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[Reprinted from the Annual Report of the Secretary of Commerce, 1934]

COAST AND GEODETIC SURVEY

REVIEW OF THE YEAR

The fiscal year 1934 has been one of unprecedented activity for the Coast and Geodetic Survey. The uniform, moderate programs of work, which are the ideal for an agency charged with the gradual performance of large tasks, were drastically disturbed by the depression. Curtailments of normal activities were accompanied by assignments of large special projects under the Government's emergency programs, with the net result that the volume of Bureau activity has far exceeded that of any previous year of its history.

The Bureau's regular appropriation for 1932, which may be regarded as normal, was $3,075,933. That for 1934 was $2,205,090, a reduction of 28 percent. At various times during the year the Bureau received Public Works allotments totaling $6,503,120 for a series of projects of field work, the first of which began in the fall of 1933 and all of which will terminate in the spring or early summer of 1935; in other words, substantially a 1½-year program of field work divided about equally between the 2 fiscal years. In addition, during the winter the Survey carried on a Civil Works Administration program of local control surveys on which, at the peak, 10,288 persons were employed, being paid directly by that Administration.

In short, when the program was at its height last winter, the Survey, which normally spends about $3,000,000 a year and employs some 1,300 persons, was spending at the rate of over $20,000,000 a year and employing some 12,000 temporary persons additional to its regular permanent force.

These concurrent reductions and expansions of the work necessarily overlapped. To illustrate, in the function of providing adequate charts for the mariner, some operations were largely curtailed, while others were even more largely expanded. These apparent contradictions would mislead anyone who did not realize the principle on which they were based. Since a major purpose of the Public Works money allotted to the Bureau was to relieve unemployment, its application was limited to projects which would afford a maximum of such relief. The goal which was voluntarily set for the Bureau was that approximately 70 percent of the money spent should be paid out directly as wages.

Operations which could not make this contribution to the relief of unemployment were curtailed. Of these, the principal ones were those carried on by the Bureau's sea-going ships. One ship was laid up throughout the year, and the working seasons of others were shortened. During the periods of operation, the personnel of all ships was supplemented by employment of men paid from Public Works funds.

National Oceanic and Atmospheric Administration

Annual Report of the Superintendent of the Coast Survey

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THE PUBLIC WORKS PROGRAM

Detailed report on the Public Works projects must await their completion, but a brief preliminary report at this time is appropriate.

The sum of $3,210,148 of Public Works money was spent during 1934. This expenditure contributed to the following extent in relieving the depression:

1. Jobs were given to 3,125 different persons in need of relief. This number includes some turn-over, of which, however, there has been very little. Full-time employment has been running at the rate of 2,300 to 2,500 persons per month.

2. The men employed were largely of the white-collar class, for whom the problem of relief has been a particularly difficult one. Twenty-nine percent of the total were graduate engineers, and 59 percent were men of college training. Only a small percentage of these men were employed on professional work. A great majority of them were used in the various subprofessional capacities of surveying work, such as rodmen, chainmen, and truck drivers. Thus the personnel of the surveying parties has been of exceptionally high caliber. In addition, they were grateful for the relief and enthusiastic about the work. The practical result of these factors is that in spite of the emergency character of the program, worth-while projects are being carried on at substantially the same unit costs as those which prevail in our similar normal operations.

3. The pay is moderate, ranging from $85 a month for hands to $150 a month for an engineer operating an instrument and in charge of a unit of the work under direct supervision. The basis on which the pay scale was fixed was to give the men a decent wage, yet one sufficiently modest so that each man always would have an incentive to get off the Federal pay roll as quickly as possible.

4. The work was widely distributed over the rural districts of each State. The operating expenses of the parties, which constituted about 12 percent of their total cost, and the subsistence expenses which the men paid out of their own salaries, were spent locally in the small communities and contributed materially to relieving local stagnation.

