One hundred scale air photos were used in studying road location in a nearby section of Rock Creek Park. A section of the Park extending from the Shoreham Hotel north to about Blagden Avenue was covered. On the photos, we have shown to scale a great variety of possible routes for an extension northerly through the Zoo and Park of the present Rock Creek Parkway. These studies were made prior to the war, and are quite preliminary in character. No final determination has yet been made as to the desirable location; and a considerable further study of the whole problem is expected. Air photos are very useful in the study of such an area.

In my exhibits, I have dealt with the use of air photos made for some other use, and how we have adopted them to our needs and found them of great value. We are now undertaking obtaining air photographs specifically for a proposed alternate location about two miles long in extremely rough topography in the mountains near Waynesville, North Carolina. We have arranged with the Tennessee Valley Authority to prepare for us, by photogrammetric methods, a contour map on a scale of $1'' = 100'$ for this proposed alternate location. Controls for the work will be the line earlier established, by ground methods, which lies at all points within 2,000 feet of the proposed relocation.

This proposed location lies between 5,000 and 6,000 feet above sea level, in an inaccessible place. In dry weather a light truck can get within $3\frac{1}{2}$ miles of one end of it. To do the job by ground methods would require seven to eight miles daily of walking over very rough terrain by the party. We have a rough estimate that the maps can be prepared by photogrammetric methods for about $1,000, whereas we estimate the cost by ground methods at about $2,000.

We expect to use the contour maps so obtained to prepare the regular road plans for the proposed improvement. This work is undertaken as an experiment in the use of photogrammetric methods in extremely rough terrain. From it, we hope to be able to determine the degree of accuracy possible for such methods under such conditions.

OHIO ADAPTS AERIAL PHOTOGRAMMETRY TO HIGHWAY ENGINEERING*

Mr. Ralph J. Lehman, Geometric Design Engineer, Ohio Department of Highways.

BEFORE enlarging upon the history of Ohio's experience in the use of aerial surveying and mapping, it will be advantageous for me to present certain organizational structure and operational procedure used by the Ohio Department of Highways, in order to illustrate the relative position of the aerial surveying unit with the other bureaus and sections. Since aerial surveying is used by us primarily as an engineering tool, we will dispense with a discussion of the administrative functions and concentrate upon engineering activities, principally those which make maximum use of aerial photographic materials.

The highway engineer has numerous responsibilities, the assignment of which is divided among the several bureaus within the Department of Highways. For instance, matters of planning, location and design are assigned to the Bureau of Location and Design, while the construction, maintenance and operation, traffic and safety, and other phases of highway engineering each warrant separate bureaus.

* Due to the unavoidable absence of Mr. Lehman, this paper was read by Warren J. Cremean, Ass't to the Geometric Design Engineer.

The Bureau of Location and Design consists of six different sections, each being responsible for a particular phase of planning, locating and designing of highways.

1. One of these units is Planning Survey whose duties are to collect and analyze factual data, prepare and perpetuate road inventories, conduct special traffic studies and perform other highway research duties.
2. The Planning Engineer is responsible for the formulation of Federal and State construction programs.
3. The Plans Engineer is responsible for the physical or structural design with the exception of bridges and culverts.
4. The Right-of-Way Engineer is responsible for the acquisition of all rights of way for the State Highway System and the determination of policy and procedure on all matters of rights of way and utility problems.
5. The Engineer of Sales is responsible for the advancement of proposed highway projects from the approved plan and estimate stage to the actual signing of a contract by the Director of Highways.
6. The Geometric Design Engineer is responsible for the determination of alignment, gradients, traffic lane capacities, and other criteria to establish the design controls for each project.

Geometric design has been given many definitions, none of which are widely accepted by the highway field. One such interpretation defines it as being those elements of design that determine the visible features of the highway which influence traffic behavior. Among these elements are horizontal and vertical alignment, sight distances, cross section components, lateral and vertical clearances, intersectional and interchange design, access connections and others.

In addition to the above features, advance planning of proposed improvements is under the guidance of the Geometric Design Engineer. Engineering investigations are required to determine first, the problem; second, alternate schemes; and third, a comparison of the various plans to determine the most economical solution; these studies vary from one route in rural areas to a combination of proposed and existing arterial highways in urban areas. Upon the determination of a plan for urban areas or the general location of a route between termini in rural areas, a second and more comprehensive study is required to determine the preliminary design features of each specific project. Therefore, it can be seen that this phase of highway planning and design encompasses those elements where photogrammetry can be applied very extensively and to great advantage, and it was logical that this man should direct the operations of such a unit to obtain the maximum benefit to the Department.

