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COAST AND GEODETIC SURVEY

REVIEW OF THE YEAR

The commercial growth of our country and the gradual expansion of its maritime and aeronautical activities have been accompanied over a long period by steadily increasing demands upon the Coast and Geodetic Survey for the services which it is its function to provide. During recent years the normal increase in this respect has been accelerated by recovery from the depression, with the result that during the past year the Bureau was called upon to render a volume of service considerably greater than for any other year in its history.

During the fiscal year 1937 orders for aeronautical charts increased 45 percent over 1936, and orders for nautical charts increased 21 percent, while for all navigational publications the increase was approximately 27 percent for the year and 125 percent as compared with the issue 10 years ago. Requests for geodetic data more than doubled during the year.

With the development of aviation, a substantial growth in the need for aeronautical charts is to be expected for some time to come, but the greater demand for nautical charts is rather remarkable. On account of the expansion of naval and merchant-marine activities during the World War, the issue of nautical charts, which previously had averaged about 100,000 copies a year, rose rapidly to a maximum of 311,000 copies, which it was thought would constitute an all-time peak. It is, therefore, interesting to note that in 1937 orders for nautical charts for the first time exceeded the war-time peak, requiring the issue of over 333,000 copies.

The work of the Bureau also has been augmented by the increased activities of other agencies. The improvement of waterways by the United States Engineers, the marking of new channels and the betterment of existing systems of aids to navigation by the Lighthouse Service, and the expanded program of the Bureau of Air Commerce all create conditions which add materially to the Bureau's work of revising its charts and necessitate the issue of new editions with greater frequency.

A continued advance in efficiency and economy of operations, through the development of improved methods and equipment, together with a moderate increase in appropriations, have enabled the Bureau to meet a part of the increased demands upon it, but existing facilities are inadequate to cover all needs. This situation is aggravated by the rapid rise in commodity prices, which has increased the cost of all branches of operations.

As a result of these conditions there is a growing arrearage in the Bureau's work, which is a cause for serious concern. Work laid out ahead for the cartographic force to chart data on hand has increased

National Oceanic and Atmospheric Administration

Annual Report of the Superintendent of the Coast Survey

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from 2,340 man-days 1 year ago to 3,143 man-days at the present time. In spite of every effort the stock of various charts becomes exhausted with increasing frequency and the work required to renew the supply cannot be accomplished promptly as it must be loaded on a production force having from 4 to 5 months' work already on hand. In the field it has been necessary to postpone indefinitely resurveys of important areas, as required to maintain the accuracy of the charts, and further to shorten the field seasons of the Bureau's survey ships on account of the greater cost of fuel oil and other supplies.

The products of the Bureau are required for the protection of life and property at sea and in the air. They are essential to the operation of our Navy and merchant marine and for military and civil aviation. The supply of such products has long been recognized as a national governmental function and consequently the Coast and Geodetic Survey is the only source of supply for this material for this country and its possessions. The volume of production, of course, is governed entirely by the demand therefor. The desirability of providing the Bureau with adequate resources which will enable it promptly and fully to meet this demand is obvious.

So far as permitted by available facilities, good progress was made in all branches of the Bureau's work. Details concerning these various activities are given in subsequent sections of this report. Among the outstanding accomplishments of the year are the completion of the series of 87 sectional aeronautical charts covering the entire United States, the completion and successful use for field surveys of the nine-lens aerial camera designed by the Bureau, the discovery of numerous dangers to navigation with the wire drag on the Pacific coast, and the extension of the use of automatic buoys to replace the station ships formerly required for the radioacoustic method of locating survey ships engaged in offshore work.

There were 1,169 employees on duty in the Bureau and in its field service on June 30, 1937, distributed as shown in the following table:

Staffs	Commissioned	Civilian				Staff totals		Total
		Classified	Unclassified			Washington	Field	
			Laborers	Seamen	Hands			
Washington office	18	303	3			324		324
Field service	153	66		[1] 495	[1] 131		845	845
Total	171	369	3	495	131	324	845	1,169

[1] Includes 51 civilian employees on duty at the Manila field station and 50 members of the crew of the ship *Fathomer*, paid by the Philippine insular government but under the jurisdiction of this Bureau.

The library and archives acquired during the year 110 hydrographic and 137 topographic sheets, representing new Bureau surveys. Other additions were 915 blueprints (mostly surveys by Army engineers); 2,089 maps; 1,291 charts; 8,298 field, office, and observatory records; 276 negatives; 295 prints; 255 lantern slides; 877 books; and 3,274 periodicals.

The regular appropriations for the year totaled $2,505,300. These were supplemented by the following additional appropriations: Transfer from Salaries and Expenses, Soil Conservation Service (transfer to Commerce), 1937, $81,700; Salaries and Expenses, Soil Conservation Service (transfer to Commerce), 1937, $4,500; repayment by Soil Conservation Service for work performed at their request, $29,654.97; Working Fund, Commerce, Coast and Geodetic Survey (Hospital and Domiciliary Facilities and Services, Veterans' Administration), $5,000; Maintenance of Air Navigation Facilities, 1937, $75,000; and Deficiency Appropriation, Pay and Allowances, Commissioned Officers, Coast and Geodetic Survey, 1936, $2,640.99.

In addition to these sums, there were available small unexpended balances on account of appropriations and allotments for the fiscal year 1936.

Collections on account of the sale of nautical charts and other publications, and miscellaneous Government property, deposited in the Treasury Department to the account of miscellaneous receipts, totaled $109,659.29, as compared with $95,589.74 during the preceding year, an increase of 14.7 percent.

