of proper proportions of road metal, silt, and clay. The work being so new, there is a very limited field to draw from, except the engineers of the different chemical companies, and on these we have leaned heavily. However, it is time we began to walk alone. The whole field is a challenge to the highway engineer who has the proper type of inquiring mind. There are many miles of secondary roads to which this class of surfacing lends itself admirably. It deserves serious consideration.

U. S. COAST AND GEODETIC SURVEY EMERGENCY PROGRAM IN INDIANA

By G. E. Lommel, Professor of Topographical Engineering, Purdue University

Before considering details of the subject of this paper, it seems necessary again to remind this group of county surveyors that there are several federal agencies engaged in surveying and map making and that these agencies could be of much greater benefit if practicing local surveyors would take advantage of the services which these same agencies offer. Many bulletins and maps are available for your use, the data and information being the results of field work of a high degree of precision.

U. S. COAST AND GEODETIC SURVEY

The most important of these federal agencies is the United States Coast and Geodetic Survey, a bureau of the Department of Commerce. This survey was organized more than a hundred years ago and is charged with the establishment of precise triangulation, traverse, and vertical control over the land areas of the United States and its possessions. During the first half century of its existence, because of the pressing need of such information, the Coast Survey's operations were limited to hydrographic and topographic surveys along the coast lines of the country with emphasis placed on those harbors which were being used extensively.

During the last half century, the activities and importance of the Bureau have increased. With more and better equipment available, nautical charts have gradually reached the high degree of accuracy and reliability of today; and, in addition, much has been accomplished in the development of the control network of lines and elevations in the interior of the country. When complete, the primary triangulation net will reach from coast to coast and from Mexico to Canada. The chains of quadrilaterals will be spaced at intervals of about 25 miles and will average 10 miles in width. The whole system, as well as

its extension into Canada and Mexico, is now (since 1900) referred to a single point (Meade's Ranch) located in central Kansas. At the present time, about 43,000 miles of horizontal control by triangulation has been established.

The objective of the vertical control survey is a spacing of level lines at approximately 25 mile intervals. About 85,000 miles of precise level lines have been run.

Thus, with the completion of this first part of the scheme of primary control, elevation above a national datum plane, geodetic position, and true direction will be available to all surveyors.

Another activity of the Coast and Geodetic Survey is a study of terrestrial magnetism. Magnetic stations have been established at many places, and from the results of observations at such stations, the engineers of the Survey have been able to work out isogonic charts which show intensities of magnetic influences on the compass needle at all points in the United States. The latest isogonic chart appears in *U. S. C. and G. S. Serial No. 540.*

With the rapid increase of air navigation and the necessity for reliable flying charts, another map-making activity has been undertaken by the Coast and Geodetic Survey. Charts are now available for many sections of the country.

U. S. GEOLOGICAL SURVEY

A second important agency for map making is the U. S. Geological Survey operating under the direction of the Secretary of the Interior. To the surveyor, the most important function of the Geological Survey is as a topographic map-making agency. The results of the field operations of the survey are published in the form of maps of quadrangles, 15 minutes of longitude by 15 minutes of latitude in size. Folios of geologic information are also published for many quadrangles. The present-day need of an intimate knowledge of soils and land uses in our agricultural communities will undoubtedly focus attention upon the accomplishments of the Geological Survey and also upon the Bureau of Soils of the U. S. Department of Agriculture.

U. S. ARMY ENGINEER CORPS

Another engineering division which has made important contributions of benefit to the local surveyor is the U. S. Army Engineer Corps. The survey information and maps issued by the Army Engineers have to do with such problems as flood control, deep waterways, and the like.

MISCELLANEOUS

The Great Lakes Survey, the Mississippi River Commission, the International Boundary Commission, the National Park Service, and the General Land Office are other federal

survey and map-making agencies which have contributed liberally to our better understanding of physical conditions in these United States.