It is essential to have complete knowledge of the physical characteristics of the area, in addition to the pattern of existing and future traffic conditions, before a reliable analysis can be made to determine the most economical location and design of a highway. In Ohio, each project regardless of its magnitude is thoroughly analyzed, and the resultant recommendations are presented in the form of an engineering report. Early in the year 1946, the Department was seeking ways and means to expedite these investigations by the procurement of more extensive information at a minimum of cost. Aerial photography was one medium considered, and after examining available equipment, it appeared that the organization of our own aerial surveying and mapping section was economically practical and should provide a satisfactory solution to the specific problem, while simultaneously establishing a unit which could be utilized in various other phases of highway work. A primary advantage of our own unit (and one

which we have since greatly appreciated) would be the ability to obtain photographic coverage at the time it can be used most advantageously. If we were required to contract the services of outside organizations, a program would have to be formulated months ahead of time, and such a practice would not permit the high degree of flexibility in operations which we have available.

The initial personnel were assigned to the Geometric Design Engineer in the Bureau of Location and Design in March, 1946 and the organization has steadily expanded to its present status.

The Aerial Surveying and Mapping Unit consists of three sections directed by a Supervisor who coordinates their respective activities in order that each assignment is accomplished with maximum efficiency. The first section, Flight Operations, which is responsible for securing aerial photographs in conformance with the requirements set forth for each project, consists of a pilot, a photographer and a mechanic. A second section, the Photographic Laboratory, which processes and develops prints stipulated for the projects, requires the services of a Supervisor of Photography who is thoroughly experienced in photographic laboratory technique, and an adequate staff of Laboratory Technicians, the number depending upon program schedules. The third section, Photogrammetry, is in charge of a professional engineer sufficiently familiar with the technique of photogrammetry to develop and prepare material most beneficial to the highway engineer. The Engineer of Photogrammetry is assisted by an Assistant Engineer, Photogrammetrists, Engineering Aides and Artists. The organization chart, Figure 1, shows the positions in the unit and the relationship of the various sections.

ORGANIZATIONAL CHART

AERIAL SURVEYING AND MAPPING UNIT

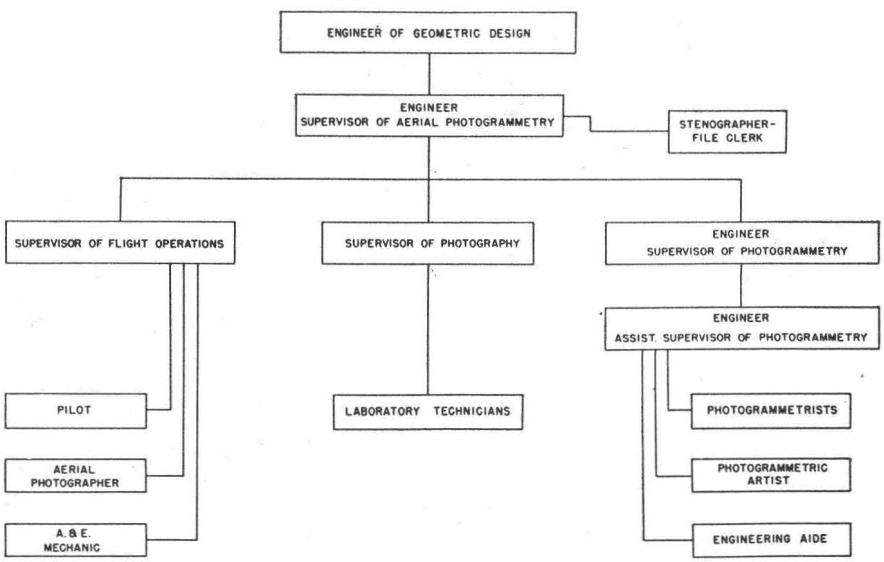

FIG. 1.

In interviewing personnel for this organization, special recognition was given to ex-service men who had received aerial training in the armed forces

which would qualify them for the various positions, and most of the present employees have had such training. The supervisor of the three units is a registered professional engineer as well as a qualified pilot, and consequently he performs the duties of Supervisor of Aerial Surveying and Mapping, Supervisor of Flight Operations and Pilot. It is fortunate to have an individual with these qualifications as the limited amount of satisfactory photographic weather permits this man to assume the administrative functions and pursue the necessary liaison duties of the organization as well as pilot the aircraft. We are also fortunate in having an Aerial Photographer who can direct operations of the Photographic Laboratory and therefore also hold the position of Supervisor of Photography. In case of his absence, one of the Laboratory Technicians, who

