REQUIREMENTS FOR COMPLETION OF MODERN MAPPING IN TEXAS*

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MAPPING covers such a wide field that it is necessary to define the particular section under discussion. Modern mapping, as used here, means the development of complete topographic maps, rigidly controlled by closely spaced precise geodetic horizontal and vertical co-ordinates and with accurate contours on intervals that will meet all requirements of engineers, geologists, agriculturalists, and all other scientists. Of course, there is a great quantity of valuable map data, vitally useful for special purposes, which does not fully meet the specification set up by this definition. All maps, from the popular advertising oil company map to the excellent Highway Planning Survey county maps, will be valuable aids in the completion of State-wide modern maps, and, conversely, all maps will be better maps when we have the completed modern topographic maps to serve as accurate uniform basis for all maps.

Completion of mapping in Texas is a project of large magnitude. No conception of the size of the task can be had without a comprehensive study of its characteristics. Realizing the importance of such a study, the Mapping Committee of the State Planning Board made this one of its projects and during 1937–38 collected an immense volume of detailed data. A summary, only, of all this information is presented in this abstract.

At the outset it was decided that the study should include four distinct phases of mapping, namely: (1) Geodetic control, (2) Topographic mapping, (3) Soil mapping, (4) Geological mapping. The procedure adopted by the Committee contemplated the development of the following information: (1) an inventory of the work done to date in each phase and appraisal of its value as a part of the program, (2) an estimate of the work remaining to be performed to complete the mapping to a rational standard, (3) development of a logical procedure and compilation of an estimate of maximum cost based on a study of operations of organizations doing mapping in this area.

Acting in accord with this policy, all agencies engaged in mapping in Texas were interviewed by mail and asked to submit the following:

1. An index map showing work done to date.
2. Information in detail describing this work, giving date of survey, list of maps prepared for public use, indicating their scale, contour interval, culture shown and an estimate of their value in a complete modern mapping program for the State.
3. A statement of the amount of work necessary to complete the mapping of the State, a rough estimate of its cost and suggestions as to procedure and chronological order of performance.

This information was requested from the following agencies and complete replies were received from all of them: U. S. Coast and Geodetic Survey; U. S. Geological Survey; Chief of Engineers, U. S. Army; U. S. Bureau of Chemistry and Soils, Soil Survey Division; U. S. Soil Conservation Service; U. S. Bureau of Reclamation; U. S. and Mexico International Boundary Commission; Brazos River Conservation and Reclamation District; Texas State Reclamation Department; Bureau of Economic Geology, University of Texas; Texas Board of Water Engineers; Texas Highway Department; Texas Highway Planning Sur-

* Delivered at Semi-Annual Meeting at San Antonio, Texas, September, 1939.

vey. The co-operation of all these agencies is hereby acknowledged, with appreciation. It is recognized that other agencies are engaged in topographic mapping, as, for instance, the major oil companies and other private concerns. Partial development of completed maps, such as aerial photography by commercial companies for public and private agencies, planimetric mapping by the Highway Planning Organization, and other similar work, are conceded to be of some value in analyzing the information now available. These will all be valuable contributions in the program but the problem is so large that their effect on the final answer will fall well within the doubtful range of variation in the unit costs of final mapping.

The brief summary to follow was compiled from information dated at the end of 1938. It is accurate as of the present date, for very little progress has been made during 1939, and until some large program is started it will continue to be sufficiently accurate for all practical purposes. Again it is pointed out that the problem is so large that elements of this character have no appreciable influence on the final answer.

Geodetic Control

In 1900 the U. S. Coast and Geodetic Survey began the development of horizontal and vertical control in Texas. There are now about 6,910 miles of triangulation for horizontal control and 20,000 miles of precise leveling in the State. The International Boundary Commission has completed a triangulation system of about 90 miles from El Paso southeast and has made a precise line survey from Roma, Texas, to the Gulf of Mexico, all of which has been tied in to the triangulation network of the U. S. Coast and Geodetic Survey. A triangulation network covering the Presidio Valley from Candelaria, Texas, to Mulato, Chihuahua, Mexico, has been established but not tied in to the U. S. Coast and Geodetic Survey network.