STATUS OF INDIANA SURVEYS

Survey information in Indiana is not as great as in other states. Only one chain of the triangulation system crosses the state. (Fig. 1.) This chain straddles the 39th parallel

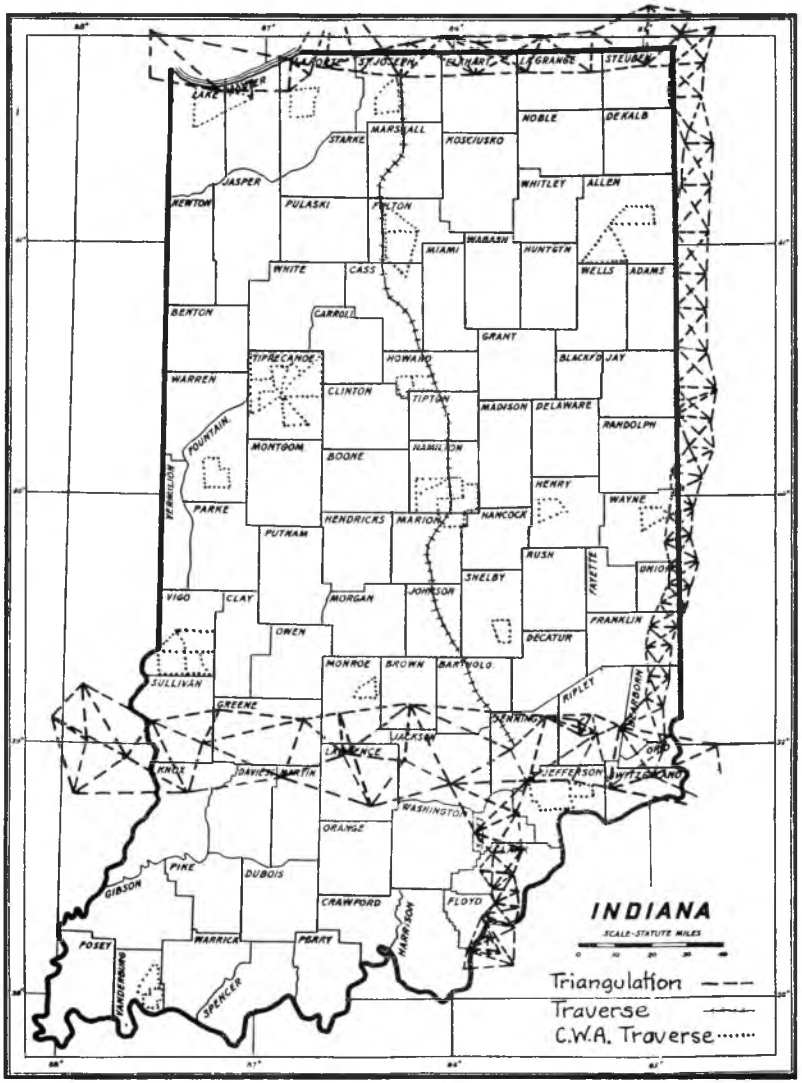

Fig. 1. Map of Indiana showing location of government triangulation chains and traverse lines, also traverse work under C.W.A.

and was run during the years 1884-1891. Another short chain connects this with the Ohio River Survey at Louisville. This connection was made in 1914.

Triangulation stations exist also along the north boundary of the state and are the results of field operations of 1879 and 1908. This work was done by the U. S. Lake Survey.

A connecting chain running north and south between the 39th parallel and the north boundary chains was established in 1932. Much of this chain is in Ohio but many points are conveniently located for those counties along the east boundary of Indiana.

A primary traverse line connects North Vernon and South Bend by way of Indianapolis.

With the exception of the Ohio-Indiana Boundary and triangulation, data on triangulation and traverse in the state are available in *Precise Traverse and Triangulation in Indiana,* Special Publication No. 79 of the U. S. C. & G. S.

Another chain of quadrilaterals running east and west is to be worked out by the Coast Survey in the near future. The reconnaissance survey has been made. The new chain will straddle the 40°15′ parallel of latitude.

Data for leveling operations in Indiana are more numerous. (Fig. 2.) The following level lines exist. (Elevations [1929 adjustment] and descriptions of bench marks can be obtained from the School of Civil Engineering at Purdue University, from the Director of the U. S. C. & G. S. at Washington, or from the U. S. Army Engineers district office at Louisville, Kentucky.)

