THE EXPANDED PROGRAM FOR THE GEODETIC SURVEY OF THE UNITED STATES

by

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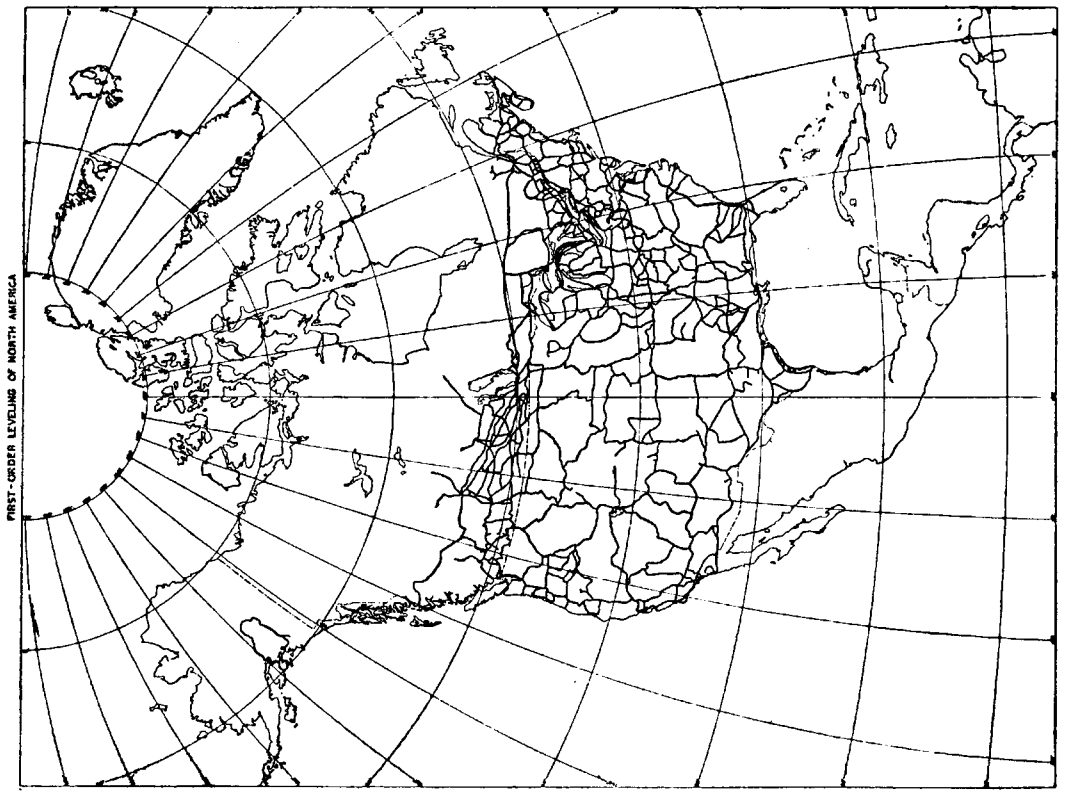
In the early beginning of the work of the Coast and Geodetic Survey, it was realized by the officials of that organization that the charts of coastal waters should be based upon triangulation. Necessarily at first the triangulation had to be done in detached arcs, each arc depending upon local astronomical stations for latitudes and longitudes. Ultimately the triangulation of the Atlantic and Gulf Coasts formed a continuous arc, extending from northeastern Maine to Mobile, Alabama.

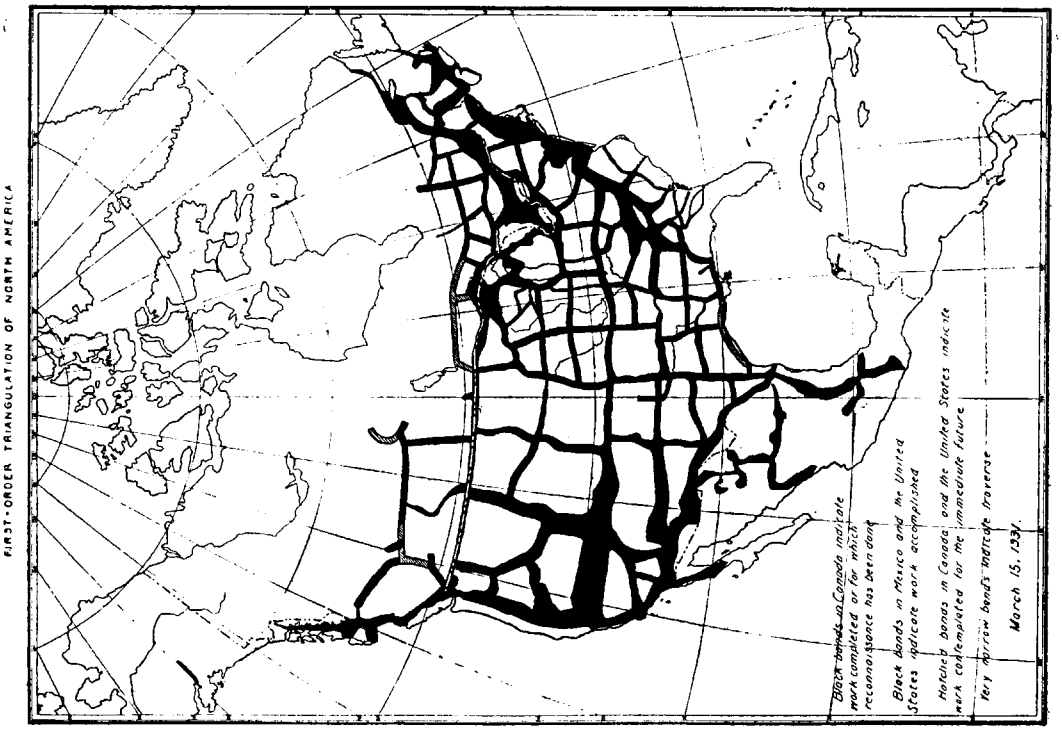
Triangulation was also made continuous along the Pacific Coast of the country. Eventually it was deemed advisable to join the work of the Pacific Coast with that of the Gulf and Atlantic by an arc of first-order triangulation along the 39th parallel of latitude. All of this work was completed prior to 1900.