This completed work provides a firm foundation for an accurate and rigid system of control for the State. All geographic co-ordinates have been computed, adjusted and checked and all elevations have been determined and adjusted so that there will be no change in this basic information. It only remains to fill in the cross lines and it has been determined that the extension of this control to meet the needs of modern mapping and other scientific uses will require that the following spacing be established:

East of the 104th Meridian—triangulation arcs located so that few points will be more than 6 miles from a control station and leveling lines so that few points will be over $2\frac{1}{2}$ miles from a benchmark.

West of the 104th Meridian—triangulation and leveling spaced twice as far apart as above.

The Coast and Geodetic Survey estimates that this completion of horizontal and vertical control can be performed for $1,620,500.

An important supplemental activity of the U. S. Coast and Geodetic Survey is the determination of magnetic declinations and intensities. To bring this data up-to-date $10,000 should be added to the above estimate. All this information was furnished through the courtesy of Mr. J. H. Hawley, Acting Director, U. S. Coast and Geodetic Survey.

Some secondary control has been run in connection with mapping work of other agencies but this need not be considered in this analysis.

In completing the geodetic control the main highways of the State should be followed. These highways are located through the centers of larger concentrations of population and land values. With stations established at intervisible

points not more than 2 miles apart these controls can be used for innumerable engineering activities in addition to the mapping control. Maps based on controls so located will provide the maximum of accuracy at points of maximum values of property.

Topographic Mapping

The major contribution of the U. S. Coast and Geodetic Survey is its horizontal and vertical control but the hydrographic maps along the Gulf coast provide an accurate border for a modern map of the area. The Hydrographic and Topographic Bureau is now engaged in the execution of a new modern basic hydrographic survey of the coastal waters of Texas, extending from the shore to the 100-fathom curve. This survey will be completed in 1941. Topographic maps have been completed along the entire Gulf coast but most of them are old and will have little value in a modern mapping program. In 1933–35 the Bureau completed planimetric maps based on aerial photographs, between Corpus Christi and Freeport. These maps are on a scale of 1:20,000 and have no contours. However, the terrain is so flat that there are few contours and these could be added at small cost.

In the field of topographic mapping the U. S. Geological Survey has covered more area than all other agencies combined. Dr. W. C. Mendenhall, Director, has made the following statement:

"In estimating the amount and the probable cost of work still to be done in completing the topographic mapping in Texas, it is necessary to take into account the work accomplished by other organizations, such as the Corps of Engineers, U. S. Army, the Brazos River Conservation and Reclamation District, the Soil Conservation Service, and the Coast and Geodetic Survey, whose work will not need to be duplicated. Information about such work was furnished to the Survey in December, 1936, and the mapping accomplishments of the several agencies, as reported to the Geological Survey at that time, are listed below. These accomplishments consist of topographic maps, planimetric or base maps without contours, and aerial photographs which are suitable for use in compiling planimetric maps. Additional mapping and aerial photography in areas covered by Geological Survey topographic maps which are considered adequate for present requirements will not contribute to the completion of topographic mapping. Therefore work of that character is credited only where it covers areas that are unmapped or inadequately mapped by the Geological Survey.

"The parts of Dallas and Fort Worth 30-minute quadrangles which have not been remapped, amounting to 2,008 square miles, should be mapped as metropolitan areas for publication on the scale of 1:31,680 or 2 inches equal one mile. The other inadequately mapped and unmapped areas of the State should be mapped for publication on the scale of 1:62,500 or approximately 1 inch to a mile. The following estimate contemplates topographic mapping in conformity with that proposed and with the plan recommended by the Federal Board of Surveys and Maps.

"The plan of the Board of Surveys and Maps includes:

1. The execution of basic horizontal and vertical control surveys by the United States Coast and Geodetic Survey. The execution of the other operations, necessary to complete topographic mapping, by the United States Geological Survey.