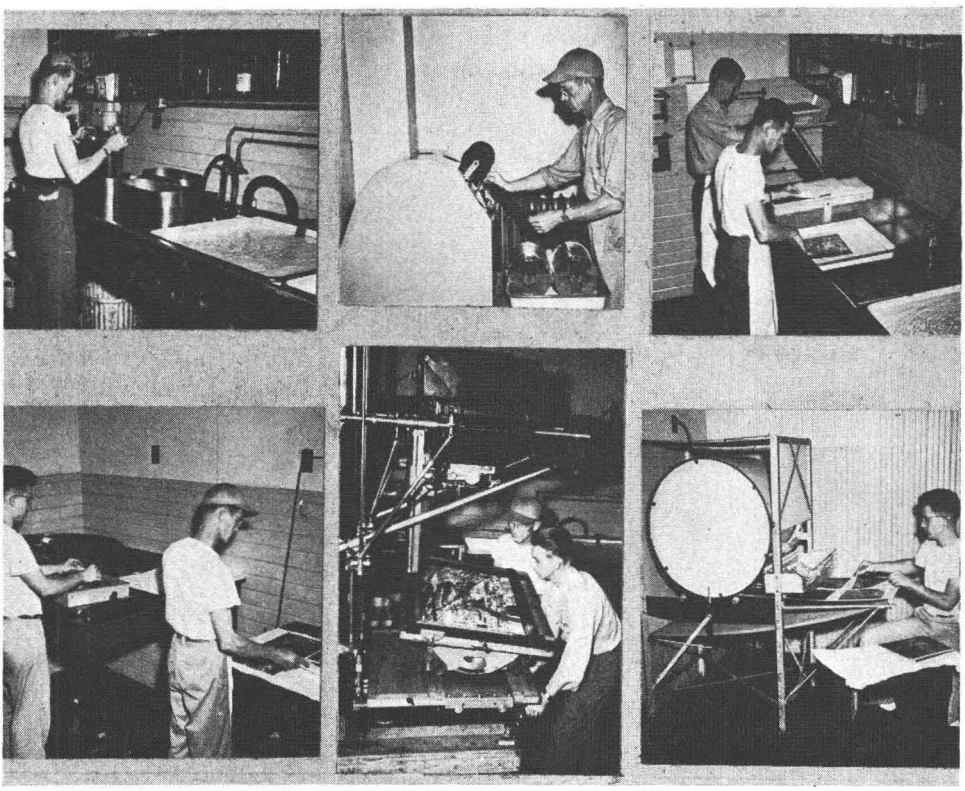

FIG. 2. Photographic Section at work.

has had Army training as an aerial photographer, can be used in the Flight Section. The Supervisor of Photogrammetry has been a member of your society since 1936 and has been active in photogrammetric work with the Manhattan Project, Engineer Research and Development Branch and the AAA program. The fact that the three key men are experienced and capable in their assigned duties accounts for the high standard of operation and production of this organization.

Before discussing the materials developed by this unit and the application of their products, it may be of interest to mention that Ohio's investment in equipment to date is approximately $35,000, consisting of $22,000 for the air-

craft, $8,000 for photographic equipment and $5,000 for the photogrammetry unit. The major portion of our equipment (Figures 2 and 3) is of the conventional type and is considered adequate for the production of photogrammetric material applicable to preliminary highway design. In addition to these, we possess two items of a more unusual nature and which I believe are worthy of elaboration.

Our aircraft, a twin-engine Beechcraft modified to our requirements from a surplus Army Air Forces AT-11, was specifically chosen with the intention of placing the photographic installation in the left half of the plastic nose section, thereby acquiring all the benefits associated with complete forward and downward visibility by both the photographer and the pilot. Figure 4 illustrates how glass was placed in the floor on the right side of the nose section between