In return for these expenditures, the public will receive the following permanent benefits:

1. A survey of the intracoastal waterway, extending along the Atlantic and Gulf coasts and of all commercially important tributaries thereto. The Federal Government is spending many millions of dollars to improve the natural waterways of these regions; and when the project, which is now approaching completion, is finished, small craft will be able to go all the way from New York to Key West, and from Apalachicola, Fla., to Corpus Christi, Tex., without having to enter unsheltered ocean waters. Charts to guide mariners through these waterways are essential to their effective use, and slightly less than half of the Public Works money is being devoted to field surveys required for the production of such charts.

2. A little less than half the money is being used to expedite progress on the program of control surveys (triangulation and leveling), which the Bureau has been carrying on at an inadequate rate for many years. These surveys are essential to the mapping of the coun-

try and to every extension of engineering projects requiring accurate knowledge of the horizontal and vertical relationships between points on the earth's surface. They are to such engineering operations what the steel framework is to a large building—they give form and strength and rigidity to the whole structure. The national demand for work of this character recently has been unusually large, and it is in response to such demand that the work is being expedited.

3. A small sum is being devoted to studies of earth movements at the central regions of an earthquake and to the response of buildings, bridges, dams, and similar structures to such movements. This undertaking is a part of a larger non-Federal effort to safeguard life and property by learning how to design such structures so that they will resist the earthquake stresses.

4. Tidal and current surveys were made in a number of important waterways where the resulting data were urgently needed by mariners and engineers.

5. Survey ships and observatories have been reconditioned.

6. The Survey is a firm believer in the principle of constantly striving to develop new instruments and equipment whereby better results can be obtained at reduced costs. Its goal has been to maintain close and constant contact with progress in science and its applications, and to appropriate for its own use any detail which can be utilized to advantage for this purpose. The unemployment situation enabled it to secure the services of half a dozen men, each a specialist along some particular line, and through those services to develop certain instruments and equipment whose subsequent use will save the Government hundreds of thousands of dollars. The need for brevity denies to these achievements the space which their importance merits. There may be mentioned, however, the shoal-water fathometer, the precision photolithographic camera, the 9-lens aerial camera and accompanying rectifying and other equipment, and a machine for drawing projections.

Finally, it is important to note that all field work was devoted to projects with which the Bureau is charged by law and has been carrying on under the regular annual appropriations. Use of the Public Works money for such purposes means that equivalent amounts need not be included in the regular appropriations hereafter made.

CIVIL WORKS PROJECT

Late in the fall, the Civil Works Administration asked the Coast and Geodetic Survey to undertake a program of local control surveys, supplemental to the regular Federal project. It asked that 15,000 men be taken on for this project, as a part of its program to provide winter work for 4,000,000 persons.

The Bureau was reluctant to undertake such a project, because it had a lively appreciation of the impossibility of getting results at low unit costs. Finally persuaded, however, that the emergency justified inefficiencies which it would not normally have sanctioned, it undertook the project.

Within little more than a month after the final word came to go ahead, some 10,000 men had been recruited, organized into units of 7 to 10 men each, equipped with borrowed or rented instruments,

supplied with transportation procured on the same basis, trained, and set to work.

This was no small achievement. The principal credit for it belongs to the 48 men whom the Survey carefully selected, one for each State, and asked, as a contribution to the welfare of less fortunate members of their professions, to organize and direct the work in his State. While lack of space precludes a detailed report on the project, no report on the Bureau's work for the year would be complete without a tribute of appreciation to these men who, faced with unusual difficulties, gave unsparingly of themselves, at only nominal compensation, to make the projects successful. Without exception, they did remarkably well.

SUMMARY OF ACTIVITIES

A fleet of 12 surveying vessels carried on hydrographic work during the year—the *Gilbert*, *Hydrographer*, *Lydonia*, *Mikawe*, *Natoma*, and *Oceanographer* on the Atlantic coast, and the *Discoverer*, *Explorer*, *Guide*, *Pioneer*, *Surveyor*, and *Westdahl* on the Pacific and Alaskan coasts. Ninety-three smaller craft, mostly leased for temporary use, also were used by these vessels and by a large number of parties engaged in coastal surveys and operating from bases on shore.

Surveys in the Philippine Islands were continued by one ship, the *Fathomer*, provided by the insular government. The *Pathfinder* formerly operated by the Federal Government in the islands was laid up during the year for lack of funds.