2. The compilation of planimetric base maps from aerial photographs taken on suitable scales (1:20,000 recommended) of all the unmapped or inadequately

Areas in square miles

	Adequately mapped areas	Inadequately mapped areas	Unmapped areas	Total area to be considered
Accepted area of Texas				265,896
(1) Topographic Maps:				
U. S. Geological Survey	24,858	57,884	183,154	265,896
Corps of Engrs., U. S. Army	6,249	—	−6,249	
Brazos River District	362	−174	−188	
Total	31,469	57,710	176,717	
To be mapped topographically		57,710	176,717	234,427
(2) Planimetric maps available: No credit				
Soil Conservation Service 1:15,840	130	2,550	221	
Soil Conservation Service 1:24,000	103	220	—	
Coast and Geodetic Survey 1:20,000	528	—	966	
Total		2,770	1,187	−3,957
Planimetric maps to be compiled		54,940	175,530	230,470
(3) Additional aerial photos available:				
Soil Conservation Service		820	26,790	
Brazos River District		500	300	
Forest Service		—	1,014	
Agr. Adjustment Admin.		380		
Total		1,700	28,104	−29,804
Aerial photos to be procured		53,240	147,426	220,666

mapped agricultural lands in the Eastern and Southern States, where boundaries of farms and fields are irregular in shape, and most fields are relatively small, and of other areas of extreme economic importance; the publication of preliminary sheets without contours; the preparation of contour maps as soon as practicable after the planimetric maps are available; and the publication of the topographic maps in advance sheet form and in final form on suitable scales for general distribution.

3. The compilation of planimetric base maps from aerial photographs taken on suitable scales (1:31,680 recommended) of all of the unmapped and inadequately mapped agricultural lands in States where individual farms and fields are relatively large and regular in shape, and of other areas of moderate economic importance; the publication of preliminary sheets without contours; the preparation of contour maps as soon as practicable after the planimetric maps are available; and the publication of the topographic maps in advance sheet form and in final form for general distribution on suitable scales."

The data listed in the table on next page cover accomplishments of the U. S. Geological Survey to June 30, 1938 and are correct to date for all practical purposes. Data in reference to work of other agencies follow.

The Corps of Engineers, U. S. Army, has been engaged in the mapping of Texas for many years. The maps cover the sections adjacent to the Rio Grande, along the Gulf Coast and in the neighborhood of San Antonio. The United States Engineer at Galveston had made some maps from actual ground surveys

Estimate of cost for State of Texas.

"(See U. S. Coast and Geodetic Survey for the estimated cost of the basic horizontal and vertical control surveys.)

"Aerial Photographs	$ 604,006
Horizontal locations of air photo points	695,426
Elevations of air photo points	695,426
Compilation of planimetric maps	3,006,150
Reproduction of planimetric maps	403,825
Contour mapping, including office processing	8,315,385
Reproduction of topographic maps in advance sheet form	118,218
Reproduction of topographic maps in final form	820,564
Total estimated cost, exclusive of control surveys by Coast and Geodetic Survey and instrumental equipment	$14,659,000"

covering only a narrow strip of land along the banks of a few of the major rivers but these maps are not in quadrangle form, although they are in suitable form for general use in reports. This same statement applies to work of the Corps of Engineers in mapping the area on the Red River for the Denison Dam. The large area of mapping by the army in Texas has been executed under the supervision of the Engineer, Eighth Corps Area, at Fort Sam Houston. Col. G. R. Lukish and Major William H. Waugh, both now retired, have furnished the following information, which is correct as of July, 1938. The older maps have some value for reconnaissance purposes, but it is conceded that those older than ten years will require extensive revision to bring them up-to-date.