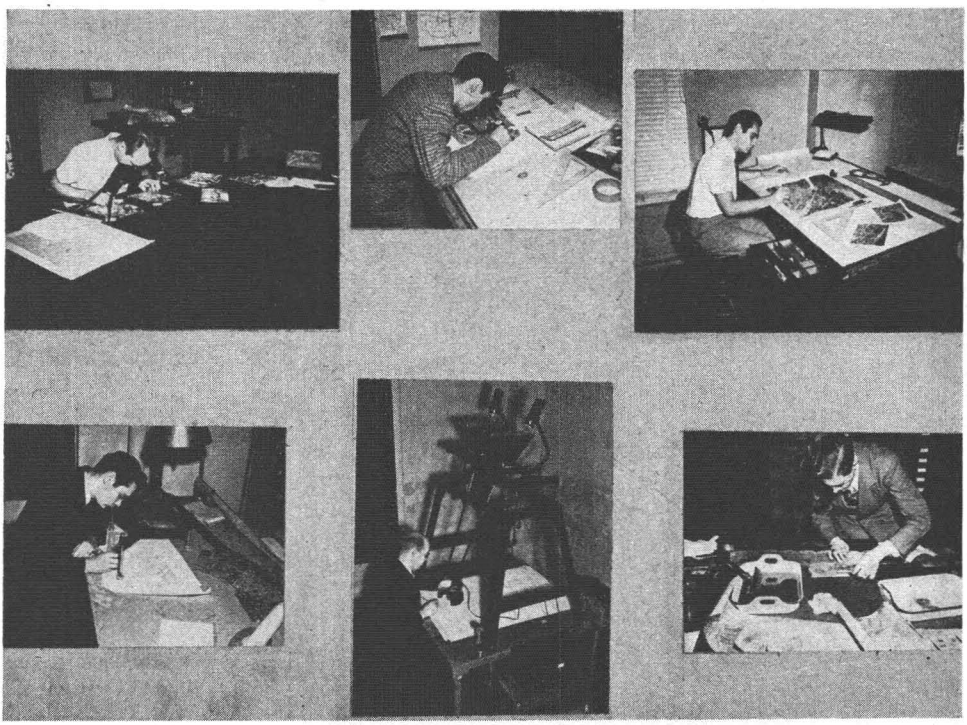

FIG. 3. Photogrammetry Section at work.

the co-pilot's rudder pedals. This enables the pilot to control the ship from the right side and have complete visibility from the horizon to points directly beneath the plane. Oblique exposures are made with our F-4 12 inch camera at the rear door which has a panel removable from the inside. The space between the bulkheads directly aft of the main cabin has been sealed against light and converted into an aerial darkroom for changing film, etc. Two army surplus AT-6's were originally used for this work but these were replaced because of the insufficient visibility for accurate tracking of low altitude flight lines, as well as other inadequate features of that ship.

The other distinctive item of equipment is a Kelsh Plotter which is used to plot topographic maps of small areas at large scales. This piece of apparatus was chosen because of its initial low cost and its ability to perform the work

which we intended, as well as the fact that the required diapositives could be prepared at a minimum of expense and effort with our existing photographic laboratory facilities.

Requests for photogrammetric material, which originate in the twelve Division Offices of the Highway Department, are submitted on forms designed by the Aerial Surveying and Mapping Unit. A request form, properly prepared indicates the purpose of the material, desired scale, coverage, number of copies, etc., and our experience has shown that all requests should be accompanied by a sketch of sufficient detail to avoid the possibility of an error which might require a reflight to be made. We encourage the submission of these requests sufficiently in advance of the engineering studies that unfavorable weather conditions will not delay the project. Consequently, it is essential to have requests submitted as soon as the need for a highway improvement is recognized in order to establish an integrated work schedule. This procedure assures a backlog of requests at all times and permits taking advantage of all satisfactory photographic weather conditions.

Subsequent to each flight, a photographic index is assembled to facilitate identification of prints covering specific areas and to provide a future reference source. Contact prints are prepared on either glossy or semi-matte paper, dependent upon their intended use, and negatives for enlargements to specified scales are scale checked by the Anderson method and rectified on our Saltzman B-9 Projector.

The photogrammetry unit prepares controlled and uncontrolled mosaics

FIG. 4. Modified Beechcraft AT-11 used by Ohio Department of Highways.

from single weight glossy prints and the finished product is surface-treated for preservation, these mosaics providing a durable working surface upon which may be placed information relative to the proposed location study.

Planimetric maps are developed with the use of mechanical triangulators and the vertical sketchmaster. An interesting and valuable application of planimetric mapping has been utilized by our department for the preparation of actual construction tracings of soil stabilization projects where the road material is reshaped preparatory to placing a surface course and no physical change in alignment or grade is being made. A combination of normal planimetry and a profile obtained with the use of aneroid barometers has enabled base sheets containing the line and profile to be furnished to the Division Offices who add the other necessary information and complete the set of plans. This procedure has permitted Ohio to develop this program far ahead of a schedule which would have been imposed by the normal time required for field surveys and the shortage of division personnel who could be transferred from other scheduled projects.

At the present time, developing topography maps with the Kelsh Plotter is limited to small areas and a scale range of 20 to 50 feet per inch with 2 foot contour intervals, but we expect to extend this work and to plot larger areas to scales and contour intervals commensurate with different uses.