Disbursements during the year ended June 30, 1937, totaled $2,738,084.36, distributed among the various appropriations as follows:

Party expenses, 1935	$226.02
General expenses, 1935	6.50
Pay, etc., officers and men, vessels, 1935	216.01
Pay and allowances, commissioned officers, 1936	64,187.85
Salaries, 1936	156.94
Party expenses, 1936	84,265.87
Repairs of vessels, 1936	12,945.19
General expenses, 1936	26,577.89
Pay, etc., officers and men, vessels, 1936	91,792.38
Pay and allowances, commissioned officers, 1937	712,956.51
Salaries, 1937	583,247.44
Party expenses, 1937	387,718.08
Repairs of vessels, 1937	53,000.98
General expenses, 1937	34,352.23
Pay, etc., officers and men, vessels, 1937	439,666.25
Maintenance of air navigation facilities, 1937	68,563.31
National Industrial Recovery, 1933-37	47,424.18
Public Works Administration, allotment to Commerce, Bureau of Air Commerce, 1935-37	560.13
Chicago World's Fair Centennial Celebration	52.24
California Pacific International Exposition	49.75
Texas Centennial Exposition	1,863.38
Public Works Administration, allotment to Interior, Soil Erosion Prevention (transfer to Commerce from Agriculture, 1935-37)	24,997.62
Salaries and Expenses, Soil Conservation Service (transfer to Commerce, C. and G. Survey, act of Apr. 27, 1935), 1936	18,327.66
Salaries and Expenses, Soil Conservation Service (transfer to Commerce, C. and G. Survey, act of Apr. 27, 1935), 1937	81,497.45
Working Fund, Commerce, C. and G. Survey (Hospital and Domiciliary Facilities and Services, V. A.)	3,432.50
Total	2,738,084.36

IMPROVEMENTS IN METHODS AND EQUIPMENT

A comprehensive program of instrumental improvement was maintained throughout the year by the Instrument Division, which included modernization of existing stock and the design of new instruments to keep pace with changing needs and advances in scientific knowledge and materials of construction.

Among the more important results of this program are:

The design of an all-metal signal lamp, which is light, strong, and free from the warping experienced in wooden lamp cases. A medium-sized signal lamp, mounted in a metal case, was also developed for use on lines of medium length and in mountainous regions where portability is especially important.

A new standard tide gage was designed for interchangeability of certain essential parts of simpler and more rigid construction and fitted with an integral all-metal cover for dust and weather protection.

A portable tide gage is in process of modernization to provide an improved gear system to reduce lost motion and friction.

A replaceable bushing for the precision theodolites and levels, in which wear of the leveling screws may be a critical factor in the instrument's accuracy, was so designed that no loosening can occur.

Methods of constructing geodetic level rods were improved to reduce cost and to speed up production.

Special attention also has been given to the improvement of magnetic observatory instruments, especially the development of convenient means of adjusting and maintaining the recording magnets of the variometers in proper orientation to the magnetic meridian at the site.

Additional usefulness of the Dorsey Fathometer, an improved type of echo-sounding instrument developed by the Bureau, was indicated during the summer of 1937, when the ship *Hydrographer* observed tides at sea with the instrument, obtaining a very satisfactory tidal curve 27 miles from shore. The computation of tidal factors for offshore areas in the past has been based almost entirely on theory and a means for obtaining actual observations will have great value.

Construction of the nine-lens aerial camera designed by the Bureau was completed and the instrument was used on the first flight for survey purposes on April 30, 1937. The Air Corps, United States Army, through a cooperative arrangement, altered a large airplane to accommodate the camera and made the flights required for the preliminary tests and adjustments, and for the surveys. The prints obtained by the camera and transforming printer measure about 35 inches square, affording an excellent, detailed, view of the ground. The large area covered by a single exposure with this camera reduces the ground control necessary for aerial photographic surveys. A marked reduction in the cost of surveying with photographs, especially in areas difficult of access, will result when the necessary equipment for mapping from the photographs can be obtained.

During the past year a crystal chronometer was first used for gravity-at-sea observations on an expedition to the West Indies in which this Bureau cooperated with the United States Navy and the American Geophysical Union. Later this chronometer, together with the Meinesz gravity apparatus, also used on the expedition, were tested in the vicinity of Bethlehem, Pa., for the purpose of determining whether the apparatus was adaptable and efficient for land observations. This equipment was also used in determining the force of gravity at several different elevations in the Empire State Building, New York City. The crystal chronometer functioned perfectly throughout. The use of this instrument has made it possible practically to eliminate time errors and it appears to be equally adaptable

to astronomical observations. It should be noted that the total error of the chronometer for the entire 6 weeks of the gravity-at-sea expedition was only 0.36 second.

During the year, further improvements have been made in gravity apparatus and methods. The recording unit of the Brown gravity apparatus, particularly as regards the radio devices, has been improved. The use of two sets of instruments has made it possible to check the accuracy of each gravity station observed.

Field tests have been made with new types of levels to determine their adaptability to first- and second-order leveling. Tests have been made on the use of color filters both for theodolites and leveling instruments. It has been found that the use of certain filters with levels eliminates some of the constant vibrations caused by the radiation of heat near the earth's surface, and the observer is thereby enabled to see the rod clearly at longer distances and thus obtain greater progress.

A new vacuum printing frame has aided in speeding up the work of processing the printing plates for the charts.

COOPERATIVE ACTIVITIES

Several officers detailed to duty with the Lighthouse Service, under cooperative arrangements with that Service, have demonstrated the value of this arrangement. Numerous details relative to the charting of aids to navigation were handled efficiently and accurately. The arrangement also has enabled the officers of the Lighthouse Service to become more familiar with charting methods.