Mapping now under way is based on a War Department 10-year program, beginning with the fiscal year 1937. This work is confined to an area 30 miles wide on the southern border of the United States from Brownsville, Texas, to Yuma, Arizona. For War Department mapping the scale is 1:62,500, contour interval 20′, control by U. S. Coast and Geodetic Survey, U. S. Geological Survey and Corps of Engineers. On this new project multiple lens aerial photographs are used and standard radial line methods employed for plotting from photographs, and the plotted sheets are adjusted to horizontal control. Contouring is done in the office, based on stereoscopic examination of aerial photos and transit vertical angles determined in the field. No mechanical contour plotting machine is used. Ninety-six quadrangles covering work done since 1922 were reviewed by the writer. The total area covered is 20,940 square miles, of which 2,946 are included in the area considered to be adequately mapped by the U. S. Geological Survey, leaving a net area of 17,994 square miles mapped by the Corps of Engineers. Of this area the State Reclamation Service has mapped 836.1 square miles in the lower Rio Grande valley and 47.0 square miles in the Sugarland quadrangle. With the exception of 3,209 square miles of mountainous topography where a 100 foot contour interval is used, the larger part of this area is mapped with a 20′ contour interval.

The U. S. Bureau of Reclamation has made topographic surveys of areas at six dam sites but none of this work has been reduced to quadrangle maps for public use. It will be valuable data for future use in those areas but can be ignored in this discussion as the area covered is not large.

The Brazos River Conservation and Reclamation District was created by the 41st Legislature in 1929, and since October 1935 its Mapping Division has carried on a program of mapping, using aerial photographs as the basis of its work. The first objective of the Division is the making of adequate maps of the reservoir areas to be included in the lakes and their environs which will be created by the construction of the thirteen major dams, as well as to make large

scale maps of the several dam sites. The most westerly dam is the Seymour, in Stonewall County, and the most southerly on the main river is the Whitney Dam in Hill County. The project also includes a major dam on the Leon River, north of Belton, one on the Lampasas, south of Belton, one on each of the North and South Forks of the San Gabriels River near Georgetown in Williamson County, and one on the Navasota River in Brazos and Madison Counties.

The work of the Mapping Division has been executed with the most modern methods known to science at the time of its inception. Aerial photographs were secured under contract with the Southwestern Aerial Surveys, Inc., of Austin, and were taken on a scale of about 1:15,000 under the requirements of standard specifications as drawn by the American Society of Photogrammetry and adopted by all Federal agencies. The topographic maps are being made by the stereoscopic plotting method and the multiplex projector was adopted for this work. The completed maps are drawn to a scale of 1:12,000 (1,000 feet = 1 inch) with a 10 foot contour interval. Topographic surveys of the dam site areas have been made with planetable and maps drawn to a scale of 1:2,400 (200 feet = 1 inch) with 2 foot contour intervals.

As of November 28, 1938, the District had completed maps covering 2,362 square miles of reservoir area. Part of the area previously surveyed and mapped by the United States Geological Survey is included in the section covered by this District and the following table correlates the work of the two agencies.

Reservoir Area	Total Sq. Mis. B.R.C. & R. Dist.	Adequately Mapped, U. S.	Inadequately Mapped, U. S.	Unmapped
Seymour	249	112.50		136.50
Breckenridge	125		25	100.00
Possum Kingdom	300	272.71		27.29
Turkey Creek and Inspiration Point	236	196.76	39.24	
Parker County	129		129	
Cordova Bend	169	143.27	25.73	
Bee Mountain	180	97.96	82.04	
Whitney	214	166.08	47.92	
Navasota	343	191.20		151.80
Leon	183	149.21	33.79	
Lampasas	95	34.73	60.27	
No. San Gabriel and So. San Gabriel	139	55.68	83.32	
Total	2,362	1,420.10	526.31	415.59

This District has provided a valuable example that will be used to establish a workable procedure in future mapping programs and allows us to set up an estimate of the cost of State-wide mapping. This "sample" after a year or more of operation, and having covered more than 1,000 square miles of the District, has developed the following unit costs:

Horizontal control	$11.96	per square mile
Vertical control	14.57	" " "
Multiplex development of relief	15.11	" " "
Drafting and reproduction	6.13	" " "
Editing	2.35	" " "
Administration	1.00	" " "
Total	$51.12	

