measurements of a large area, thus obtaining more detailed information than is otherwise feasible.

3. Photogrammetric measurements must be made in conjunction with current meter readings for proper reduction of data. The long periods of meter observation allows the removal of eccentricity introduced into the instantaneous photogrammetric observations by meteorological disturbances.
4. Data are provided by the photogrammetric technique for future predictions when referenced to basic data obtained by conventional methods.

The Coast and Geodetic Survey plans to apply photogrammetry to current surveys as a production operation whenever more detailed information is needed than can be readily obtained by conventional methods. The extension of photogrammetry to this phase of oceanography illustrates again the increasing ability of photogrammetry to aid in the solution of many scientific and engineering problems. It is essential that members of the scientific community make the best possible use of this relatively new tool of photogrammetry and remain alert to the broader applications which can be made in the future.

A detailed technical bulletin is now in preparation and will be available shortly. A copy can be secured by writing to the Director, U. S. Coast and Geodetic Survey, Washington 25, D. C.

## References

1. Harris, W. D. and Taylor, Jr., C. B. "Measurement of Tidal Currents at Lituya Bay, Alaska, Introducing Aerial Photogrammetric Methods." *The International Hydrographic Review*, Vol. 38, no. 1, January 1961.
2. Forrester, W. D. "Plotting of Water Current Patterns by Photogrammetry." PHOTOGRAMMETRIC ENGINEERING, Vol. XXVI, No. 5, December 1960.
3. Cameron, H. L. "Water Current and Movement Measurement by Time-Lapse Air Photography. An Evaluation." PHOTOGRAMMETRIC ENGINEERING, Vol. XXVIII, No. 1, March 1962.
4. U. S. Coast and Geodetic Survey, "Manual of Current Observations." Special Publication no. 215, Revised (1950) Edition.
5. von Arx, W. S. "An Introduction to Physical Oceanography." Addison-Wesley Publishing Company, Inc. 1962.
6. U. S. Navy Hydrographic Office, "Oceanography" Part six of *American Practical Navigator* (1958) Bowditch. H. O. Pub. No. 9, Part 6.
7. Johnson, J. W. and Wiegel, R. L. "Investigation of Current Measurement in Estuarine and Coastal Waters." The State Water Pollution Control Board, State of California, 1958.

# *Forest Road Survey Practice—Northern Region**

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ABSTRACT: *The techniques which are discussed are those adopted by the Northern Region, U. S. Forest Service, in providing all types of road survey data, ranging from area reconnaissance through route reconnaissance and rights-of-way determination to the production of basic road design surveys. The equipment utilized is noted. These techniques and equipment are used in various combinations depending on the exact nature of the basic problem.*

THE preparation of map and photogrammetric engineering data of all kinds for the 16 National Forests which comprise the Northern Region, U. S. Forest Service, is the responsibility of the Surveys and Maps Branch, Division of Engineering. One of the major portions of this task is the preparation by photogrammetric methods of road reconnaissance, location, and design maps. In addition, rights-of-way maps, bridge site surveys, cadastral plats, recreation, and administrative site maps are prepared. The Northern Region, when things go according to the basic plan, uses a three-tiered attack to

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meet the overall photogrammetric road survey needs. Although the overall objective of the Forest Service is to obtain complete standard-accuracy topographic coverage, many of the National Forests which are being served are in the unfortunate position of being largely unmapped, topographically speaking.

## Area Reconnaissance

The first phase of operations is concerned with providing basic area form-line coverage, should standard-accuracy topographic maps be unavailable; hence the term, "Area Reconnaissance" is applied to the operation. If standard topographic maps are available, no area reconnaissance mapping is done. The word "topographic" is used rather loosely as the maps so produced are not standard-accuracy topographic quadrangles, but instead are form-line or terrain study maps of reasonable and useful internal accuracy. No special field surveys are conducted, nor are special project photographs flown. Existing photography and existing horizontal and vertical control are utilized throughout.

The available photography is listed as to focal-length and scale, and the horizontal and vertical control as to density. A "shotgun wedding" is then arranged; the "groom"—scale of photography—being forcibly married to the "bride"—control—the exact choice of partners depending on the amount of control available. If little control is available, small-scale photography, often AMS high-altitude or other mapping coverage, is used. If a good density of control is available, larger-scale photography is chosen. It must be borne in mind that the end product of this operation is to be minimum usable quality form-line map coverage of the area of interest, and having only a tenuous connection to standard datums.

The area reconnaissance map provides the Forest Engineer with a tool with which he may examine all possible routes into and through his area of interest. He may select one or two, or possibly three, which will best serve the Multiple Resource Use requirements of the Forest for timber management, watershed and erosion, grazing, recreation, fire control, and other phases of Forest management.