1. U. S. Army Engineers Survey of Wabash Valley—mouth to Terre Haute.
2. U. S. Army Engineers Survey of Wabash Valley—Terre Haute to Huntington.
3. U. S. Army Engineers Survey of East and West Forks of White River.
4. U. S. Army Engineers Survey of Eel River.
5. U. S. Army Engineers Survey along Ohio River.
6. U. S. C. & G. S. level line from Lawrenceburg to Vincennes.
7. U. S. C. & G. S. level line from Lawrenceburg to Indianapolis.
8. U. S. C. & G. S. level line from Shelbyville to Vincennes.
9. U. S. C. & G. S. level line from Terre Haute to Indianapolis.
10. U. S. C. & G. S. level line from Washington to Indianapolis.
11. U. S. C. & G. S. level line from Indianapolis to Warsaw.
12. U. S. C. & G. S. level line from Warsaw to Jackson, Michigan.

Fig. 2. Map of Indiana showing government level lines and magnetic stations.

13. U. S. C. & G. S. level line from Elkhart to Walton, Michigan.

14. U. S. C. & G. S. level line from Chicago, Illinois, to Warsaw.

15. U. S. C. & G. S. level line from Warsaw to Leipsic, Ohio.

16. U. S. C. & G. S. level line from Mitchell to Oakland, Illinois.

17. U. S. C. & G. S. level line from Mitchell to Louisville, Kentucky.

The U. S. Geological Survey has adopted a scheme of quadrangle surveys for the state. When complete, the state topographic map will be composed of 167 quadrangles of topographic information, with contours to a 20-foot interval, and on a scale of 1 inch to the mile. At present, 36 quadrangle maps have been issued. These cover about 10% of the total area of the state. Most of this is in the southwest corner of the state.

The U. S. Department of Agriculture through the Bureau of Chemistry and Soils prepares and publishes soils survey maps of counties. In Indiana, 38 of the 92 county soils maps have been issued to date and in 13 others aerial mosaics have been made as a preliminary to the making of the soils map. (Fig. 3.)

Army engineers' maps which are available include a series of Ohio River maps (Nos. 179 to 234) to a scale of 1 inch = 600 feet and a contour interval of 5 feet; a series along the Wabash River from the mouth to Terre Haute (Nos. 1 to 13), scale 1 inch = 1,000 feet, C. I. 5 feet; a series along the Wabash from Terre Haute to Huntington (Nos. 14 to 46), scale 1 inch = 1,000 feet, C. I. 10 feet; a series along the White River from Mt. Carmel to the junction of the east and west forks (Nos. 1 to 6); a series along the east fork of the White to Columbus (Nos. 6 to 29); a series along the west fork to Indianapolis (Nos. 6 to 53); and a series along the Eel River from Worthington to the south boundary of Putnam County (Nos. 2 to 9). All these latter are printed to a scale of 1 inch = 1,000 feet and a contour interval of 10 feet.

An index map of these series is also published by the Corps of Engineers.

U. S. C. AND G. S. EMERGENCY WORK IN INDIANA

The Civil Works Program of State Control Surveys which were begun about December 15, 1933, under the direction of Dr. W. K. Hatt, Head of the School of Civil Engineering at Purdue University, acting as State Representative of the U. S. C. & G. S., has made possible the establishment of many monuments in 18 counties of Indiana. The principal objectives of the program were to give work to our unemployed engineers and, at the same time, to collect data which can be used in extending the present control system into areas where such control does not exist.

Thirty parties of ten each were organized and field work was done in the vicinity of the following cities: Gary, LaPorte, South Bend, Fort Wayne, Rochester, Newcastle, Kokomo, Richmond, Indianapolis, Shelbyville, Lafayette, Bloomington, Veedersburg, Terre Haute, Madison, and Evansville.

