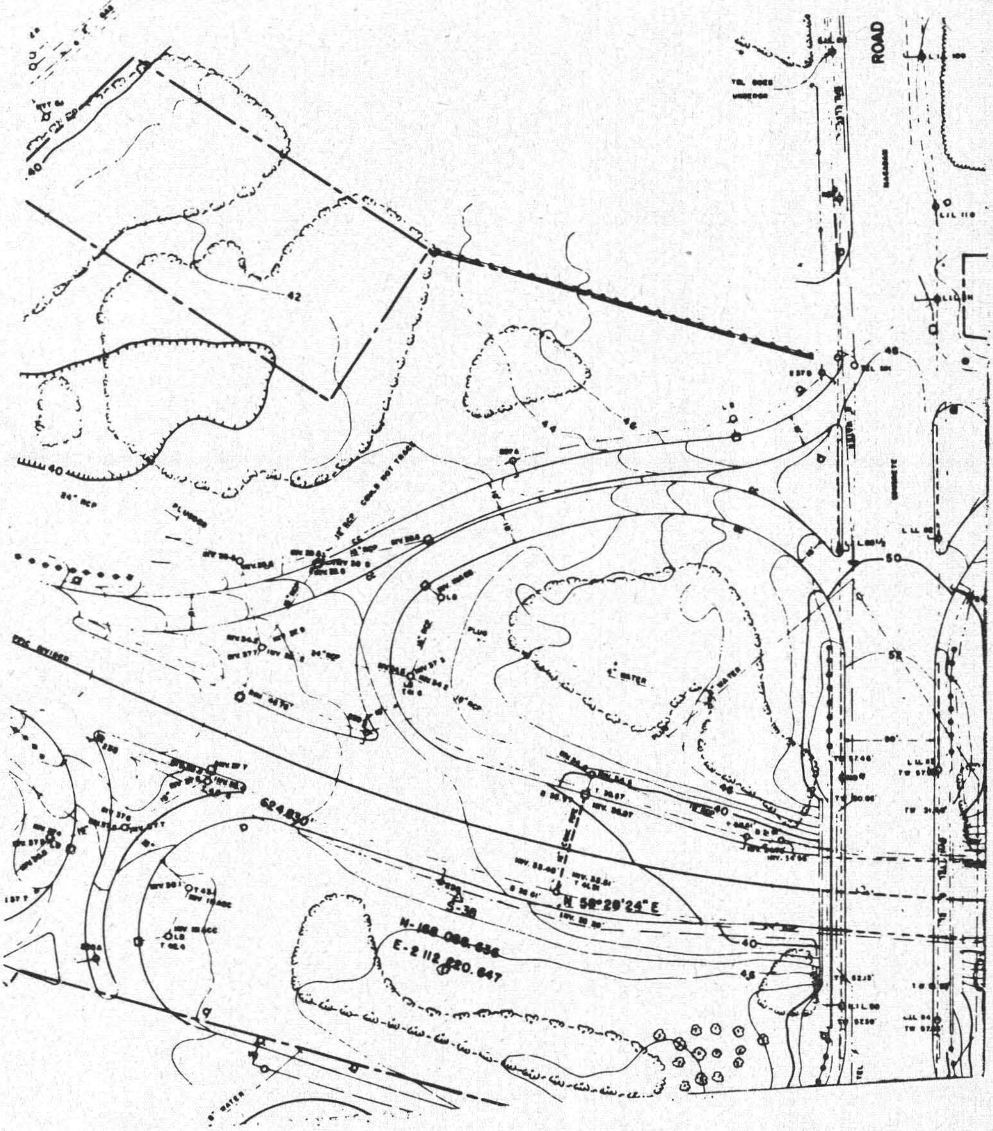

FIG. 2. Portion of survey prepared for highway design purposes. Original scale 1:600, contour interval—2 feet.

HIGHWAYS AND PHOTOGRAMMETRY

Highway engineering projects make up one of the larger groups on which we see the application of photogrammetry. All such projects on which we are involved make some use of aerial photographs early in the planning phases for general location studies. The scales involved are usually large for this purpose—about 1:10,000 or larger—as the bulk of our work of this nature has been in or adjacent to developed areas.