The following projects were handled on a cooperative basis with the organizations named:

Geodetic control survey agencies of Connecticut, Massachusetts, and New Jersey: Determination by these organizations of magnetic declination at many new stations and at some of the existing magnetic stations of the Bureau, the work including diurnal variation observations in some cases.

Department of terrestrial magnetism, Carnegie Institution of Washington: (*a*) Better determination and maintenance of national and international magnetic standards as a result of joint observational programs at the Cheltenham Magnetic Observatory; (*b*) operation of a cosmic ray meter at Cheltenham Magnetic Observatory; (*c*) continuation of atmospheric electric and earth current observations at Tucson Magnetic Observatory (with added cooperation of the Bell Telephone Laboratories and the Mountain States Telephone & Telegraph Co. in the work at Tucson); and (*d*) the extension of weekly broadcasts of magnetic conditions for the benefit of the investigators in the field of radio transmission. The Navy Department, science service, and others also have cooperated in the latter work.

Special tide and current surveys: Completion of a tide survey of Barnegat Bay, N. J., in cooperation with the New Jersey Board of Commerce and Navigation; assistance to the United States Engineers and Bureau of Fisheries in their current surveys of Galveston Harbor and York River, Va., respectively; and special current observations on *Stone Horse Shoal*, *Ambrose*, and *Scotland* lightships, through the cooperation of the Bureau of Lighthouses.

Soil Conservation Service: Extension of second-order triangulation in Indian reservations in South Dakota, Utah, Washington, and Wyoming for use in controlling mosaics from air photographs.

Florida mapping project, under auspices of the Works Progress Administration: Completion of arc of second-order triangulation between Orlando and Okeechobee, and elsewhere.

Forest Service: Triangulation in the vicinity of Cedar Point, Idaho, to locate fire towers.

Galveston district engineer, Corps of Engineers, United States Army: Completion of leveling in progress at the close of the last fiscal year, consisting of some 250 miles of lines in the vicinity of Galveston Bay.

California Works Progress Administration: Rerunning lines of levels in the vicinity of San Jose, Calif., for the purpose of studying earth settlement.

Seismologists of the University of Montana (with funds allotted by the Public Works Administration): Rerunning of old lines of levels and the extension of new leveling in Helena, Mont., and vicinity.

Works Progress Administration project of King County, Wash.: The continued detail of an officer to assist in airphotographic mapping and extending necessary triangulation.

New Jersey, Massachusetts, and Connecticut geodetic control surveys and the Pennsylvania State planning board: Detail of an officer for limited periods to assist in the extension of control surveys.

United States Navy and the American Geophysical Union gravity-at-sea expedition to the West Indies: Detail of an officer to make the necessary instrumental preparations, including the standardization of the Meinesz apparatus, and to accompany the expedition.

Guatemala-El Salvador Mixed Boundary Commission: Detail of an officer to determine a Laplace azimuth on the boundary between the two countries.

An officer was assigned to each of the computing offices of the State geodetic survey projects in Arkansas, Connecticut, Georgia, and Oklahoma to supervise the personnel, paid by the Works Progress Administration, engaged on geodetic computations.

The Bureau continued serving in an advisory capacity with 14 States in carrying on horizontal and vertical control surveys as part of the Works Progress Administration program initiated by this Bureau in November 1933 under the Civil Works Administration.

CHART PRODUCTION

The results of the Bureau's field surveys, together with information from other sources, are utilized for the production of nautical charts of the waters of the United States and possessions for the benefit of the mariner, and aeronautical charts of the land area for use by the aviator. It is essential for safe navigation that these charts show existing conditions with the highest possible fidelity. This can be accomplished only by the frequent revision of charts to cover the continual changes in topographic conditions and in the lights, buoys, radiobeacons, etc., maintained by the Federal Government as aids to navigation both on the sea and in the air.

Improvement in channels and waterways to meet the increasing demands of commerce required the issue of 110 revised editions of the nautical charts within the year. To meet further the requirements of marine commerce in those places where detailed surveys have re-

cently been made, 23 new charts on larger scales were compiled and issued as listed below.

MASSACHUSETTS: Westport River and approaches.
NEW JERSEY: Shark and Manasquan Rivers.
SOUTH CAROLINA:
- Charleston Harbor entrance.
- Parts of Coosaw and Broad Rivers.
- Longitude 78°58′ to McClellanville.
- McClellanville to Wadmalow River.

SOUTH CAROLINA and GEORGIA: Port Royal Sound to Johnson Creek.
GEORGIA: Johnson Creek to Brunswick River.
GEORGIA and FLORIDA: Brunswick River to Nassau Sound.
FLORIDA:
- Port Everglades.
- Nassau Sound to Matanzas Inlet.
- Matanzas Inlet to Mosquito Lagoon.
- Delray to Cape Florida.

LOUISIANA: Barataria Bay and approaches.
CALIFORNIA:
- San Clemente Island.
- Anacapa Passage.
- Santa Cruz Channel.
- San Miquel Passage, Cuyler Harbor.

ALASKA:
- Portland Canal, Dixon Entrance and Hattie Island.
- Etolin Island to Midway Islands.
- Midway Island to Cape Spencer, including Lynn Canal.
- Marmot Bay and Kupreanof Strait.
- Kodiak and St. Paul Harbors.

Orders for aeronautical charts to meet the needs of civil and military aviation have continued to increase greatly in consonance with the growth of the aviation industry. To maintain the accuracy of these charts in sections of the country where the establishment of new airways, airports, and other new construction has made important changes, there were printed 96 revised editions of 71 individual charts.

At the close of the year there were available 87 sectional aeronautical charts, covering the entire United States, and 4 of the regional series. The completion of the series of sectional charts enabled the military services to discontinue publication of aviation strip maps, thus eliminating overlapping and duplication.