Some thirty-two major parties (with a number of subparties) were engaged in most States in geodetic triangulation, base-line measurements, reconnaissance for triangulation, and gravity and astronomic observations.

Details of these activities and of the Bureau's tide, current, magnetic, and seismologic work are given elsewhere in this report.

Field stations were maintained at Boston, New York, New Orleans, San Francisco, Seattle, Honolulu, and Manila; handling these areas in supervisory matters, furnishing direct information as to charting needs, and supplying the public with nautical information. Operations in the Philippine Islands were supervised by the Manila station.

The Washington office of the Bureau received from these many sources of supply a large amount of basic field data which were subjected to the various processes, including the compilation and printing of nautical charts and airway maps, required to make the information obtained available for public use.

There were received in the library and archives, 213 hydrographic and 228 topographic sheets, each representing new Bureau surveys. Other additions were 1,112 blueprints (mostly surveys by Army engineers), 2,410 maps, 2,141 charts, 14,613 field, office, and observatory records, 198 negatives, 404 prints, 118 lantern slides, 1,064 books, and 4,303 periodicals.

The files contain many early maps, compiled sketches, and charts not made by this Service. With the use of recovery funds, they are being thoroughly repaired by a map researcher, to make them more readily usable.

A total of 2,691 employees was serving the Bureau on June 30, 1934, shown in the table following, compared with 2,024 in 1933 and 1,422 in 1932:

Staffs	Commissioned	Civilian				Staff totals		Total
		Classified	Unclassified			Washington	Field	
			Laborers	Seamen	Hands			
Regular appropriations:								
Washington office	14	236	4			254		254
Field service	157	73		[1] 620	[1] 62		912	912
Total	171	309	4	620	62	254	912	1,166
Public Works funds:								
Washington office		214				214		214
Field service		138			1,173		1,311	1,311
Total		352			1,173	214	1,311	1,525
Grand total	171	661	4	620	1,235	468	2,223	2,691

[1] Includes 40 civilian employees on duty at the Manila field station and 50 members of the crew of the hip *Fathomer*, paid by the insular government but under the jurisdiction of this Bureau.

The regular annual appropriations for the year, totaling $2,205,090, were supplemented by an allotment of $35,000 from "Air Navigation Facilities, 1934", and $6,503,120 from the appropriation "National Industrial Recovery, 1933–35", making available a sum totaling $8,743,210.

Expenditures during the year ended June 30, 1934, totaled $4,588,394.42, distributed among the various appropriations as follows:

Salaries, 1933	$21.25
Party expenses, 1933	23,071.40
General expenses, 1933	1,450.97
Party expenses, 1933, emergency construction	223,414.62
Pay and allowances, commissioned officers, 1933	51,128.09
Pay, officers and men, vessels, 1933	13,042.85
Repairs of vessels, 1933	2,647.57
Air navigation facilities, 1933	899.93
Salaries, 1934	460,710.88
Party expenses, 1934	299,561.16
General expenses, 1934	19,980.21
Pay and allowances, commissioned officers, 1934	522,890.87
Pay, officers and men, vessels, 1934	368,734.82
Repairs of vessels, 1934	50,697.32
Air navigation facilities	29,376.15
Topographic survey of United States, contributions	141.49
Working fund, Department of Commerce	243.59
Chicago World's Fair Centennial Celebration	614.51
Second polar year program (State transfer to Commerce Department), 1932–34	6,274.44
National Industrial Recovery, 1933–35	[1] 2,512,687.21
Special deposits	805.09
Total	[1] 4,588,394.42

[1] This sum will be increased by outstanding vouchers, covering expenditures by field parties and others, not yet received in the office for settlement.

Collections on account of the sale of nautical charts and other publications, deposited in the Treasury Department to the account of miscellaneous receipts, totaled $72,621.50, as compared with $51,269.48 during the preceding year, an increase of nearly 42 percent.

The following report shows the amount of work done in connection with certain activities during the present and 1933 fiscal years, compared with that of the previous 4 fiscal years.