The operation proceeds along standard map preparation lines. A base is prepared at the largest scale commensurate with the scale of the photography and the type of stereoplotter to be used. The control is plotted thereon. In many cases it is necessary to scale this control from existing Forest Service planimetric maps or to utilize Land Plat distances if the photo identification of section corners is available, or even scale control from planimetric plane-table base sheets. Needless to say, a great deal of ingenuity must be exercised in preparing the base. Stereocompilation of the area reconnaissance maps is usually assigned to the K.E.K. paper-print plotters.

It will be noted that final map scale has not been mentioned except to say that the compilation will be at the largest scale possible, considering the scale of photography and type of stereoplotter. This has been avoided as the scale will vary from project to project. The form-line interval has been semi-standardized at 100 feet in order to match the "C" factor of the K.E.K. plotters, and the only concession made toward supplying a standard map horizontally is to compile at the largest possible scale in terms of even feet to the inch, that is, compilation at a scale of 2,000 feet to the inch or similar multiples of even feet per inch. We have, however, compiled maps at 700-odd-feet-per-inch scales when forced by photoscale-plotter circumstance. Recently, an engineer on one of the Forests complained quite strongly over one of our area (reconnaissance) maps. The complaint was not the content, or the accuracy, but the fact that it was drawn at a scale of 1:20,000—"try converting that to even feet per inch!"

Seriously, while this complaint may seem strange to those engaged in standard topographic quadrangle mapping, and to those used to working in representative fractions, it will be understood and agreed to by those engaged in highway engineering, and the Highway Engineers. Imagine working out cross-sections at scale of 1:2,000 or 166.6 ft. to the inch!

## Route Reconnaissance

Following the completion of the area reconnaissance map and its submission to the Forest Supervisor and his staff, quiet, on that project, reigns supreme, at least until the Forest Engineer, having "walked the lines," decides which route or routes into or through the area of interest he wishes to have investigated further. At this stage, the Forest will submit a route reconnaissance request. The area map now comes back to us with the proposed route or routes delineated thereon and accompanied by a specification sheet defining the minimum curvature allowable, the ruling favorable and adverse grades, the termini, and any controlling features along the way. These features may consist of blocks of timber where logging is planned, private land to be avoided if practicable, or bad ground which *must* be avoided.

The planning for this compilation takes on a different tone. No longer is there concern with providing adequate form-line coverage in the shortest possible time and at the lowest possible cost. Available photography will again be used, and possibly, available control, But this is no "shotgun wedding." Only the best available photography will be considered for use and only good control will be used. Should the available control be completely inadequate for individual model setting in the Kelsh stereoplotter, a C-8 bridge will be run to extend that which is available to cover the strip to be mapped.

The base is now prepared, but this time to a planned scale, usually in the neighborhood of 1,000 or 500 feet to the inch, with a 20- or 40-foot interval. This procedure is possible since, although the same photography is being used as was used in constructing the area reconnaissance map. The work is scheduled for the Kelsh-type plotters. The two-plus enlargement of the K.E.K. stereoplotter is no longer a limiting factor.

The map drawn to satisfy the route request will consist of a minimum strip of topography usually extending some 500 to 1,000 feet on either side of the proposed route. A modified grade-contour will be plotted following the completion of the mapping of the strip within each individual model, and before that model is disturbed. The criteria set up by the National Forest in the original route request are adhered to; for example, no sustained grades steeper than six percent favorable (eight percent pitches are tolerated) or four percent adverse (up in the direction of a log haul) will be plotted; the minimum curve radius specified will be observed with some slackening of the grade on minimum radius curves, to give the road designer leeway in his design work. The specifications will vary from project to project, sometimes heavier grades being permitted, sometimes lighter grades being required. The rather scant width of the strip used at this stage of road location may seem odd to those engaged in main highway location, but in the mountain canyons of the Northern Region, a road can't be shifted sideways very far.

In addition to providing the strip map with the route or routes plotted thereon, a set of photographs is furnished the customer with the several routes, complete with stationing, transferred thereto. This is done to assist the field engineer in examining the routes on the ground, flagging the line if necessary, and in deciding which of the routes is best suited for construction. A report is also furnished; this gives a general description of each route, and a tabulation by stations showing the station number—even and plus—the grade, the per cent side-slope, the cover conditions, i.e., clear, partly timbered or heavily timbered, and the station elevation. In some instances this report also includes a geologic analysis of the route by station.