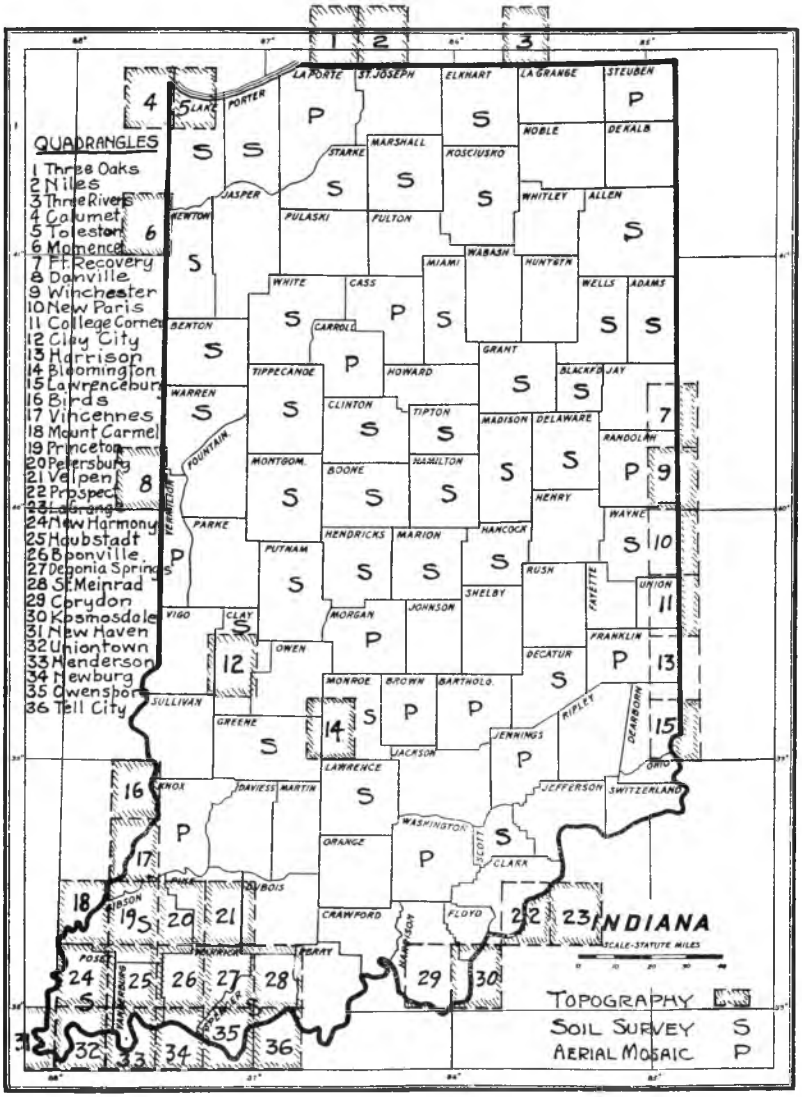

Fig. 3. Map of Indiana showing present status of topographical surveys.

Specifications for traverse line control under which the field work was done were sent from the Washington office of the Coast Survey.

Interesting features of these specifications are:

1. If possible, control lines to begin at an established traverse or triangulation station already fixed by the Coast Survey.
2. Standard concrete monuments to be set at all primary traverse points.

3. Permissible error of closure of traverse loop set at 1 in 10,000.

4. Standardized steel tapes to be used.

5. When supported throughout, a tape pull of 11 lbs., and when supported at two ends, pull of 22 lbs. to be used.

6. Temperature reading to be recorded at every application of the tape.

7. Difference in elevation between the two ends of the tape to be measured and recorded.

8. Lines to be measured twice, a discrepancy of .01 per 100 being allowed.

9. Direct measurements between traverse stations to be made, if possible, but offset measurements and secondary traversing between main traverse stations to be permissible.

10. Angle value determinations to be made by two sets of six repetitions each on the inside angle and on the explement angle at each main traverse station; two sets of three repetitions on angles and explements of secondary traverses.

11. Prominent land marks to be tied into the traverse line control by repetition.

12. Differential levels to be run over the traverse stations, error not to exceed $.05\sqrt{\text{no. of miles run.}}$

With weather conditions as they have been during the winter and with the necessity of using available unemployed engineers and available equipment, the results of this field work have been very satisfactory. Although none of the traverses have been calculated for closing error, the field notes indicate that the results of such calculations will be well within the rather conservative limits set by the Coast Survey specifications. To date, the field parties have run about 623 miles of traverse lines. With better weather conditions during the spring months and with the winter's experience behind them, this total should be increased materially before the project is ended.

Time permitting, one of the objectives of this survey is completion of the control net in the counties in which the parties are now operating. This, if followed by complete calculations of closures and distribution of errors, will give to the county surveyor a good system of coordinates established with a degree of accuracy far higher than any ordinary survey which he makes.

The control system thus established will also be of value to the soils survey. It can also be used in the future as a basis for a topography survey of either the whole county or of any portion of the county. County road surveys, state highway surveys, city surveys, land surveys, and the like can begin and end on one of these monuments and in that manner perpetuate the local survey, gradually building up complete survey information in the several counties of the state.