The steady and substantial growth in the need for nautical and aeronautical charts and related publications is shown by the following table giving the distribution of these publications for the past 4 years.

Item	1937	1936	1935	1934
Nautical charts [1]	333,366	275,800	309,765	293,889
Aeronautical charts [1]	277,878	178,973	61,268	38,313
Strip maps	----------	12,186	9,210	11,304
Air planimetric maps	4,544	4,236	2,907	558
Miscellaneous maps	3,166	2,857	2,192	1,339
United States coast pilots	8,062	6,167	6,077	7,046
Intracoastal waterway pilots	1,463	1,022	943	1,027
Distances between United States ports	559	429	588	1,435
Tide tables	24,567	24,184	21,984	24,851
Current tables	9,114	9,002	7,588	7,652
Tidal current charts	1,628	1,607	1,705	701
Practical air navigation	1,837	5,167	----------	----------
Total	666,184	521,630	424,227	388,115

[1] Annual reports prior to 1936 did not include charts withdrawn from sale because of the issue of revised editions.

"Cartography," a manual outlining the principles of constructive cartography, was compiled and published early in the year. This met with unusually favorable comments from engineers, cartographers, and students of this branch of science in the development of human activities. A revision of the manual "Practical Air Navigation" is being made to meet the demand for a new edition of this publication. Printed for the benefit of aviators, this publication has been particularly successful in meeting the needs of a new group of chart users. The published supply has been exhausted and orders have continued to come in for additional copies.

HYDROGRAPHY AND TOPOGRAPHY

On the Atlantic coast, the vessels *Oceanographer*, *Lydonia*, *Gilbert*, and *Welker* completed surveys off the approaches to New York and continued work southward along the Delaware and New Jersey coasts. At the end of the fiscal year they were at work off the New Jersey coast extending the coastal surveys from the shore line out to approximately the 1,500-fathom contour.

The *Hydrographer*, with the tenders *Faris* and *Pratt*, completed hydrographic surveys eastward along the Gulf coast of Louisiana as far as the Delta of the Mississippi River, and in the spring of 1937 took up work in the vicinity of Galveston, Tex. These new basic hydrographic surveys extend from the coast line out to the edge of the coastal shelf, which, in this particular region of the Gulf of Mexico, lies about 100 miles offshore. These extensive shoal areas are being thoroughly surveyed and the work has been greatly speeded up by the use of the Dorsey Fathometer, which was mentioned in last year's report. With this fathometer, a vessel under way at full speed can obtain 20 soundings per second and the results provide a most satisfactory hydrographic survey with respect both to accuracy and economy.

The continued use of the taut-wire apparatus and sun azimuths for the fundamental control of hydrographic operations has strengthened all of these surveys of the Atlantic and Gulf coasts, and the work has been further facilitated by the satisfactory development of the sonoradio buoys mentioned in last year's report. These buoys are used in connection with the radioacoustic method of ascertaining the position of a ship engaged in offshore surveys. Anchored and accurately located, they receive the sound of a bomb exploded under water near the survey ship and transmit an instantaneous radio signal so that the survey ship, knowing the time required for the sound to reach the buoy and the velocity of sound through the water, can compute its distance from two or more buoys and thereby ascertain its position. These easily portable and entirely automatic units have given results beyond original expectations, distances up to 60 nautical miles having been obtained. Their use results in greater economy of operations and the elimination of hazards to the small vessels formerly used for this purpose.

As previously stated, construction of the nine-lens aerial camera designed by the Bureau was completed during the year and, after test flights in the vicinity of Dayton, Ohio, it was used successfully in the field for an airphotographic survey of the head of the Chesapeake Bay to secure data for a new chart made necessary by recent

improvements in the Chesapeake and Delaware Canal. This work was completed in 3 days, ending on May 2, 1937. During this period the shore line and other land features, as required for charting purposes, were photographed over an area of about 1,600 square miles. A number of the photographs were sent out for field inspection preparatory to the compilation of maps therefrom.

Small airphoto compilation units were continued in Connecticut, New Jersey, Maryland, Virginia, and Florida.

The *Mikawe* continued inshore topographic and hydrographic surveys in Florida, New Jersey, and Maryland.

A special wire-drag project was carried out to locate obstructions detrimental to the shrimp fishing industry in the vicinity of the Cape Fear River. More than 50 submerged snags, or other obstructions, were accurately located and subsequently marked by the Lighthouse Service.

A shore party continued basic topographic and hydrographic surveys of the Florida Keys eastward of Key West.

Work was continued in the Washington office on the compilation and assembly of accumulated triangulation data along the Atlantic and Gulf coasts. Index sketches, descriptions of stations, and positions are being prepared in temporary form for public use until it becomes possible for the Bureau to publish these data in permanent form. These valuable triangulation data are needed by many engineers within the Government service, as well as those in civil life, and the accessibility of the data to them is important. Until provision for funds is made to publish these data in permanent form, their reproduction in temporary form by lithography serves as a substitute.

On the Pacific coast hydrographic surveys were continued by the *Pioneer* and *Guide*. The *Pioneer* was engaged in surveys in the vicinity of the Santa Barbara Islands and the *Guide* conducted wire-drag and offshore surveys in the vicinity of Cape Mendocino. Numerous rocks, dangerous to shipping, are being discovered and charted by the use of the wire drag on this coast.

The *Explorer* completed basic surveys in the southern part of Puget Sound, and in the spring of 1937 took up work in Sumner Strait, Alaska, where she will make complete triangulation, topographic, and hydrographic surveys.

A shore party continued triangulation, topographic, and hydrographic surveys of the Columbia River, Oreg.