Specially prepared oblique photographs are used for a pictorial presentation of proposed improvements. This is accomplished by opaqueing the negative so that an enlargement can be made which will show all the photographic detail except the area required by the proposed improvement, after which the ultimate development is portrayed in its proper perspective by an artist. As a substitute for the usual methods utilized by engineers to present a proposed plan, these products have been remarkably effective in presenting proposed highway improvements, especially complex urban traffic interchanges and expressways, to local groups who are unable to visualize a contemplated improvement on straight line diagrams, schematic drawings or blueprints.

A special service performed by our unit is collecting and furnishing plane coordinate data for field surveys. The Ohio Department of Highways is emphasizing the importance of tying surveys into the State Plane Coordinate System whenever possible and, as such a procedure is extremely valuable for aerial survey work, we encourage this activity in all our contacts with field offices.

The application of photogrammetric materials in Ohio has conformed closely to the general sequence set forth in the paper presented by Mr. Pryor at the last annual meeting of the Society. They are:

1. General reconnaissance.
2. Reconnaissance of alternate routes.
3. Preliminary Design.
4. Depicting proposed improvements.

The general reconnaissance studies for highway location usually begin by analyzing the volume and character of traffic and the type of terrain, in order to select terminal points between which a continuity of design is indicated. After selection of the termini, adequate aerial coverage is obtained by the Aerial Surveying and Mapping Unit and a mosaic developed, usually to the scale of 1000 to 3000 feet per inch. The completed mosaics, accompanied by two photographic copies of the mosaic and two sets of contact prints, one on glossy paper and the other on semi-matte, are furnished to the requesting agency which stud-

ies the mosaic in search of feasible alternate routes. These are quickly discovered from a study of visible general features such as extremely bad soil conditions, land use, arrangement of right of way, physical conditions, etc. In urban areas, much valuable information concerning the existing street system, and many other factors which must be given serious consideration in developing a complex arterial highway plan, is available on the photographs. After the alternate routes or schemes have been selected from the mosaic, each location is placed on contact prints and studied with a stereoscope from the standpoint of vertical and horizontal alignment.

Reconnaissance studies of alternate routes are carried forward with complete knowledge of traffic requirements established for the route between termini. This enables the engineer to adjust alternate locations through the use of stereo pairs and to select an alignment and grade which will meet design requirements, all of this preliminary investigation being possible without field survey work (Figure 5). After the highway engineer is satisfied that all feasible alternate

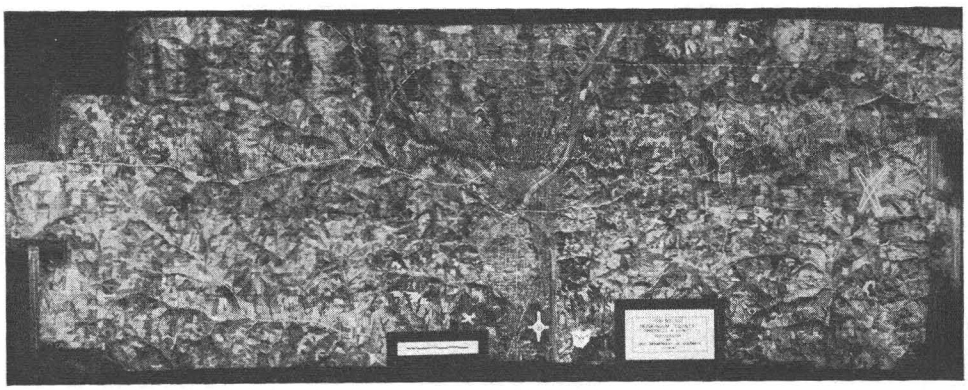

FIG. 5. A small scale mosaic used for studying alternate highway locations.

routes have been modified to meet established design criteria, he must compare the advantages and disadvantages of each line and determine if any of them can be eliminated from further consideration. After this has been accomplished, he can proceed with his analysis of cost versus benefits on each remaining alternate, and, with a minimum of field work and the use of U.S.G.S. topo sheets, the engineer can make a comparative cost analysis in sufficient detail to support his recommendations. The use of materials, prepared by the Aerial Surveying and Mapping Unit in arriving at the most practical solution to a highway improvement, definitely reduces the field work and preliminary engineering costs, but more important the complete information made available to the engineer assures him that all possibilities have been considered and the best solution selected.