These costs include all salaries, supplies, expenses, transportation, aerial photographs, prints and enlargements. They do not include depreciation on

equipment. Finished maps are on a scale of 1:12,000 with 10 foot contour intervals. It should be borne in mind that aerial photographs for this work were taken with a camera not designed for the multiplex. Since the work was started there has been perfected and made commercially available wide angle lenses mounted in precision cameras and also instruments of the multiplex type for processing these photographs. This equipment produces improved quality of photographs, minimum lens distortion, and facilitates the work with corresponding improvement in the quality of the finished product and definite reduction in the cost. This reduced cost is due to the following factors: (1) larger areas will be covered by each photograph, (2) horizontal and vertical control may be wider spaced, and (3) each pair of photographs inserted in the multiplex will produce a larger area of map at the same cost as with the photographs used with the smaller area lens used by the contractor for the District. It should also be noted that with the completion of geodetic control, as recommended in this report, there will be a strong rigid control which will be spaced so as to be usable for modern wide angle lens photography with very little additional ground work. In the above estimates the total for horizontal and vertical control is more than 50% of the entire cost of the maps.

These data have been furnished by Major Eric Haquinius, Engineer in Charge of Surveys and Mapping for the Brazos River Conservation and Reclamation District.

The Texas State Reclamation Department has mapped 2,821.4 square miles of the overflowed areas of the larger rivers in Texas and their chief tributaries as well as a large part of the coastal plains. The first maps were made in 1910 and while all the maps are accurate in control and topography, no doubt some of the older issues will need to be revised to bring them up-to-date, as some ground features, such as levees, etc., have been built since they were made. The scales vary from 1:6,000 to 1:24,000 and contour intervals from 2′ to 5′. In addition, the Department mapped 27 square miles of Corpus Christi and vicinity and 120 square miles of Fort Bend and Wharton Counties. Of this total area only about 1,000 square miles are outside of the area covered by the U. S. Geological Survey and the U. S. Army. The area has been mapped on a larger scale and with a higher standard of accuracy due to the detail required and all this 2,800 square miles may be considered to be completed to an adequate standard for modern uses. These data were prepared by Ralph J. McMahon, Reclamation Engineer.

The State Board of Water Engineers, Bureau of Economic Geology, Harris, Cameron and Galveston Counties, have co-operated with the U. S. Geological Survey in the mapping of 16,500 square miles, all of which are included in the area covered in Dr. Mendenhall's table.

It thus appears that there is much duplication in the work that has been completed and after a careful study of all the data it is concluded that 42,852 square miles may be considered to be adequately mapped. A good share of this area is Army mapping on a scale of 1:62,500, and some of it should be remapped. There is a considerable area that is rugged terrain where these Army maps will be entirely adequate for the present. It would seem conservative to estimate that one-half of the U. S. Geological Survey and one-half the Army area will need to be remapped in the early part of the program. The Brazos River Conservation and Reclamation District area of 2,362 square miles and the State Reclamation Department area of 2,800 square miles are adequate for all purposes, bringing the total area to 24,000 square miles.

Using Dr. Mendenhall's total estimate of $14,659,000 for the completion

of the topographic mapping, plus $1,630,500 for geodetic control, and applying it to the 234,427 square miles in Dr. Mendenhall's table, we arrive at a unit cost of $69.50 per square mile for the uncompleted area. My analysis leads me to believe that we should consider an area of 242,000 square miles to be mapped and on this basis the total cost will be $16,819,000.

The cost shown by the Brazos River Conservation and Reclamation District is $51.12 per square mile. This cost was determined on an area less than 1% of the total area of the State. Methods and equipment were new and personnel untrained. Undoubtedly a considerable reduction in this cost can be made in a State-wide program. Scales used are 1:12,000 and 10 foot contour intervals. For a considerable portion of the State a smaller scale and wider contour interval will serve satisfactorily. For a comparatively small area, a larger scale and narrower contour interval will be indicated and planetable mapping will be necessary to supplement the stereoplotting. A conservative analysis of these facts leads to the conclusion that mapping can be completed for $50.00 per square mile. This figure applied to the 242,000 square miles results in $12,100,000. Adding the $1,630,500 for geodetic control we arrive at a total cost of $13,730,500. With assurance of adequate funds for completion, no doubt a considerable saving could be made and it seems logical to assume that if $1,000,000 were made available each year the State of Texas could be completely and adequately mapped in 12 to 15 years.