The *Surveyor* and *Discoverer*, with the tenders *Wildcat* and *Helianthus*, continued work on original surveys in the Aleutian Islands in the vicinity of and west of Unimak Pass. This work is difficult and hazardous, due to the severe weather conditions prevailing in the region, as well as the lack of previous surveys. Safe anchorages are scarce and the exposed coasts are forbidding and difficult to land upon. One party on Unimak Island is using horses for transportation while making the topographic and triangulation surveys of the Island. This will obviate landings on the exposed coasts from the survey vessels. The surveys which are being made are most important to insure the safety of vessels which may use the desirable westward route to the Orient through Unimak Pass, north of the Aleutian Islands, as well as to naval vessels and commercial interests

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in the Islands. The *Surveyor* and *Discoverer* also ran lines of soundings across the Gulf of Alaska to and from the working grounds.

The *Westdahl* completed triangulation in conjunction with the International Boundary Commission in the vicinity of Juneau, Alaska, and in the spring of 1937 took up work in the vicinity of Taku Inlet.

The 13 United States Coast Pilot volumes published by the Bureau contain a wide variety of important information supplemental to that shown on the charts, such as a description of the coast and information concerning waterways, as well as maritime data for all the ports of the United States and possessions. It is essential that these Pilots be kept up-to-date, and this is done by annual supplements and revisions based on field examinations. During the year 10 supplements were published and 4 Pilots were being revised for new editions.

Two field examinations were in progress, one of the Philippine Islands and the other of Puerto Rico and the Virgin Islands.

In the Philippine Islands, the *Fathomer* completed triangulation, topographic, and hydrographic surveys of the northeast coast of Luzon Island and at the beginning of the fiscal year 1938 was prepared to take up work on the west coast of Palawan Island.

On August, 15, 1936, the *Fathomer* was stranded in a typhoon in Port San Vicente, a small landlocked harbor on the northeastern extremity of the Island of Luzon. The severity of this storm can well be described by mentioning that the lighthouse and lightkeeper's dwelling on Cape Engano, in the vicinity of Port San Vicente, both concrete structures, which had withstood such typhoons for 50 years, were destroyed. The ship was salvaged and put in as good, if not better, seaworthy condition than prior to the accident, by the Insular Government from a typhoon fund which is maintained for this purpose. The lowest official barometer reading recorded in the Philippine Islands probably was taken on the *Fathomer* during the passing of the center of this storm. The reading was 26.96 inches (685 mm).

The *Pathfinder* remained in a decommissioned status at Manila.

Field stations were maintained at Boston, New York, New Orleans, San Francisco, Seattle, Honolulu, Territory of Hawaii, and Manila, P. I. The station at Manila supervises all field surveys in the Philippine Islands and compiles and prints the charts of the archipelago. All stations continued to render invaluable service; to the Bureau, through the supply of data for the correction of the charts of their vicinities, and to the public by the dissemination of information resulting from the Bureau's work.

Hydrography, topography, and coastal triangulation

Locality	Hydrography			Topography		Coastal triangulation		
	Sounding lines	Area	Soundings	Shoreline	Area	Length of scheme	Area	Geographic positions
	Miles	*Square miles*	*Number*	*Miles*	*Square miles*	*Miles*	*Square miles*	*Number*
Approaches to New York Harbor, New York and New Jersey coasts	13,441	6,774	124,051					
North Shore Long Island Sound, Connecticut				96.0	57.3			
Vicinity of New York City, New York, and New Jersey				195.0	57.8			
Inland Waterway, Barnegat to Cape May, N. J	2,850	92	115,392	374.0	175.0			
Vicinity of Norfolk, Va., and N. C				65.7	93.7			
Entrance to Cape Fear River, N. C		37						
St. Johns River, Fla	1,154	85	36,163	548.0	18.0			1
Florida Keys, Fla	1,355	116	50,458	709.4	313.5	5	40	7
Coast of the Gulf of Mexico, Louisiana and Texas	12,989	7,389	126,885	31.0	11.0	17	136	17
Vicinity of the Santa Barbara Islands, Calif	9,069	11,616	45,189	11.0	5.0			3
Vicinity of Cape Mendocino, Calif	1,504	475	22,724	19.4	7.5			
Columbia River, Oreg., and Wash	1,275	61	43,785	153.0	8.0	21	38	157
Puget Sound, Wash	1,041	32	43,861	194.8	82.9	36	15	97
Southeastern Alaska	953	48	31,742	131.3	117.0	67	313	84
Aleutian Islands, Alaska	11,894	3,888	121,035	402.9	718.0	308	2,705	236
Philippine Islands	5,587	3,755	105,412	129.4	191.0	57	151	51
Total	63,112	34,368	866,697	3,060.9	1,855.7	511	3,398	653

GEODESY

The geodetic work of the Bureau consists of triangulation, leveling, gravity, and related measurements in the field, and the computation, adjustment, and compilation of the results of these measurements in the office.

The triangulation and leveling stations provide basic starting points for all mapping and for many other kinds of surveying operations. They are used in the delineation of State, county, city, and international boundary lines; in alinement and profile surveys of railroads and highways; in the location of drainage and irrigation canals; and in practically all engineering operations where extensive works must be coordinated in both geographic position and elevation. The perpetuation of these stations is assured, since they can be definitely reestablished, if destroyed, from undisturbed triangular stations, even though the latter may be some distance away.

During the year, 2,211 miles of first- and second-order triangulation and 2,770 miles of first- and second-order leveling were completed, the work being done in 19 States.

One gravity party was in continuous operation establishing stations in Alabama, Arizona, Louisiana, New Mexico, Oklahoma, Rhode Island, Texas, and Virginia. Old stations in Louisiana, Oklahoma, and Texas were reoccupied to test the coordination of the work of several different seasons.