Year groups	Hydrography	Topography	Triangulation			Reconnaissance	Leveling		Gravity observations
			First order	Second order	Coastal		First order	Second order	
	Soundings	*Miles of shore line*	*Miles*	*Miles*	*Miles*	*Miles*	*Miles*	*Miles*	*Number*
1929	846,517	1,726	1,200	85	878	2,155	1,290	--------	13
1930	780,049	2,273	1,430	--------	863	885	727	--------	7
1931	782,044	2,472	2,895	--------	812	2,720	5,737	156	--------
1932	767,322	1,959	3,400	--------	803	5,950	5,945	1,555	35
Total	3,175,932	8,430	8,925	85	3,356	11,710	13,699	1,711	55
1933	1,387,027	4,407	3,625	--------	2,476	4,350	11,324	2,940	148
1934	2,520,406	14,877	7,440	1,080	1,969	8,810	16,153	28,670	118
Total	3,907,433	19,284	11,065	1,080	4,445	13,160	27,477	31,610	266

DEVELOPMENT OF METHODS AND INSTRUMENTS

A brief comparison of the results of old and modern methods of deep-sea hydrography is indicative of the degree of recent advances in hydrographic surveying for chart construction.

A sounding in 20,000 feet of water with wire required about an hour, during which the vessel had to be stopped. This same sounding today is made in a little over 8 seconds by means of an echo-sounding apparatus, with the vessel at full speed. By old methods the vessel's position was approximated by dead reckoning, while today it is determined accurately by radio-acoustic ranging.

By the modern method a bomb composed of a small quantity of TNT, timed to explode when it has sunk about 100 feet, is dropped overboard where it is desired to obtain the ship's position. A chronograph on the survey vessel receives electrically from its hydrophone, and records graphically, the impulse from the explosion. The subaqueous sound wave also travels at known velocity to hydrophones at two or more suitably located stations near the shore, where the vibrations set up cause an electrical impulse to travel through amplifiers to a thyratron in a temporary radio station on shore. The actuation of the thyratron at each shore station causes the radio transmitter automatically to send out a signal at the exact instant of the arrival of the sound wave, the radio signals from which are received by the survey vessel's radio receiver and transmitted to the chronograph, where the time of receipt of each is graphically recorded on the same tape which timed the explosion's impulse. Since radio transmission may be considered instantaneous for these distances, the elapsed times indicated on the tape are those required for the sound wave to travel by the water from the ship

to each shore station. These time intervals can be measured from the chronograph tape to one one-hundredth of a second, from which the distances from the shore stations are then computed and the position of the survey ship readily and accurately determined. On one occasion the sound wave from an explosion carried through a distance of 206 miles, and distances of 75 to 100 miles are not uncommon.

In connection with experimental work on the velocity and the path of sound in sea water for use in radio acoustic ranging, developed by this Bureau on offshore hydrographic surveying, the personnel on the ship *Pioneer*, off the coast of southern California, developed a deep-sea hydrophone which was used successfully to a depth of 5,100 feet. This instrument is unique in design, in that it can withstand the enormous pressure at any great depth, although built with a keenly sensitive diaphragm.

The fathometer is based on the precise measurement of the elapsed time required for a sound made on the vessel to go to the bottom and return as an echo, and while of inestimable value in hydrographic surveying from about 15 fathoms to abysmal ocean depths, it is not adapted to shoal-water surveys.

During the past year a new type of fathometer was developed for sounding by echo in depths from a few feet to 20 fathoms. Since the velocity of sound in sea water is about 4,800 feet per second, some idea may be had of the almost unbelievable accuracy of the time element in this newly developed instrument, which must measure the elapsed time for the sound to travel, for example, a depth of 3 feet to the bottom and return, a total distance of but 6 feet, requiring only 0.0012 of a second for the round trip. As the instrument is designed to measure this depth within one-tenth of a foot, its accuracy of measurement of this elapsed time must be within 0.00004 of a second.

When sounding in depths of 5 fathoms with the hand lead, it is possible for the sounding boat to travel at a speed of about 4 miles per hour and to get one sounding every 20 seconds, or every 135 feet over the bottom. With the shallow-water fathometer it will be possible to travel at a speed of at least 12 miles per hour and to get 400 soundings every 20 seconds, or every 12 inches over the bottom, furnishing a most complete profile of the bottom.