In urban areas, where a system of arterial highways is required to meet present and future traffic needs, large scale aerial pictures are used in addition to small scale mosaics. Large scale prints, normally 200 feet per inch, are used in determining detailed location and design of access facilities and traffic interchanges, thereby permitting the designer to readily visualize all the physical characteristics of the area and to study alternate schemes which will meet traffic needs and hold right-of-way costs at a minimum. It also provides complete information relative to the existing street system which, in most instances, will require some

alteration in order to become a part of the ultimate facility. We have found that these large scale pictures furnish sufficient information to make comparative cost analyses, with the exception of underground utilities.

The type and preliminary design of bridges are determined from a site plan prepared of the area. Figure 6 illustrates a comparison of a bridge site plan prepared from ground survey with one prepared by photogrammetric methods. The aerial exposures for this project were made with standard film in a non-precision camera of $8\frac{1}{4}$ inch focal length lens. At the low altitude of 825 feet above

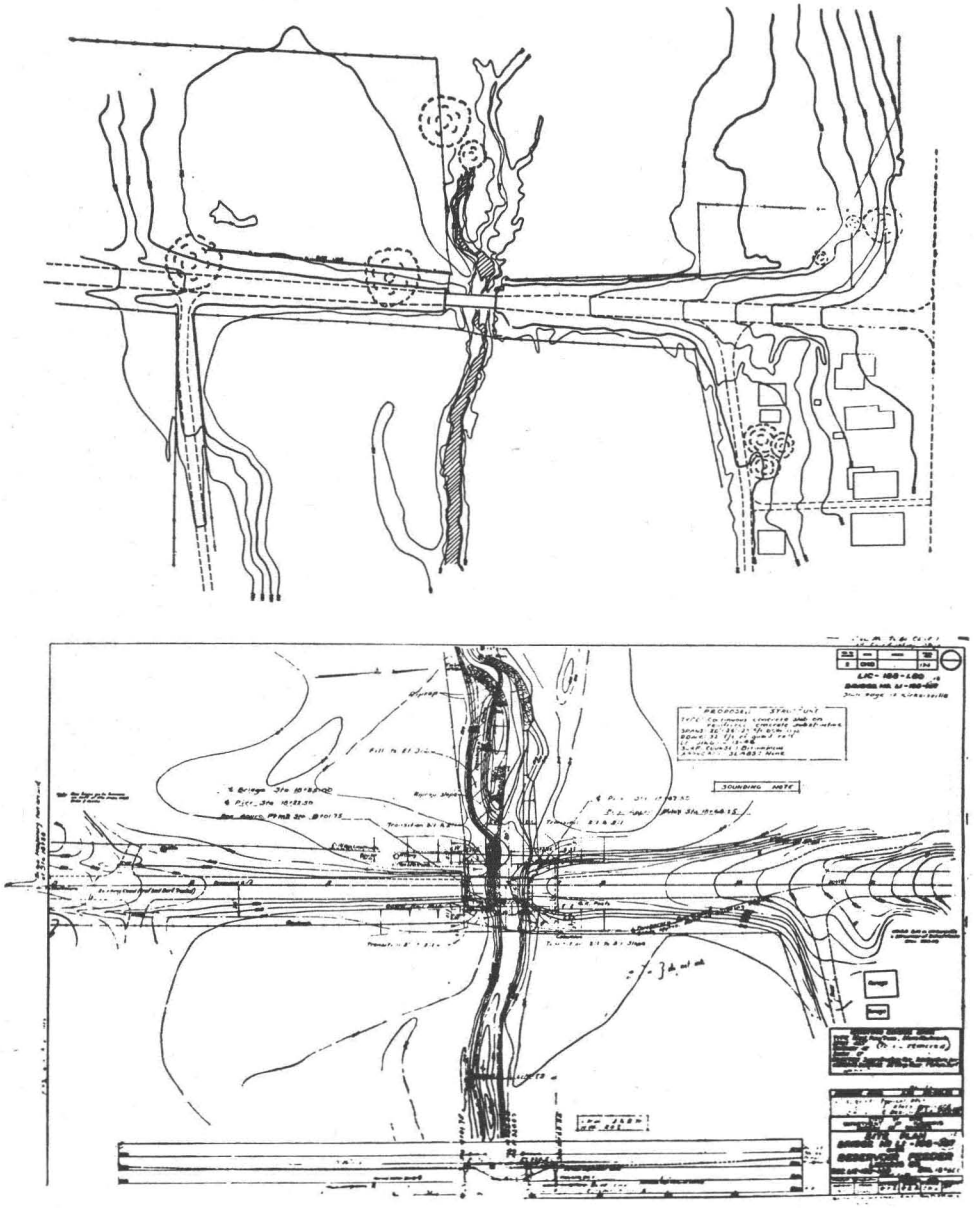

FIG. 6. *Top:* Bridge. Site plan with 2 foot contour intervals prepared by Kelsh Plotter. *Bottom:* Bridge site plan with 1 foot contour intervals developed from ground survey.

the surface, the inability of the camera to cycle fast enough to permit exposures with 50 to 60 per cent overlap in sequence necessitated a separate pass for each exposure, but the exceptional forward visibility afforded by our aircraft made it relatively easy to duplicate the flight path of the previous run to complete the stereo pair for the area.