The United States Lake Survey, charged with charting the waters of the Great Lakes, carried on triangulation as a basis for its charting operations. The Lake Survey triangulation was connected with that of the Coast and Geodetic Survey in New York State and also by an arc running southward from Chicago to the work along the 39th parallel.

After about 1900 it was realized that triangulation had many uses besides furnishing control for the charts of the coast. Projects were outlined by which the interior of the country would have arcs at frequent intervals all tied into a single system. Starting in 1902 radical changes were made in the methods of conducting triangulation work in the field. Acetylene lamps were designed which could be used for night observations. The use of the lamp greatly expedited the work, for on all nights, except when there was rain or fog, the light from the lamps could be seen and observed upon. The lights were frequently not very steady but some investigations indicated that, if about thirty-two pointings were made over each line, the mean of the angle observations was quite free from the effect of any large accidental errors. In other words, the accidental errors were paired out. Heliotropes were used to a limited extent as objects on which to point, but heliotropes were found to be much less satisfactory than the lamps. There are very few days when the sky is entirely clear and the delays incident to waiting for heliotropes to show tend to throw rather large errors into the observed angles. Then again heliotropes could only be used in the late afternoon because of the unsteadiness of the atmosphere at other times.

Appropriations for the geodetic work during the early part of this century were quite small and only a moderate amount of progress could be made. Starting about 1915, increased appropriations were made for control surveys and successive increases were made until the field appropriation, which is in


FIRST-ORDER LEVELING OF NORTH AMERICA


FIRST-ORDER TRIANGULATION OF NORTH AMERICA
Black bands on Canada indicate work completed or for which reconnaissance has been done
Black bands in Mexico and the United States indicate work accomplished
Hatched bands in Canada and the United States indicate work contemplated for the immediate future
Very narrow bands indicate traverse
March 15, 1931.

addition to the pay of the engineers engaged on the work and of the mathematicians employed in the office, was about $100,000 annually. This amount was slightly reduced after the World War.

Beginning with the fiscal year 1931, the appropriation for field operations was increased from a total of $98,600 to $326,800. Of this latter amount $30,000 is made available for the employment of mathematicians and computers in the Washington Office, $5,000 is devoted to operating the Variation of Latitude Stations at Ukiah, Calif., and Gaithersburg, Md., and $10,000 is used for making tests of the stability of the earth in regions of seismic activity. It will be seen that approximately $280,000 are available for the field expenses on the regular geodetic control surveys of the country.

The Coast and Geodetic Survey is following a plan which calls for arcs of first-order triangulation and lines of first-order leveling spaced at intervals of about one hundred miles with certain cross arcs and cross lines for purposes of adjustment. According to the plan the intermediate areas will be controlled by arcs of second-order triangulation and lines of second-order leveling. All of this work is being done as a Federal project and paid for from funds appropriated by the Federal Government. The remaining intermediate areas will be controlled by second or third triangulation and leveling, but this work will be done in connection with the making of topographic maps or in conducting engineering operations. It is probable that most of the expense of completing the control surveys, that is, putting in the detailed work between the first and second order arcs of triangulation and between the first and second order lines of levels, will be paid for by funds of the states, cities and counties or perhaps occasionally by funds of private corporations.