The Instrument Division was required to procure and recondition larger quantities of equipment, much of a special nature, and furnish instruments as needed, so that field work could be taken up as promptly as parties were organized.

Experiments continued with the production of more satisfactory material for theodolite precision-graduated circles; in lessening the cost of constructing precision level rods; in reducing the cost of containers and shipping charges on station marks, now used by the hundreds of thousands; in the apparatus for obtaining subsurface samples of sea water, making it more positive and prompt in action; in the timepiece of the portable tide gage, by eliminating lost motion; and in connection with the development of equipment for seismological studies, especially the strong-motion apparatus, of value to engineers and architects.

Topography by aerial phototopographic ethods is now being done with 5-lens cameras. With recovery funds, designs have been prepared for a 9-lens camera for this work, bids for the construction of which were sent to manufacturers. Instead of separate films for each lens as now required for the 5-lens camera and the resulting 5 photographs for each exposure assembled, fitted, and mounted, the proposed 9-lens camera is designed for the rays of light at exposure from all 9 lenses projected to a single film, resulting in one 35 by 35 inch photograph. At a flight height of about 13,750 feet, for a scale of 1 to 20,000, this single photograph covers a flight strip 11 miles wide, reducing to one-third the number of photographs now necessary. From present estimates, it will decrease the cost of control by about 50 percent and the total cost of phototopographic mapping by about 40 percent.

With a new camera the Bureau's original topographic and hydrographic surveys are now copied to exact scale. As a result of this accuracy, field surveyors check measurements of the data shown and revise directly on them changes since the previous survey, eliminating considerable duplication of surveys formerly needed to determine exactly what changes have occurred between surveys of different dates. Other processes are also simplified. An auxiliary copyboard and a reversing mirror in connection with the camera lens furnish reverse copies, valuable in chart production details.

A new upright whirler was installed for use in coating the process aluminum plates with albumen solution, replacing a worn-out horizontal-type whirler. Because of its upright position, a small amount of coating fluid carefully poured on the center of the plate is spread uniformly by the revolving motion, the speed being stepped-up from slow motion for spreading to a fast speed for drying, the latter process being aided by electric-heating coils. The new machine gives a better coated surface with less waste of materials and time is not lost in cleaning up a heavily gummed machine.

It is no longer necessary for hydrographic units first to prepare an outline drawing before any soundings can be made in areas cut by the various meanderings of numerous waterways. A print is now made in the Washington office from an air phototopographic compilation plate on transparent celluloid in silver white ink, on which vermilion powder is dusted while wet. Burnished down on special paper, an exact duplicate of the topographic features is obtained, including projection lines, control points, and shore-line, eliminating not only former laborious details of transferring from the topographic sheet and checking the accuracy of this transfer but supplying more data, with a saving of time in the field.

DIVISION OF CHARTS

A total of 294,000 copies of nautical charts was printed during the year. Twelve new nautical charts were published, and 154 revised editions reissued. The issue of charts and related nautical publications and commerce airway maps exceeded that of the preceding fiscal year, as shown in the following tabulation of these products issued during the last 5 years by the Washington office.

Items	1934	1933	1932	1931	1930
Nautical charts	[1] 267,924	216,936	249,311	259,862	258,286
Coast Pilots	7,046	4,116	5,825	6,480	7,651
Intracoastal Pilots	1,027	1,399	2,255	1,909	2,208
Tide and current tables	32,503	31,609	49,014	50,306	42,737
Tidal current charts	701	958	635	1,784	326
Commerce airway maps	47,685	29,369	19,402	17,468	[2] 12,004

[1] Not including 5,892 issued by Manila office.
[2] Previously distributed by Aeronautics Branch.

Ever alert to improvements in charts in the interests of simplification, the following changes were inaugurated during the year: The note referring to the unit of soundings shown was enlarged to catch the eye more readily; prominent lights, including lighted buoys, were emphasized by a yellow spot; the locations of radiobeacons and radiocompass stations are brought out by a purple circle; the landmark symbol was enlarged and the identifying reference to the landmark made clearer; the use of the sand symbol between the low-water line and the 18-foot curve is supplanted in certain charts by a blue-color tint; and roads and streets on certain charts are being indicated by single lines.