The variations of latitude observations at Ukiah, Calif., and Gaithersburg, Md., were continued throughout the year with satisfactory results. The records have been forwarded directly to the central office of the International Latitude Service. Cooperation with other agencies in the extension of control surveys is covered elsewhere in this report.

While the situation regarding horizontal and vertical control surveys was greatly improved through the use of emergency funds from 1932 to 1935, there is still a large amount of work required to provide the basic data for any future mapping program. That the adoption of such a program is imminent seems certain if we are to judge either from the standpoint of national economy or from the practices of countries whose experiences with mapping are much longer than our own. Practically all of the countries of Europe have been accurately mapped, and Great Britain and Switzerland are now remapping their countries in greater detail than ever before.

It is particularly important that the data resulting from the computation and adjustment of control surveys be available for distribution immediately upon the adoption of any mapping program in order that delays and inefficient operation may be avoided. The present demands for these data are a convincing proof of their value even in their present state of incompletion. A tabulation of requests for information over a period of 2 months from May 7 to July 7, 1937, showed the receipt of 670 requests for geodetic data, of which 380 could not be fully supplied on account of noncompletion of field or office work.

Geodetic triangulation, base lines, reconnaissance, and leveling, and astronomical and gravity observations

Locality	Length of scheme	Area
TRIANGULATION, FIRST ORDER		
	Miles	*Square miles*
Colville and Spokane Indian Reservations, Wash	100	4,000
Pine Ridge and Rosebud Indian Reservations, S. Dak	390	6,400
Fort Hall Indian Reservation, Idaho	60	1,800
Uintah-Ouray Indian Reservation, Utah	130	4,550
Upper Rio Grande, Colo	90	2,850
Southern Ute Indian Reservation, Colo	160	4,445
San Juan River, Utah	120	4,800
Little Colorado River, Ariz. and N. Mex	220	10,600
Lower Rio Grande, N. Mex. and Tex	200	6,350
Yarmouth base net, Mass	4	12
Wellfleet base net, Mass	5	15
Newbury base net, Mass	1	6
Bohlen-West Hills Connection, N. Y	2	14
Northern New Jersey	32	320
Collinsville, Conn., to Providence, R. I	82	987
Total	1,596	47,149
TRIANGULATION, SECOND ORDER		
Shoshone Indian Reservation, Wyo	75	5,250
Orlando to Okeechobee, Fla	140	1,400
York to Lee, Fla	150	1,500
Shady to Lily, Fla	160	1,600
Northern Idaho	90	1,800
Total	615	11,550
BASE LINES, FIRST ORDER		
Yarmouth, Mass	2.2	--------
Wellfleet, Mass	2.7	--------
Newbury, Mass	4.8	--------
Matecumbe, Fla	3.5	--------
Total	13.2	--------

Locality	Length of scheme	Area
RECONNAISSANCE, FIRST ORDER TRIANGULATION		
	Miles	*Square miles*
Colville and Spokane Indian Reservations, Wash	100	4,000
Pine Ridge and Rosebud Indian Reservations, S. Dak	390	6,400
Fort Hall Indian Reservation, Idaho	60	1,800
Uintah-Ouray Indian Reservation, Utah	130	4,550
Upper Rio Grande, Colo	90	2,850
Southern Ute Indian Reservation, Colo	160	4,445
San Juan River, Utah	120	4,800
Little Colorado River, Ariz. and N. Mex	220	10,600
Lower Rio Grande, N. Mex. and Tex	200	6,350
Yarmouth base net, Mass	4	12
Wellfleet base net, Mass	5	15
Newbury base net, Mass	1	6
Bohlen-West Hills Connection, N. Y	2	14
Connecticut-Rhode Island boundary	45	360
Total	1,527	46,202
RECONNAISSANCE, SECOND ORDER TRIANGULATION		
Shoshone Indian Reservation, Wyo	75	5,250
Lake Wales to Melbourne, Fla	45	450
Abilene to Benjamin, Tex	80	960
Hollis to Duncan, Okla	120	1,800
Iowa Park to Breckenridge, Tex	115	1,610
Cross City to La Crosse, Fla	40	400
Northern Idaho	90	1,800
Crystal City to Menard, Tex	155	1,550
Eastland to San Saba, Tex	105	1,575
San Saba to San Antonio, Tex	85	2,125
San Antonio to San Diego, Tex	140	1,680
Osage to Decatur, Tex	160	2,080
Decatur, Tex., to Norman, Okla	135	1,960
Norman, Okla., to Caldwell, Kans	160	2,080
Caldwell to Salina, Kans	130	1,950
Okeechobee to Fort Myers, Fla	70	490
Total	1,705	27,760

State	First order	Second order	State	First order	Second order
LEVELING	*Miles*	*Miles*	LEVELING—continued	*Miles*	*Miles*
California	90	120	Ohio		254
Georgia	67	23	Oregon	330	257
Idaho	26	173	Pennsylvania		191
Indiana	5	46	Tennessee		40
Maine		74	Vermont		78
Montana	29		Virginia		43
Nevada		131	Washington	146	210
New Hampshire		47	West Virginia		6
New Jersey		63			
New York	76	117	Total	769	2,001
North Carolina		128			

State	Number of determinations		State	Number of determinations	
	New	Redeterminations		New	Redeterminations
GRAVITY			GRAVITY—continued		
Alabama	21	1	Pennsylvania	1	
Arizona	4		Oklahoma		2
Louisiana	6	2	Rhode Island	2	
Massachusetts	1		Texas	22	12
Mississippi		1	Virginia	16	1
New Mexico	9				
New York	1		Total	83	19

The office computation and adjustment of 42 arcs of first-order and 33 arcs of second-order triangulation were completed during the year, and the computation of 25 arcs of first-order and 15 arcs of second-order triangulation were in progress. Office computations were also made of 5 first-order and 7 second-order bases. A field party in New York City was engaged on triangulation, leveling, and plane-coordinate computations during the last 7 months of the year.