Soil Mapping

From information prepared by Mr. W. T. Carter, Inspector, District 4 at College Station, and furnished to the Mapping Committee through the courtesy of Dr. Charles E. Kellogg, Chief, Soils Survey Division, U. S. Bureau of Chemistry and Soils, the following statement in regard to soil mapping has been prepared.

Agriculture is the chief source of income for the largest number of inhabitants of the State and its soils will always constitute its most valuable natural resource. It is of prime importance that the character of the surface soil be known and that its potential capabilities be definitely determined in order that this resource may be so utilized as to yield the maximum return and that it be conserved so as to remain a heritage for future generations. This intimate study of the soil has been carried on in Texas by the U. S. Bureau of Chemistry and Soils and the Texas Agricultural Experiment Station.

The history of soil surveys in Texas dates back to the year 1901, when a part of Montgomery County was surveyed by the Bureau of Soils of the U. S. Department of Agriculture. The soil survey of the United States had started only two or three years prior to this date, and as no soils surveys had ever been undertaken anywhere before in the whole world, the first few years were devoted largely to developing ways of doing the new work. Some survey work has been carried on every year in Texas since 1901 and in 1918 the entire program was given impetus by a co-operative arrangement between the U. S. Bureau of Chemistry and Soils (Bureau of Soils, prior to 1938) and the Texas Agricultural Experiment Station. In this co-operative work the two organizations expend approximately equal amounts on field work. The maps and reports are published by the U. S. Department of Agriculture in Washington and are distributed by the Department, Members of Congress and the Superintendent of Documents.

The soil survey consists of an inventory of the soil and land resources of a particular area, usually an entire county. The soil profile is carefully examined, studied and described, from the surface down to the unchanged geological for-

mation. With this information at hand the soil, subsoil and substrata of the soil are classified, correlated, mapped and described in the bulletin for that area. In addition to this study of the physical characteristics of the soils in the field, certain additional information is collected as to the suitability and productive capacity of the soils for crops. These additional data are obtained from several sources, such as by interviewing farmers as to the production of various crops, from experiment stations and, where necessary, by actual tests and analyses of the soil to determine the character and amounts of chemical constituents and plant nutrients in the soil. The field work must be performed by trained workers who are experienced and careful and who will devote considerable time to the duties incident to the investigation. The agricultural utility and value of a soil can not be ascertained without an understanding of the functions and features of the subsoil and substrata and a rating of the potential capabilities, and the classification of the land can not be definitely determined unless the soil profile, including topsoil, subsoil and substratum have been examined and physical and chemical characteristics determined. A mere scanning of the surface of the land is not sufficient for an accurate determination of land value and classification. The soil surveyor goes carefully over all the land at close intervals and examines the soils and subsoils and maps the soils in units of similar character, the smallest of which is the soil type.

In addition to their use for farm planning and administration, the soil maps and reports have value for other purposes. The location of the State's agricultural experiment stations has been determined after a careful study of the several geographic areas wherein soils and climatic conditions are approximately similar. The agricultural research on soils most representative of large soil provinces is thus available to the farmers on these soils. This policy will be continued in locating additional stations and when all the State has been surveyed, or such part as is warranted, no landowner need be without the results of research as regards the soils of his farm.

Home seekers and land buyers avail themselves of the information in soil survey reports and maps to secure the kinds of soils suitable for the types of agriculture in which they wish to engage. Large undeveloped areas of Texas land will be placed in cultivation, as future economic requirements demand, these areas being made available through improvement by drainage, irrigation and other means of this character, and by the development of crops of wider climatic adaption. The soil survey is indispensable in the development of these areas in the planning of the use of the land and in the classification of the land so that marginal and sub-marginal areas may be developed without loss of energy and funds on improper uses.

Soil surveys are useful and essential in agricultural education and in the demonstration of information on the improvement and proper use of soils and crop planning, and they furnish accurate, reliable and practical foundation material on which demonstrations and instructions can be based, for use of the agricultural colleges, vocational teachers in public schools, Extension Service agents and others.