After route selection has been fairly well determined from the photographs and other considerations involved, the strip concerned is usually mapped by photogrammetric methods at scales of from 1:1,200 to 1:2,400 and with contour intervals of 2 to 5 feet. With these maps supplying the bulk of the information required, the final location is planned, the highway designed and detailed construction cost estimates prepared. The final preparation of contract plans and the procurement of

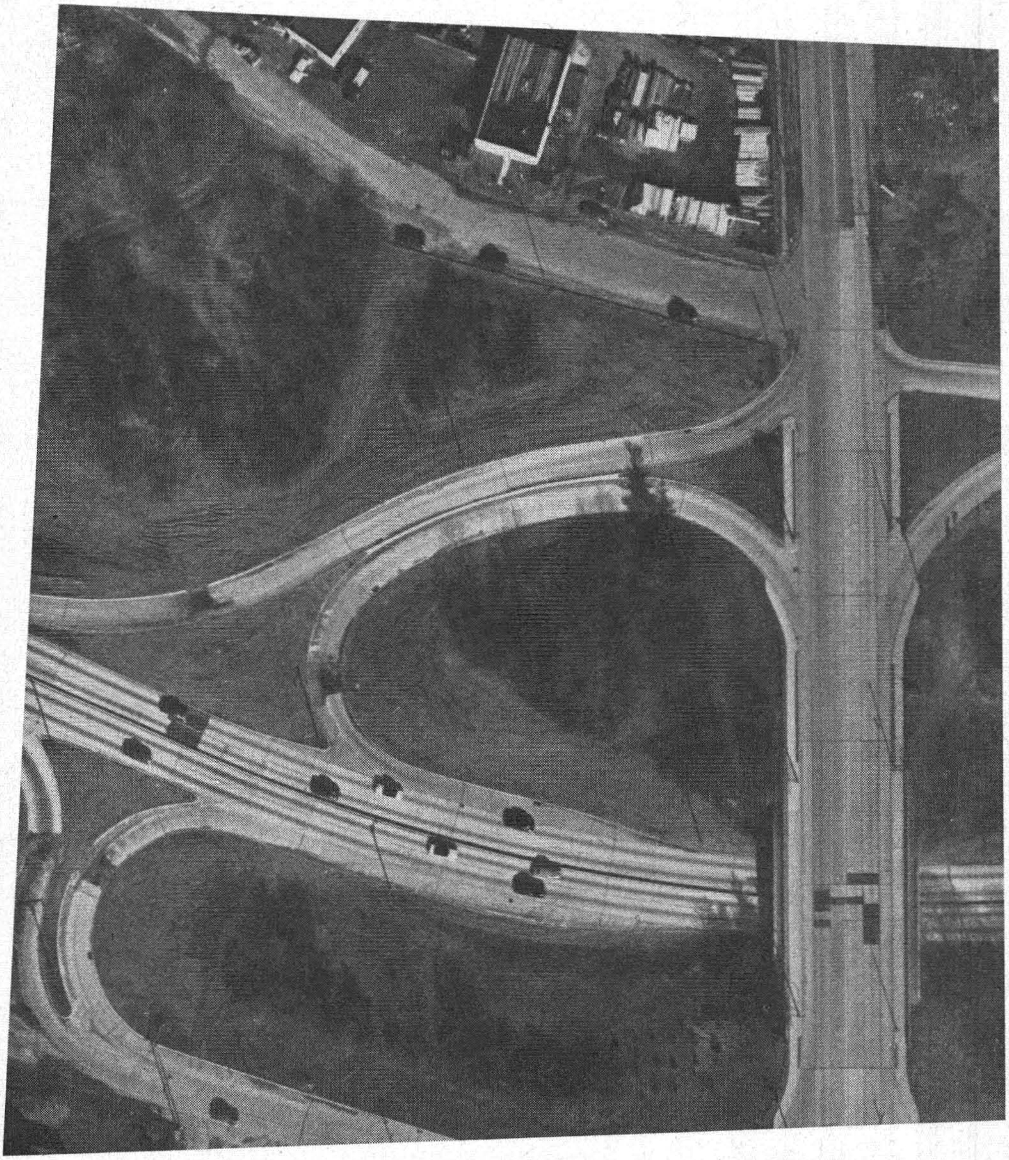

FIG. 3. Portion of aerial photograph of area covered in Figure 2. Original scale 1:4,000. Scale of this reproduction about 1:1,300.

data on which to base contract payments usually follows detailed stake-out and cross sectioning by conventional ground methods.

On one highway project for which our firm performed surveys and mapping, photogrammetric methods were used to a large extent in the preparation of data on which to base contract plans. On this project, the nature of the location problem was such that its solution was primarily dependent upon an existing parkway, an existing right-of-way and the development of the adjacent areas. Prior to initiation of any surveys, the alignment and grade of the new highway had been determined to such an extent that they were subject to change by only a few feet, usually less than ten and not exceeding fifty feet. In this case it was possible to proceed directly with surveys and mapping to collect data for the preparation of contract plans.