After processing the film in the conventional manner, contact positives were made on sensitized glass plates of 0.130 inch thickness, these plate-pairs being inserted into the projectors of the Kelsh Plotter and adjusted to bring the images into complete coincidence, level and proper scale. The planimetry and contours were then traced by the Kelsh operator, producing a print at a scale

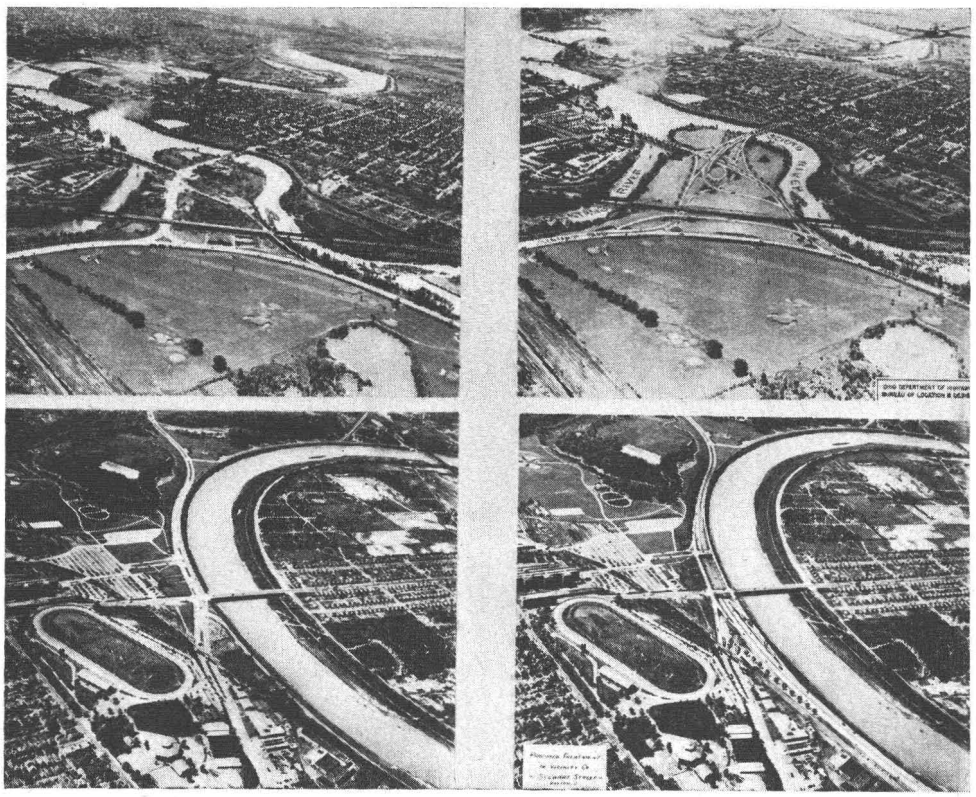

FIG. 7. Artist's perspective of proposed highway improvements.

of 1 inch equal 25 feet with 2 foot contour intervals. In order to make a direct comparison with the site plan developed by ground survey method, the 1 inch equal 25 feet model was photographed with a copy camera to obtain an enlargement to 1 inch equal 20 feet, and the resultant negatives were aligned on a light table and the cloth tracing completed. The control for this site plan consisted of two center line stations painted on the pavement plus four stations in the corners of the model, the latter comprised of 2 foot circles of lime placed on the ground prior to flight.

In comparing production costs for the two methods of preparing this specific site plan, we discovered that the photogrammetric method resulted in a total cost of approximately one-fourth that of the ground survey method.

The method used in depicting a proposed improvement on aerial photographs has been discussed previously. These drawings are invaluable in portraying a project to all agencies or individuals having an interest in the improvement and have been found very helpful in comparing the utility and aesthetic value of one type of traffic interchange with another. These presentations also provide complete information relative to vehicle operational characteristics for use by the engineer responsible for pavement marking and signing. Figure 7 illustrates some proposed improvements in Ohio in which the preliminary design was developed principally from aerial photographs.

The above discussion has covered the most widely used applications of photogrammetry in addition to those previously discussed, in some of which we have barely scratched the surface.