The service of these maps and reports is not confined to agricultural workers, for they are in constant use by other agencies in development of the resources of the State. Geologists use the soil maps to trace the outcrops of formations and these surface indications are a valuable aid in the investigation of sub-surface conditions. An increasingly wide use is developing in the highway field where the maps and reports are useful in the design of roadbeds. Soil science is very much in the limelight in highway work at the present moment and the character

of surface and sub-soils is an important factor in the proper design of a modern highway. No doubt highway engineers will find increasing uses for the soil surveys and maps as they develop the procedure of soil study. In land use planning, now a very important state and national issue, a detailed soil survey is obviously essential in order to know and evaluate properly the potential capabilities of various soils. Land appraisal, flood control, soil conservation and other studies relating to the land, all require an exact knowledge of each of the soils and their extent and location in the area under consideration.

A co-operative publication, "The Soils of Texas" (Bulletin No. 431) which has been published by the Texas Agricultural Experiment Station, consists of generalized soil map and report showing the principal soil divisions of the State and is a compilation of information collected in soil survey work. This bulletin, as well as the entire editions of many soil survey reports, has been entirely distributed and is no longer available except as references in the files of certain libraries. Soil surveys made prior to 1912 are not only out of print but also are out-of-date according to our present standards and should be remapped and the soils re-correlated to bring the data up-to-date. The number of areas thus requiring re-mapping is 29, and their total area is about 17,000 square miles, or approximately one-fourth of the total area of the State that has been surveyed in detail. Of the surveys made since 1912, most of which do not require much revision, there are a number out of print, as the authorized editions have been entirely exhausted.

Since 1901, 82 areas in Texas have been covered by detailed surveys, the soil maps having a scale of one inch equals one mile. A few of these have not as yet been published but are in the process of publication. The area covered to July 1936 is approximately one-fourth the total land area of Texas.

In addition to the detailed surveys, eight areas including several counties each in west and south Texas have been covered by reconnaissance soil surveys made on a scale of one inch to six miles. These areas include about 140 counties, but as some 18 counties included have also been covered by detailed surveys, the net area of the 122 counties having reconnaissance surveys is about 98,000,000 acres, or approximately 58% of all the land area of the State. The reconnaissance surveys were made rapidly to secure general information for large areas which were being settled and, although most of the published reports are out of print, it is believed that it is better to concentrate on detailed surveys rather than re-survey out-of-date reconnaissance areas.

Due to rough and stony lands and soils shallow or loose and otherwise unsuited to cultivation, largely situated in western Texas, there are 27 counties which will not require detailed soil surveys. The total area of these is 53,931 square miles. There are 52 counties with detailed soils surveys which do not require re-surveys. The total area of these is 50,705 square miles. There are, therefore, 175 counties which require soil surveys or re-surveys and the total area of these counties is 157,762 square miles, averaging about 900 square miles to the county.

The 175 counties to be surveyed, if they are to be covered in 15 years, will average 12 counties per annum. This schedule requires 36 well-trained men working continuously throughout the year. Under the present system in which the soil survey men have to construct their own maps, this field work costs about $14.00 per square mile. If adequate base maps were available, as will be the case when the mapping plan is adopted, the cost will be reduced to $10.00 to $12.00 per square mile for the field work. On the basis of $14.00 per square mile, the total cost of the field work for the 157,762 square miles will be $2,208,608.

On the present basis of co-operation with the costs divided equally between the State and Federal Departments, the cost to the State will be $1,104,304 and if the surveys are completed in 15 years the cost per annum will be $73,622 for each organization, exclusive of the cost of printing. As a co-ordinated part of the entire program of mapping it is believed that soil mapping of the whole State may be completed, including printing, for $3,000,000.

Geological Mapping

Dr. E. H. Sellards, Director of the Bureau of Economic Geology, University of Texas, has prepared the following statement for use by the Committee:

"Geologic maps are of two kinds: areal and structural. Areal geologic maps show the outcropping formations over a given area. Structural maps, on the other hand, show by the use of suitable symbols geologic structure of the region under consideration.

