Drainage Studies From Aerial Surveys

F.C. RILEY, Park Aerial Surveys, Inc., Louisville, Kentucky

This paper discusses the need for control surveys in highway work, the Federal authority to extend the existing first- and second-order control networks, the burden placed on the U.S. Coast and Geodetic Survey, and items of cooperation between Federal and State agencies to supplement and expedite the work. In this need the States turn to experienced private engineering firms.

Also discussed are the use of State plane coordinates as a basis for control, electronic measuring devices, and precise surveying equipment and methods. Benefits to highway departments of adequate horizontal and vertical control on a national scale are outlined, as are National Defense benefits.

● A FEDERAL Highway Act enacted in 1956 became an important impetus to the future security and economic well-being of the United States. Today, some of the fruits of this most ambitious of peace-time engineering undertakings are beginning to show. The face of the Nation is being changed. Arterial highways are gradually creeping from city to city and state to state, over mountains, rivers, deserts, and fertile valleys, pumping new life-blood into the heart of America. The benefits of the program are many and varied. To an engineer it represents a challenge to his initiative and ability. The contractor sees the job taking shape with new and better construction equipment. Truckers see shorter, faster, more economical routes. Land developers envisage mushrooming of cities at interchanges. It is evident then that these new highways will be the center of much activity and development. So it is no accident that Section 119 amends the Federal Aid Law definition of the term "construction" to include "the establishment of temporary and permanent geodetic markers in accordance with specifications of the Coast and Geodetic Survey in the Department of Commerce."

The U.S. Coast and Geodetic Survey is the recognized authority on control surveys and is charged with establishing the basic first- and second-order horizontal and vertical control on which all other surveys in the country depend. Due to its efforts, data on the 1927 North American datum are available for use by engineers and surveyors on some 150,000 triangulation stations throughout the United States. These and other data are available in two forms: (a) geographic positions with latitudes, longitudes, and true azimuths; and (b) State plane coordinates with X and Y rectangular coordinates (eastings and northings) in feet and grid azimuths.

Of course, when the vast reaches of this country are envisioned, one can see that theirs is no small assignment. In an effort to establish a rapidly expanding control network in the shortest possible time it was necessary to follow the less formidable routes and to triangulate over large areas from mountain top to mountain top. The USC & GS has long been aware of the sparseness and relative inaccessibility of triangulation stations. Realizing this, it has for many years been supplementing the primary network by the establishment of additional stations near towns, airports, and colleges and along existing highways and railroads. Still, there remain areas that have not been touched. Several means of filling in the gaps have been proposed. It seems that the USC & GS is quite flexible in its thinking and is willing to cooperate in any possible manner that will result in the filling-in of these areas. In a talk presented at the 17th Annual Meeting of the American Congress on Surveying and Mapping, Captain I. E. Rittenburg, Assistant Director for Administration, USC & GS, had this to say:

ERRATUM

HRB Bulletin 312, p. 40: Title of paper should read "Geodetic Control for the Interstate Highways."

> We are working closely with the Bureau of Public Roads in the formulation of policy and procedures in initiating and implementing control-survey projects in cooperation with the various States. It is important that the necessary accuracies be maintained and proper connections to the Federal Network be made if these surveys are to perform their designated functions.
>
> Under the policies and procedures established jointly by the Bureau of Public Roads and the Coast and Geodetic Survey the initiative must be taken by the States. The Bureau of Public Roads is ready to approve those projects which meet the established criteria. The Coast and Geodetic Survey is likewise willing to assist any State which desires to establish permanently marked geodetic control along its interstate highway routes. The assistance we offer is most flexible and will be tailored to the wishes of any State. We are prepared to cooperate fully with any State and to work out the best method of operations within the policy and budgetary limitations of that State.