Already there are in the United States 26,400 miles of arcs of first-order triangulation and 3,700 miles of lines of first-order traverse. The traverse was executed a decade or more ago, prior to the introduction of the BILBY steel tower. The cost of running triangulation through flat, heavily wooded country with the use of wooden towers was excessive and, therefore, traverse was adopted as a substitute. There is no necessity now for depending upon traverse, except where horizontal control work must be carried on in a marshy area. There are such areas in the United States which are crossed by railroads or highways. Traverse can be carried along these latter with a high degree of accuracy but it would be impracticable to transport and erect towers away from road in order to have triangulation across the area.

There are now in the United States 60,500 miles of first-order leveling. All of the work since 1900 has been done with an instrument designed in the office of the Coast and Geodetic Survey. It is an improved instrument which enables the observer to work in quite strong winds and to take lengths of sight as great as 150 meters. A progress of 100 miles a month is frequently made by a single observer.

Work now in progress includes a revision and strengthening of some of the earliest work by an arc of first-order triangulation which will extend from Corpus Christi, Texas, eastward along the Gulf Coast to Tallahassee, Florida, then around the Florida coast to the vicinity of Jacksonville, Florida, and from there northward along the coast to New York Harbour. Connections

will be made frequently with existing third-order triangulation along the coast. This will make it possible to derive final geographic positions for any existing coastal triangulation stations or for stations along the coast which may be established hereafter.

It is realized that the shore line is the limit of the continent as well as the limit of the ocean and gulf and, therefore, should be placed in exactly the same geographic position on the charts as on the maps extending to the coast from the interior. This first-order triangulation along the Gulf and Atlantic Coasts will make it possible to accomplish this very desirable end.

Already first-order triangulation has been extended along or close to the Pacific Coast of the United States and connections have been made at a number of places with the coastal third-order triangulation.

In 1924, a method was devised by the Survey for the adjustment of a large network of arcs of triangulation. Late in that year an adjustment was begun of the network of arcs in the western half of the country lying between the 98th meridian and the Pacific Coast. The adjustment required the work of about twelve mathematicians for a period of approximately fifteen months. The result of the operation was that the most probable values for the junction points of the various arcs were obtained. The sections of the triangulation net were then fitted in between these junction points. The western half of this country now has triangulation so strong and so accurately adjusted and computed that no changes in positions of stations will be made in the future, except where there may be horizontal movements due to earthquakes. It is believed that areas affected by such earthquakes will be so small in extent that they will present only very local problems.

The great success obtained in the application of this method to the adjustment of the western half of the country has made it seem desirable to adjust the triangulation net in the eastern half of the United States. This adjustment has been going on for some months and it is expected that the most probable values of the junction points will be obtained late in the present year. After these values have been obtained, the sections between junction points will be fitted in in a manner similar to that followed in making the western adjustment. Necessarily, in making the eastern adjustment, the geographic positions, lengths of lines and azimuths along the 98th meridian, to which the eastern adjustment is joined, will be held fixed. This means that when the eastern adjustment is completed we shall have a connected network over the whole country and the results will be as satisfactory as if the net had been adjusted as a single unit rather than in two parts.

The United States Coast and Geodetic Survey, the Geodetic Survey of Canada and the Geographic Service of Mexico have been co-operating in a most effective manner whenever any geodetic work was required along international boundaries. The Geodetic Survey of Canada and the Coast and Geodetic Survey co-operated in extending an arc along the 49th parallel from the Lake of the Woods to the Pacific Coast and the two organisations worked together in extending an arc from the northwest corner of the United States northward along the coast of British Columbia and through Southeast Alaska to a point at the head of Lynn Canal.

The Mexican organisation and the Coast and Geodetic Survey have been co-operating to the extent of making connections between the triangulation systems of the two countries. Only three such connections have been made — one near Brownsville, Texas, and Matamaros, Mexico, near the 98th meridian; another near El Paso, Texas, and Ciudad Juarez, Mexico; and a third near the Pacific Coast.

The accompanying illustrations show the arcs of first-order triangulation and lines of first-order leveling in North America as on March 15th, 1931.

The leveling nets of the United States and Canada were adjusted together in order to obtain the most probable value for the junction points of the lines of the combined nets. After this adjustment had been made, it was decided that the values of the elevations of the junction points should be held fixed for the United States and the sections of the level lines between points should be fitted in. This work is now progressing rapidly and it is hoped that within the next year all of the adjustment will have been completed.

Some very interesting results have been obtained from the adjustment of the level nets. It has been found that the mean height of the ocean at a number of tidal stations on the Pacific Coast averages about two feet higher than the water at tidal stations on the Gulf and Atlantic Coasts. It has been found that the mean height of the water at northern tidal stations on both the Atlantic and Pacific Coasts are higher than the mean position of the water at southern tidal stations. The level net is so strong that the differences found in the heights of the mean sea level are surely a physical fact and are not due to errors of leveling. The leveling is so strong and there are so many closed loops that there is no possibility of errors occurring which are as great as the differences in the mean elevations of the ocean surface at the several tidal stations.