Personnel detailed to the Washington office by the Chief of Engineers, United States Army, were engaged in the adjustment of the triangulation along the Mississippi River from Vicksburg, Miss., to New Orleans, La. The manuscript for the publication containing the results of this adjustment was also being prepared.

Two large level adjustments were made during the year. One of these was the readjustment of the leveling in southeastern Texas, which was made necessary as a result of new leveling and a change in the tidal datum. The other was a readjustment in the southeastern part of the United States, where several errors in old lines had been detected. Several small adjustments of second-order leveling were also completed.

The office computations and isostatic reductions were made of 97 gravity stations in various States which were determined by this Bureau, and the isostatic reductions were made of 48 stations in Pennsylvania, the data for which were furnished by the Gulf Research & Development Co., and of 56 gravity-at-sea stations in the West Indies. In addition, the isostatic reductions for 31 old gravity stations in the United States were revised because of the availability of improved maps.

Two geodetic publications were printed during the year, one an international report on geodetic work done in this country over the 3-year period, 1933–35, and the other a revised manual for the use

of lightkeepers on triangulation. Three other publications were in press at the end of the year, two of which are State publications giving the results of triangulation in Utah and Wyoming, and the third a State publication on the leveling in North Carolina.

The report for 1935 mentioned the systems of plane coordinates which have been devised for all the States. These have now been in use for a sufficient period to demonstrate their practical value and adaptability to the general problems of surveying and mapping. The purpose of the coordinate systems is to form a practical method of referencing all local surveys to a uniform system which is also connected to the Federal net of horizontal control, and thus be available for future use. Another purpose is to have a system suitable for small local areas which is simple for the average engineer to apply and does not involve the more difficult computations of geodetic coordinates.

These systems of plane coordinates have each been made to cover as large an area as possible consistent with political subdivisions and the problem of obtaining scale accuracies practically within 1 part in 10,000 for the entire United States. In some States, like New Jersey, a single coordinate system is sufficient, while in California six different zones are required. The number of zones naturally depends on the shape and size of each individual State.

New Jersey and Pennsylvania have enacted legislation which makes the plane coordinate systems for each of those States legal for referencing land surveys. The Federal Board of Surveys and Maps, after considering the coordinate systems for a period of about a year, decided to recommend them to all surveying and mapping agencies throughout the country. The adoption of these systems will ultimately result in a tremendous saving to the Government, as all future surveys properly referenced thereto will be good for reuse as long as their monuments exist.

TIDES AND CURRENTS

The rise and fall of the tide plays an important role in the development and complex activities of our water-borne commerce, affecting as it does the hydrographic planes of reference for charts, the location and design of piers, bridges, and factories, and the schedules of deep-draft ships. The tidal data essential for these various activities are derived from tide observations.

During the year continuous tide observations were obtained from 38 primary and 29 secondary tide stations, distributed as follows: 26 on the Atlantic coast, 11 on the Gulf coast, 25 on the Pacific coast, 4 in Alaska, and 1 in the Hawaiian Islands. Of these stations, 31 were conducted in cooperation with other organizations: United States Engineers, 12 stations; Navy Department, 7 stations; State of Delaware, 3 stations; and 1 station each with the Department of Agriculture, State of Texas, Woods Hole Oceanographic Institute, town of Stratford, Conn., Los Angeles Harbor Department, city of Santa Monica, Port of Oakland, Port of Willapa Bay, and the University of Washington.

Supplemental data covering shorter periods of observations were obtained in connection with hydrographic surveys and other activities for some 125 other places.

The commercial value of water-front property makes the accurate determination of local datum planes and their relation to sea level datum of prime importance in the determination of boundaries. To supply such information, the Bureau is undertaking comprehensive tide surveys of coastal sections. On the Pacific coast, a survey of San Francisco Bay, started in June 1936, was continued during the year to determine with precision the tidal datum planes at various points and develop whether any changes in the tidal regime may have taken place in consequence of changes in hydrographic features at various points in the bay.

Accompanying the rise and fall of the tide is a horizontal movement of the water known as the tidal current. This ebb and flow affects the speed and direction of a ship and controls the circulation of the tidal water throughout our bays and harbors. A knowledge of the current is consequently of practical importance to both navigation and harbor engineering.

Information derived from the tide and current investigations by the Bureau are made available to the public in tide and current tables and miscellaneous publications.

Advance information regarding the stage of the tide is covered in the tide tables issued annually in two volumes. The Tide Tables, Atlantic Ocean, 1938, contain daily predictions for 49 reference stations and differences for obtaining predictions for about 2,400 other places. Revised data for the New Jersey coast and for the Florida Keys were incorporated in these tables. The Tide Tables, Pacific Ocean and Indian Ocean, 1938, contain daily predictions for 49 reference stations including 2 new Alaskan stations, Cordova and Dutch Harbor, and data for obtaining predictions at some 1,800 other places. Considerable new and revised data for Puget Sound and the North Pacific Islands were entered in this edition.

To supply the mariner with advance information relative to the velocity and direction of the current likely to be encountered at any time, two current tables are issued annually. The Current Tables, Atlantic Coast, 1938, contain daily predictions for 18 reference stations and differences for obtaining predictions for about 900 other stations. The Current Tables, Pacific Coast, 1938, contain daily predictions for 11 reference stations and current differences for some 500 other stations.