It appears that geodetic control might be extended by utilizing any of several possible programs. For example, in Tennessee and in other states some geodetic control extension is being accomplished by USC & GS field parties. In Mississippi, control is being extended by State highway personnel under the direction of the USC & GS; however, due to the limited manpower of the USC & GS, and geodetic surveying being a highly specialized field, other states have resorted to negotiation with private engineering firms for prosecution of the work. The Kentucky Department of Highways feels that there is merit in the latter method. Therefore, it engaged Park Aerial Surveys, Inc., Louisville, Ky., to begin control extension about a year ago. Priority for work was established, and since that time approximately 120 mi of second-order traverse have been established with errors of closure ranging from about 1:19,000 to 1:275,000. In addition to the 120 mi of traverse, approximately 165 mi of second-order levels were run. Permanent bench marks were established at intervals of approximately 1 mi. Traverse stations were set at intervals of approximately 3 to 5 mi. Each station consisted of a surface mark and underground mark, two reference marks, and an azimuth mark. Bronze disks with appropriate markings were used and were set in concrete posts in accordance with USC & GS specifications. The traverse was accomplished by second-order methods as described in USC & GS publication. The instruments used for the traverse work consisted of a Wild T-2 theodolite, a Tellurometer for measuring distances electronically, a set of traverse lights consisting of seal-beam units set on tripods for stability, and also a pair of Standardized Lovar chains used to measure distances of less than ½ mi. All angles were turned through 12 positions of the circle, direct and reverse. Any single observation that differs more than 5 sec from the mean is rejected and rerun. The leveling was also run using USC & GS second-order methods. The equipment consisted of a Wild N-III precise level, a pair of calibrated geodetic leveling rods, an umbrella to shade the instrument at all times, and a pair of steel turning pins for use by the rodmen. Out of 54 level lines and spur lines that were run, 37 met first-order criteria, 15 met second-order criteria, only 2 were rejected because they exceed the second-order limit and they were satisfactorily rerun. However, even though 37 lines appeared to be first order, second-order methods were used and considered of that accuracy unless notified otherwise by the USC & GS. All field notes were recorded in regular USC & GS field books, and all computations were made in the Louisville office on standard USC & GS computation forms. Traverse computations were based on the Kentucky State plane coordinate system and were in a nature of preliminary or field computations. These computations were then sent to the USC & GS office in Washington, where they were checked and final adjustments were made.

All control lines originated and terminated on USC & GS triangulations stations or bench marks, which were of second-order accuracy or better. This is necessary to insure that the resulting work is of the required accuracy. Furthermore, when second-order accuracy is required, second-order methods and precise instruments must be used.

The use of State plane coordinate systems offers the better approach to the extension of control. More engineers and surveyors are familiar with plane surveying than with geodetic surveying. Most engineers and surveyors have had little or no training in the making of geodetic computations. On the other hand, the system of plane coordinates presents the opportunity to translate the old familiar metes and bounds surveys into positions having definite X and Y values when ties are made to known positions. From here, it is a relatively simple matter to convert those plane coordinate positions to geographic positions or to the Universal Transverse Mercator System of coordinates. The mathematics is not too difficult and the critical part of the operation rests with the performance of the field work. It must be done by second-order methods, and definitely has to be tied to control monuments of second-order or better accuracy.

Some engineers may question the need for this work, but it is generally conceded that the intricacies of modern highway design require accuracies in surveys that were unwarranted in the early years of highway building. One has only to compare a modern complicated interchange to a simple grade crossing of a few years ago. What better means is there to "nail down" an interchange or a bridge location than by a tight system of coordinated positions? Also, this density of control stations will provide an easy and economical means for starting and terminating all Interstate Highway centerline surveys. After the line has been hubbed it can be computed, thus eliminating equations in the line. Property ties may also be made to the computed centerline, resulting in X and Y coordinates of property corners. This method of describing property is permitted in several States. Errors in design computations or layout become apparent at once because of the many cross-checks that are afforded. Also, over-all planning and design have not yet reached the place where they can be performed instantaneously. Thus it is necessary to work on a few segments at a time. Coordinated positions assure that the pieces will fit together perfectly.

Although this paper deals with geodetic controls for the interstate system, it is felt that eventually such controls will be extended and used in connection with the design of all future primary and secondary highways and also railroads throughout the country.