Aerial photographs have proved very valuable in the study of soil and rock formations and in problems dealing with progressive stream bank recessions endangering highway embankments. Several years ago, a detailed study was made to locate sources of granular material for use in construction and maintenance of secondary roads in the southeastern part of Ohio, and aerial photographs together with U.S.G.S. topographic sheets were an invaluable aid in locating areas for detailed investigation. There are several proponents of the use of aerial photographs as a routine procedure in the preparation of soil profiles; they are not used by Ohio at present for this purpose, but they are very valuable in locating new roads to take advantage of good soil conditions and to identify such obvious pitfalls as deep deposits of peat.

Many drainage problems have been analyzed with the help of aerial photographs in the past, and a much more extensive use is contemplated in the future. Arriving at a reliable estimate of runoff from areas of less than three square miles is probably the most controversial problem confronting the highway drainage engineer, and aerial photographs will play an important role in the plan to solve that problem. Several small drainage areas have been selected throughout the State, and accurate runoff measurements are being obtained and compiled by the United States Geological Survey, in order to classify the different typical areas and to provide a more accurate method of estimating runoff by comparing photographs of a specific area with a typical area of the same classification.

The projection of our unit's present activities includes continuation of traffic studies by obtaining successive exposures over the critical area, thesis aid to Ohio State University Engineering students, special studies such as the durability of paint used for pavement markings by photographing a series of paint test lines at different periods in order to compare wearing ability, and the preparation of small scale maps for areas where highway locations are appreciably affected by the terrain. Additional applications in this field, and in which we have been requested to participate, include high water studies along the Scioto River for the Scioto-Sandusky Conservancy District, soil erosion studies along the Lake Erie shore line by the Division of Public Works and pavement performance studies through the use of large scale continuous strip photography.

We have been greatly interested in a dry photographic process, termed Xerography, being developed by the Battelle Research Organization of Columbus, Ohio. The perfection of this process may enable us to reproduce mosaics directly onto the plan sheets of our highway improvements.

Excluding the other activities mentioned above, the completion of bridge site plans, of which we have scheduled fifty for 1949, and the preparation of base sheets for soil stabilization plans on the current construction program are ex-

pected to save the Department enough money to pay for the annual cost of operating the Aerial Surveying and Mapping Unit.

Although we have actually just begun using photogrammetric methods in our highway work, the past and present achievements of our unit as well as the large number of its potential applications have thoroughly convinced us that it warrants a permanent place in our organization.

1948 FIELD OPERATIONS OF AERO SERVICE CORPORATION*

Virgil Kauffman, President, Aero Service Corporation

LAST year, your semiannual meeting, which was the first in a number of years, was held in Philadelphia, and quite a number of you folks here today attended and saw the normal operations of a company engaged in commercial photogrammetry.

At that period, we were able to show you in fair detail the number of things we conduct within our plant. Since then, we have had to go out for some of the more involved and sketchy and risky portions of the work we do, that is, our air operations.

In addition to our air operations, we also have ground operations, but since I am privileged to tell you about some of these operations, I am leaving out our groundwork in the field, that is, our field engineering surveys, and I am leaving out the operations of the photogrammetric work within the United States.

Last year we completed our thirtieth year of operation. It is a rather old company operating aircraft. It put us at our highest pressure, because we had operations extending from the northern portion of Canada to South Africa. In all cases we had to equip expeditions for sometimes severe winter work, where temperatures ran as much as 40° below, with very delicate instruments. We had to equip operations to go across the Atlantic and frequently to fly into and across Africa and to engage in operations there, ten or twelve thousand miles from the base and source of supplies.

With the aid of our staff, moving picture cameras are carried along to give us some sort of a report of the conditions encountered. The film covers a sequence of flight operations of three particular jobs, one being in Canada in wintertime, the second, operations in the Far North and the vicinity of the Arctic Circle in summer, and the third one in Africa, which is in operation at the present time.

I will endeavor to explain these moving pictures as we go along. First, I want to tell you that all of them are in connection with airplane photometric work; the film ties in very closely with photogrammetry, because, first, we must have proper base information on which to place the on-the-ground information and lock it together; it involves cameras, both in covering terrain for the preparation of base maps, and for determination of the exact positions of the aircraft after the work is flown.

I might say this, that these pictures are not altogether scientific. Our men work hard, and they play hard. They get mixed up with a lot of geography, and some work includes a lot of it, but I think the film will give you an idea of what these men go through in their routine schedule of work for the Aero Service.

* Introduction to a color film shown at Annual Meeting of the American Society of Photogrammetry, Washington, D. C., January 14, 1949.