The Surveys and Maps Branch does not choose the road location. The maps show only the route or routes along which tighter engineering data was requested, and along which it is feasible to build the type road described is the specifications. The Forest Engineer and his staff are responsible for choosing the final road location.

The route reconnaissance package is now complete and is forwarded to the field for use. The Forest Engineer may now take one of two paths; he may choose his final route, flag the line, run his ground surveys, design and build the road. In such a case, the Surveys and Maps Branch will hear no more about it. However, he may choose to initiate the last phase of the basic three-tiered plan:

### Road Design Survey

One of the proposed routes, or a slight variation therefrom, is chosen by the Forest Engineer from office and ground examination of the proposed locations, and a request for a design survey is forwarded to the Surveys and Maps Branch, Regional Office. This request is not for a complete design of the road, complete with bridges and parking areas; it is simply a request for a complete engineering survey—a request that there be supplied all survey data necessary for the design of the road by the Highway Engineers. A full-scale engineering project is launched; the old files are dug out and general coverage photographs extracted therefrom along with the previous maps, not for mapping use, but for planning. The final map scale is fixed at 1″ = 100′; the control specifications are firm, third-order or better. The control files are examined in conjunction with the photos and maps. A control plan is developed and, insofar as possible, the positions of new control points are picked. Field crews, both Surveys and Maps Branch and National Forest, are alerted; these new stations, along with the old, are occupied; and are targeted both for control and photographic operations; distances are read with the electronic distance measuring devices, and angles with the theodolite. Elevations are established on all photographic targets by reciprocal vertical angles or by spirit levels. Third-order control is considered to be the minimum standard to be attained. Project photography is then flown using a precision mapping camera. No more *"making-do"* photographically—two scales of photographs are obtained, one at approximately 1:12,000 —the control flight—and one at 1:6,000 or close thereto, for strip map compilation. This latter photography is usually flown by flight strip segments, segments centered on the proposed road centerline.

Following completion of the photography and the field surveys, the material is returned to the Regional Office for control computation, for target visibility check, and for check for completeness of coverage.

Upon completion of the control computations and other preliminary office operations the control photographs, mapping photographs, and control, are passed along to the C-8 stereoplanigraph where the control photography is bridged, passpoints tying the compilation flying to the control flight being picked and included in the bridge as it proceeds. The "$X$," "$Y$," and "$Z$," coordinates for each control and passpoint are taken off, one by one, by the Ecomat Readout device and are translated onto punch cards. These cards are then assembled into the proper decks, forwarded to the computer, and the bridge adjustment made. The final output from Data Processing consists of a listing of all control points with their coordinates referred to the proper State Plane Coordinate System expanded to conform to the mean project elevation; elevations are referred to sea level datum—all at the scale at which we wish to plot the strip design map, i.e., 1 inch equals 100 feet with a 5-foot contour interval.

Following the completion of the bridge and plotting of the base sheets, the strip map is compiled using a Kelsh plotter and turned over to the design engineers, either Forest or Regional Office, for the selection of the final alignment. With this selection completed, and the alignment transferred to the manuscript, the cross-sectioning is done photogrammetrically and these data tabulated and all material returned to the Roads and Trails Branch or the National Forest.

While we have not had the opportunity, for a variety of non-photogrammetric reasons, to lay any of our design jobs "on-the-ground" in final form, preliminary field investigations indicate that no significant problems will be encountered since all projects are heavily pre-targeted, consecutive targets being intervisibly placed. The reporting of firm data on this phase of the projects will, however, have to await the completion of many more miles of field work; it is hoped we will be able to present a report following next field season.

To give the reader an idea of the volume of work being processed, the following production figures covering the fiscal year 1962 are included. These are general in character, no attempt having been made to tabulate map mileages by scale in addition to type:

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| Area Reconnaissance | 452 square miles |
| Route Reconnaissance | 484 lineal miles |
| Rights-of-Way | 65 lineal miles |
| Design | 3 lineal miles |

The design figure is rather misleading. The apparent over-concentration on area and route reconnaissance at the expense of design has developed naturally from an attempt to effect a maximum distribution of our limited production capacity among the 16 National Forests in meeting the needs of Multiple Use planning. Eighty miles have been scaled and computer adjusted, but lack of plotter capacity has forced us to delay design map compilation. In addition, 50 lineal miles are scheduled for C-8 bridge and computer adjustment this year. The installation, in January, of our third Kelsh plotter, also being double shifted, will enable us to schedule one instrument entirely on road design surveys. The K.E.K. plotter and two of the Kelsh plotters will be used for area and route reconnaissance and for large-scale administrative and recreation site maps.