The great expansion in field surveys by the Bureau and State organizations collaborating in the control network placed a heavy burden on the Chart Division in the reproduction of preliminary basic data. This was particularly true in the photograph laboratory because of the special consideration requested in the speedy delivery of the material when it reached that point in the office.

Frequent requests are received by the Bureau from organizations or individuals for photographic copies of original hydrographic and topographic surveys. Such hydrographic surveys are used by geologists in the study of submarine formations; by institutions engaged in oceanographic research; and as evidence in admiralty cases. Copies of topographic surveys are used by civil departments in planning and development; by individuals in registering property; by land courts; and in law suits over property boundaries. Both types of surveys are used in beach erosion and pollution studies.

The Air Commerce Act of 1926 directs the Secretary of Commerce to foster air navigation, chart the airways, and provide maps for safe navigation. Under this responsibility this office compiles, flight checks, and publishes the air maps of the Bureau of Air Commerce. Twenty-five sectional airway maps are now available of the 87 which will cover the United States. Seven new sectional maps were published and 35 new editions and 8 strip maps revised. To supplement these sectional maps pending the completion of the entire project, maps of routes along airways will continue to be published. Revisions of these maps to include new or changed conditions constitute a continuing effort. During the past year the New York map was printed three times, the Chicago map three times, and the Los Angeles map four times.

DIVISION OF HYDROGRAPHY AND TOPOGRAPHY

A marked increase in hydrographic work has resulted from the use of recovery funds. Besides the alleviation of unemployment by direct wages to the men employed, the Bureau was able to accomplish many long-delayed original and revisional surveys. Among others, present charts around the islands off the southern California coast are based on surveys of a preliminary nature. The Navy requested fleet anchorage charts of these areas, and these surveys have now been made and the anchorage charts will soon be constructed.

Californians have long urged the adequate charting of the Sacramento and San Joaquin Rivers and of the highly developed agricultural areas comprising their deltas. The additional funds permitted the completion of the hydrographic surveys of these rivers and their numerous tributaries and a phototopographic survey of the 1,200 square miles of the deltas, and charts showing its results are in process.

The offshore surveys between San Francisco Bay entrance and San Nicolas Island, a distance of 300 miles, which were also extended 90 miles off the coast, beyond the 2,000-fathom contour, were completed during the fiscal year. The surveying of this unfinished 23,000-square-mile area by the *Pioneer* and *Guide* completed the main surveys along the entire Pacific coast line from Juan de Fuca Strait to the Mexican border.

The survey of the Aleutian chain of islands in Alaska was started in the spring of 1934 by the ships *Surveyor* and *Discoverer*. Work was started at Unimak Pass on a survey of this chain extending for 900 miles from the Alaskan coast almost to the coast of Siberia. Owing to the short surveying season in this high latitude, several years will be required for its completion, but when the survey is finished and the results charted, trans-Pacific vessels bound for the Orient will be able to follow the great circle track to the northward of the Aleutians and considerably shorten the passage.

On the Atlantic coast there were accomplished, with the additional funds, revision surveys of the inland waterways of the Atlantic and Gulf coasts. The surveys of a large part of these areas had not been revised since the Civil War, and the greater part of the large area constituting the Louisiana deltas had never been surveyed, because of its almost impenetrable character and the difficulties attendant with old ground methods. With the modern aerial phototopographic methods 3,000 square miles of coastal Louisiana and Mississippi were surveyed during the latter half of the fiscal year and the results compiled on 1:20,000-scale sheets.

To bring obsolete charts up to date, 21 survey parties, composed of about 600 men, working from shore bases, were engaged the entire year on surveys of the intracoastal waterways from Boston to Corpus Christi. It is anticipated that before another year has passed modern surveys will be available for charting accurately and adequately the inland waterways along the entire Atlantic and Gulf coasts.