These plans were essentially a highly detailed topographic map of the route, at a scale of 1:600 with a contour interval of two feet and with the newly planned work drawn in place. The route was flown in this instance at a height of 2,000 feet with a six-inch mapping camera. Using this photography in the Autograph A-5 and integrating it with the field cross sectioning work, it was possible to save considerable field and drafting time in locating all the myriad of details required. These details include such features as guard rails, lamp posts, man-holes, catch basins, underground drainage and utility lines, traffic signs, etc. in addition to that data customary in our usual topographic mapping. Figure 2 shows a portion of one of the maps we prepared on this project and which served as the base for the contract plans. Figure 3 is a portion of an aerial photograph covering the same area and indicates how much of the detail can be secured from it.

On the project I was just describing, I made a use of aerial photographs that was new to me and, in so far as I know, has not been described by others. As I indicated before, the alignment and grade of the new highway were established within close limits in advance. With those data before me and by stereoscopic study of the photographs, I was able to mark out on the photographs the approximate limits of the grading work that would take place. The photographs so marked were supplied to our field parties to guide them in the extent to which they would need to take their cross section measurements in the field.

Colombian Projects

For about the past two years we have maintained an engineering staff in Colombia, South America. That staff has been engaged in several projects, the principal ones being railroad and road locations. In the unmapped areas involved, aerial photographs and photogrammetry have been exploited to the utmost. In general, the first step has been to cover the areas embracing possible routes with aerial photographs at a scale of about 1:40,000. Stereoscopic study of these photographs has permitted selection of a narrow band, or alternate bands, which provides the most economic location. From the same photography topographic maps have next been compiled photogrammetrically for the selected bands. Based upon these maps a route is planned and preliminary cost estimates are prepared. The maps have been compiled at a scale of 1:10,000 with contour intervals of 15 and 5 meters, the smaller interval being used in the relatively infrequent open areas that are encountered.

For all mapping work the procurement of control has presented almost unsurmountable obstacles. Most reliance for vertical control purposes has been placed

FIG. 4. Oblique view of racetrack installation which is being mapped photogrammetrically.