The description of tidal bench marks and their elevation above the principal tidal datums are being made available to engineers through a series of publications covering the various coastal States. During the year, publications were issued for the States of South Carolina, Georgia, New York, and Louisiana, and those for Florida and New Jersey are in preparation.

A special publication was issued giving in detail the results of current surveys in Narragansett and Buzzards Bays, and Nantucket and Vineyard Sounds.

TERRESTRIAL MAGNETISM

The inadequate contribution during the year to the magnetic survey of the United States, particularly with regard to the occupation of stations to determine the secular change, is cause for concern, since the usual 5-year map due in 1940 cannot be prepared without consid-

erable increase in this type of field work. The magnetic data furnished for the preparation of nautical and aeronautical charts are in danger of becoming less and less reliable with lapse of time. There can be no substitute for a systematic annual survey, which is not possible under present conditions with the funds available. In addition, a strong demand has developed for more accurate and more frequent determinations of vertical intensity to meet the needs of local magnetic surveys for geological investigations.

In order that the results of observations of the earth's changing magnetism may be made available for safe and satisfactory use by the mariner, aviator, land surveyor, geophysical prospector, and the investigator of terrestrial magnetism itself, it is essential to keep track of the changes so that observations at all stations, old or new, may be brought up to date. The completion of work of this type during the year has been below a proper minimum and has included only a portion of the central and southwestern parts of the United States. Determinations of magnetic declination (sufficiently accurate for all purposes except secular change reductions) have been made by various field parties of the Bureau, by State Geodetic Surveys, and by others.

Observations have been continued at all five of the magnetic observatories of the Bureau, forming in every case a continuous series with preceding records. Such observations were started at Cheltenham, Md., in 1901; at San Juan, P. R., in 1926; at Tucson Ariz., in 1909; at Honolulu, Territory of Hawaii, in 1902; and at Sitka, Alaska, in 1902. The value of the past year's work to science and industry is related directly to the length of the span of years over which similar records have been obtained.

The Cheltenham Observatory is beginning to assume an important place in regard to magnetic standardization because of its almost continuous use for this and related purposes by the Bureau and by the Department of Terrestrial Magnetism of the Carnegie Institution of Washington.

The never-ending demand for magnetic information has been met through correspondence, by publications, by furnishing original or photostatic copies of records, and by broadcasts of magnetic information originating within the Bureau.

Distribution of magnetic observations during the year is shown by the following table:

Place	Stations				Place	Stations			
	Repeat		Declinations	Total		Repeat		Declinations	Total
	Old	New				Old	New		
Alaska			17	17	Oklahoma		1		1
Arizona			6	6	Oregon			3	3
California	2	1	27	30	Texas	1	1	11	13
Florida			33	33	Virginia			1	1
Kansas	1			1	Washington			8	8
Louisiana	1	1		2	Pacific Ocean			143	143
Missouri		1		1					
Nevada	1			1	Total	6	5	251	262
New Mexico			2	2					

SEISMOLOGY

The seismological work of the Bureau properly deals with furnishing data needed for the solution of practical problems. Earthquakes are located and described by collecting and analyzing noninstrumental and instrumental reports from many sources. Instruments are maintained in readiness to obtain records of destructive earthquake motions which are needed in connection with the design of earthquake resistant structures. For the same reason the natural vibration periods of buildings and other structures and of the ground have been determined, and ground-tilt measured. Measurement of crustal changes by geodetic methods is described elsewhere in this report.

The instrumental data for locating earthquakes are obtained from a number of seismological observatories, of which the Bureau operates four directly—San Juan, P. R.; Tucson, Ariz.; Sitka, Alaska; and Ukiah, Calif. (at the International Latitude Station)—and six with more or less cooperation at Columbia, S. C.; Chicago, Ill.; Bozeman and Butte, Mont.; Honolulu, Hawaii; and College, near Fairbanks, Alaska. A number of independent stations also make their records available. Many of these records are furnished to various organizations for special studies.

Immediate interpretations of the instrumental records are furnished by many stations so that epicenters are located immediately for all important earthquakes. Cooperation of the Jesuit Seismological Association and Science Service makes this possible. This preliminary information is of interest to the public and useful to the individual stations.

Information regarding earthquakes and related matters appears in form of bulletins and in the annual series of publications entitled "United States Earthquakes."

Recording of strong earth motions continued in California, Montana, and Panama, and new stations were established in Nevada. Fifty instruments were operated in California, four in Nevada, four in Montana, and one in Panama. One instrument is held in reserve at Washington, D. C., and one at Chicago. Tests of the accelerographs were made on a shaking platform at the Massachusetts Institute of Technology to determine the fidelity with which earth motions are recorded. Several records were completely analyzed, and progress was made on a mechanical method of analysis.

Twenty-six sets of vibration observations were made on bridges in 16 locations; there were 7 tests in 5 buildings without a shaking machine, and 21 tests in 15 buildings with such a machine; 4 vibration tests at Boulder Dam, and 27 ground tests using artificial methods to set the ground into vibration. Observations of the last-named types were made for the Veterans' Administration in California in connection with hospital facilities.

Four tilt-meters continued in operation with the cooperation of the University of California.

Intensive questionnaire coverage was obtained in the case of 10 earthquakes, and 70 pictures of earthquake effects were taken. More than 1,200 noninstrumental reports on earthquakes were received covering approximately 150 earthquakes.

Special Publication No. 201 describing all phases of the strong-motion work was issued.

An officer of the Bureau attended the meeting of the International Geodetic and Geophysical Union at Edinburgh, Scotland. Coordination of methods and international prosecution of work was advanced in terrestrial magnetism and seismology.

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