"Areal geologic maps serve the following purposes: They show the outcropping belt of various formations such as limestones, shales, sandstones, and other rock formations. Valuable mineral deposits such as iron ore, phosphate rock, kaolin, or building stone contained in these formations are designated by appropriate symbols. Such maps are of use to landowners, to mineral producers, in road building and in dam construction. They are useful likewise in soil conservation and in all phases of land use and serve a useful educational purpose.

"The purpose of a geologic map is to express what is known of the distribution of formations in the region under consideration. As geologic knowledge progresses, new maps are needed. This is true of both areal and structural geologic maps. In Texas both areal and structural geologic maps have been issued for the State. These maps should be revised from time to time as new information is accumulated.

"Maps of the State as a whole are necessarily on a relatively small scale. Maps with greater detail are needed for all parts of the State. Fairly detailed geologic maps have been issued by the U. S. Geological Survey for several 15-minute quadrangles in the State. Geologic maps on a county unit for 23 counties have been issued by the Bureau of Economic Geology of the University of Texas, In addition to quadrangles and county units, geologic maps have been issued on several special areas, not defined by either quadrangle or county.

"On the accompanying map* there is shown by appropriate symbol (1) quadrangles in Texas of which geologic maps have been made by the U. S. Geological Survey; (2) counties in Texas of which county geologic maps have been made by the Bureau of Economic Geology of the University of Texas; (3) most of the larger special areas of which geologic maps have been made except certain areas for which the maps made are to be classed reconnaissance rather than detailed. Areal or structural geologic maps have been made for a considerable number of areas too small to be indicated on an index map of this scale.

"Program of Mapping

"The county has been found to be a convenient sized unit for geologic mapping and it is desirable to continue mapping until the counties of the State have been mapped. In the meantime, occasion may arise requiring special mapping of smaller areas as quadrangles or otherwise. The regional mapping including revised geologic and structural maps of the State as a whole should be revised and reprinted as new information is obtained."

* The map accompanying Dr. Sellards' statement.

It is difficult to establish a cost of geological mapping in Texas. The total cost will depend on the degree of detail. At one extreme we have the geologic map of the State prepared by the Bureau of Economic Geology on which is expressed the information at hand in so far as it can be shown on a map of this scale. This map excellently serves the purpose for which it was prepared. At the other extreme, if we were to prepare a map in great detail it would be necessary to carry on extensive boring or excavating as well as very minute examination of surface features to provide a map on a large scale with high degree of accuracy as to the geologic conditions and formation content. Considering the uncertainty as to just what degree of accuracy will be required to provide rationally usable geologic maps, it is estimated that one million dollars will be necessary to provide for satisfactory mapping in this field.

Conclusions

Using the maximum estimates for each of the various phases of mapping, we arrive at the following total cost for the State:

Geodetic Control	$ 1,630,500
Topographic Mapping	15,189,500
Soil Survey Mapping	3,000,000
Geological Mapping	1,000,000
Total	$20,820,000

This figure would appear to be the maximum outside cost of complete topographic, soil and geological mapping for the State. On the topographic mapping it was stated that the availability of one million dollars per year for 12 to 15 years should complete it. The inclusion of soil and geological mapping will require 16 to 19 years for completion.

There is a large amount of preliminary study that should be completed before any program of mapping is started. The most important question to settle first, in my opinion, is the matter of proper scale for maps and contour interval to be adopted. These points must be given serious thought by engineers, geologists and soil scientists to insure the most satisfactory final maps, when the program is started.

The Special Committee of the Mapping Committee of the State Planning Board included Mr. John D. Miller of Austin, Dr. E. H. Sellards, Director, Bureau of Economic Geology, University of Texas, Dean W. R. Woolrich of the Engineering Department, University of Texas, and the writer as Chairman. This committee was appointed by Mr. Ralph J. McMahon, Chairman of the Mapping Committee of the State Planning Board. Major E. A. Wood, Director of the Planning Board, served as ex-officio member and secretary of the subcommittee.