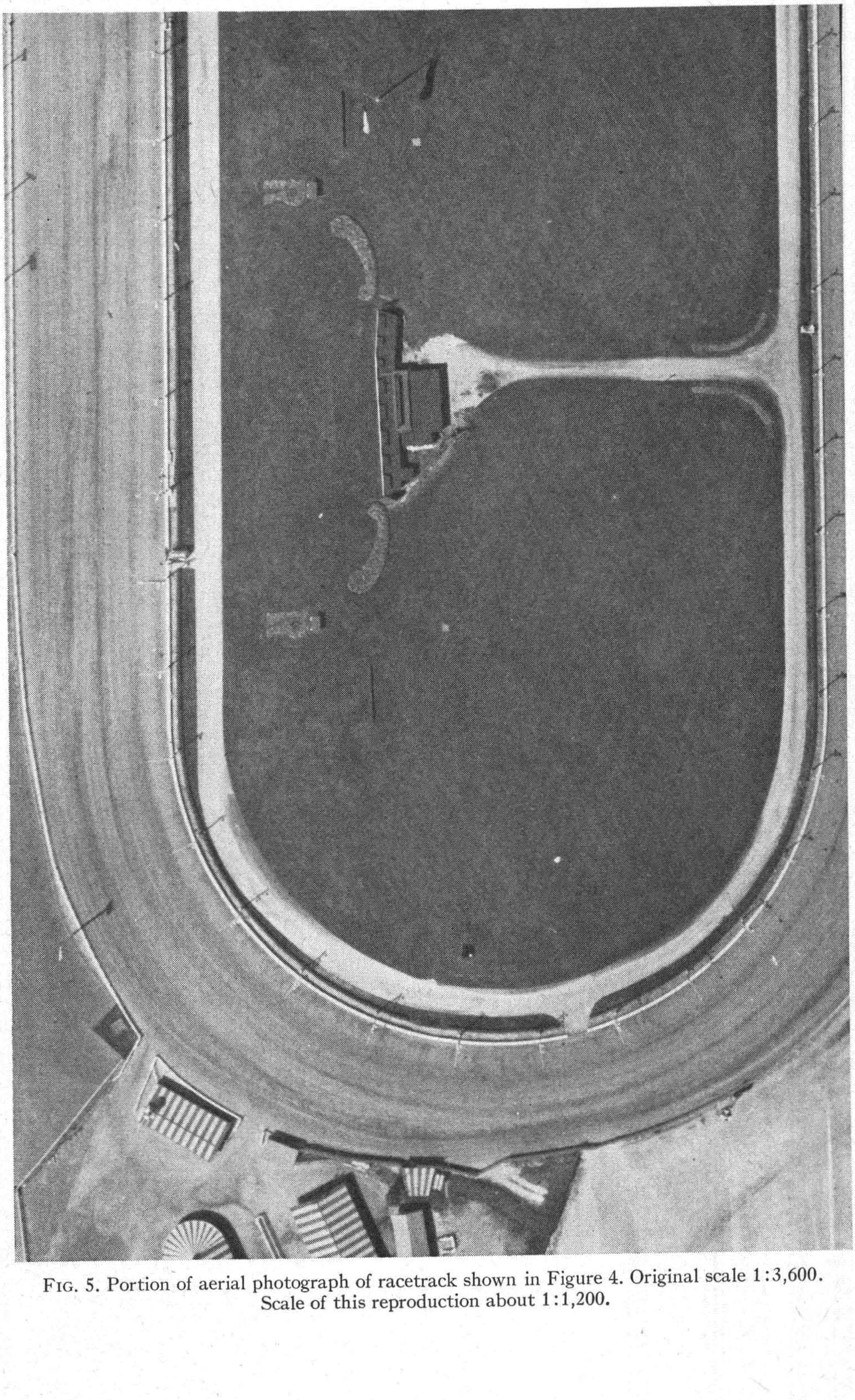

FIG. 5. Portion of aerial photograph of racetrack shown in Figure 4. Original scale 1:3,600. Scale of this reproduction about 1:1,200.

upon airborne radar profiles flown for the work. Horizontal control has seldom been ideal. It has consisted of astronomic work, fragments of traverse work or a combination of the two. In a few cases, we have had to rely on the airborne radar measurements to establish scale, with no absolute positioning being known. In spite of the control difficulties the resulting mapping serves its purpose which is the selection of the best route. In the final analyses, the route is run out on the ground and any deficiencies in the mapping are compensated for at this stage. The experience has indicated that only a relatively few changes are necessary at the time of staking out on the ground.

Other Projects

Although the projects I have mentioned above have made up the largest part of our photogrammetric work in connection with engineering projects, there are many more varied types we have encountered. A few will be mentioned briefly to indicate their diversity.

With a power company's engineers we have employed photogrammetric methods to prepare maps on which to plan power line locations. An interesting point on this work was the use of vertical control established by the Johnson Elevation Meter.

For a power plant engineer we have measured the volume of the coal in stock piles for inventory and consumption statistics.

For an engineer planning a sewer layout in a developed community we have used photogrammetric methods in the performance of the necessary surveys.

In connection with the development of real estate subdivisions we have mapped photogrammetrically several areas, these maps being used in all the various engineering problems involved in such developments. Contrasted to such developments are those completely built up areas in the city which are being razed for redevelopment. An early step in such projects is the condemnation proceeding which requires surveys and maps. We have worked some photogrammetric methods into the preparation of the surveys and maps required for such purposes.

The final project I would like to mention is one currently in work for the engineer of a race track which is illustrated in Figure 4. A complete survey, employing partial photogrammetric methods, is in process for this track and all of its grounds and installations. This survey will provide much of the base data for all the problems that the engineer has to solve in the maintenance and operation of this facility. These range from planning parking facilities for the hopeful patrons of the pari mutuel windows to planning the location for the photogrammetric camera equipment that settles the question as to which horse's nose is ahead at the wire and which patron goes home enriched thereby. Figure 5 is a portion of a vertical photograph of the race track area and illustrates the great amount of detail that can be secured by the photogrammetric method.

Conclusion

I hope that the varied work I have briefly mentioned has indicated to you some of the applications that we are making of photogrammetry in connection with engineering projects. When used judiciously and properly integrated with other surveys, we have at our hands a tool that will do much to reduce the cost of engineering surveys, will speed planning operations and will result in better planning. Our biggest problem in the use of this tool is to convince those remaining engineers who still disbelieve in its potentialities and that it is the proper tool to use on their projects. This problem is being overcome little by little and we will see it disappear in not too many years. I venture to forecast that within the next five years, you will read or hear of a case where payment quantities for earthwork are determined on the basis of before and after measurements made photogrammetrically. When this occurs, the biggest part of the problem will have been solved and you will find engineers calling more and more on the photogrammetrist to aid them on their projects.