Another undertaking completed was the topographic survey of the entire south shore of Long Island and the complete hydrographic survey of the waterways along Hempstead Bay to Montauk Point, accomplished between March and November of 1933. With the view

to having a covering chart issued before the 1934 yachting season, there was a concentration of effort on field surveys, revisions, checking of beacon locations, and follow-up of newly-dredged channels. Chart No. 578, "Inland Waters—Shinnecock Bay to Great South Bay", appeared June 30, about 14 months after the field work started. Revision surveys, less extensive but much needed projects, were made in various other areas.

A Public Works allotment of $184,200 was made to the Bureau for reconditioning the survey fleet. Contracts were awarded shipyards under competitive bids for reconditioning the *Explorer*, *Discoverer*, *Surveyor*, *Pioneer*, and *Guide* in Seattle, and the *Lydonia* and *Oceanographer* at Norfolk.

Seven 75-foot patrol boats were transferred from the Coast Guard, and contracts for alterations to fit them for survey work were awarded various shipyards on the Atlantic and Gulf coasts.

The following table shows the work done by the Division of Hydrography and Topography during the year ended June 30, 1934:

Hydrography, topography, and coastal triangulation

Locality	Hydrography			Topography		Coastal triangulation		
	Sounding lines	Area	Soundings	Shore line	Area	Length of scheme	Area	Geographic positions
	Miles	*Sq. mi.*	*Number*	*Miles*	*Sq. mi.*	*Miles*	*Sq. mi.*	*Number*
Portland to Penobscot Bay, Maine						90	1,112	197
Boston and Cape Cod, Mass	1,476	97	37,229	67	19	64	775	88
Connecticut River to Rikers Islands, Conn. and N. Y	1,770	101	105,291	413	142	81	288	414
Hempstead Bay to Montauk Point, Long Island, N. Y	6,683	343	234,525	297	78	51	212	152
Vicinity New York City, N. Y. and N. J				1,173	450			
Raritan River to Manasquan Inlet, N. J	153	8	6,165	50	16	22	110	143
Chesapeake Bay, Md	2,868	153	104,456	240	65	44	174	135
Ocean City to Chincoteague, Md. and Va	6,836	3,892	72,659	61		3	5	69
Nansemond and Back Rivers, Va						47	110	106
Wilmington to Savannah, N. C., S. C., and Ga						167	700	273
Charleston to Fernandina, S. C., Ga., and Fla	15,480	593	557,621	5,388	2,073	86	167	206
Port Everglades to Alligator Reef, Fla	2,373	231	107,436	37	2	121	740	195
Mississippi Delta, Miss. and La	6,840	804	238,572	5,015	2,914	333	3,560	291
Vermillion Bay to Galveston Bay, La. and Tex	6,896	5,681	102,469	196	103	94	430	94
Galveston to Corpus Christi, Tex	6,390	555	189,166	552	306	247	1,380	177
Mexican border to Monterey Bay, Calif	23,631	13,298	234,622	508	273	125	555	198
Sacramento and San Joaquin, Calif	1,416	680	171,663	162	317			60
Hood Canal and Puget Sound, Wash	77	4	2,409	54	22	163	356	297
Revillagigedo Channel, Alaska	1,297	140	37,715	222	224	33	33	77
Gulf of Alaska and Aleutian Islands, Alaska	2,273	15,420	7,104	20	18	37	120	75
Prince William Sound, Alaska	5,196	1,590	58,620	127	151	92	3,061	27
Kodiak Island, Alaska	6,111	977	76,277	180	164	21	48	43
Balabac Island, east coast Luzon, P. I	12,279	5,187	176,407	115	388	48	423	58
Total	110,045	49,754	2,520,406	14,877	7,725	1,969	14,359	3,375

It is noted that over 2,500,000 recorded soundings were made in hydrographic surveys, whereas during a normal year about 700,000 are made. Topographic and hydrographic field sheets received from the field were 424, as compared with 181 in 1933 and 164 in 1932. Since some additional funds were made available in the previous fiscal year, the comparatively large number of field sheets received in 1934 is of surveys made partly in the former year. The increased output from recovery funds will be reflected in the fiscal year 1935.

The use of the airplane and aerial camera in topographic work is being steadily increased. Base maps of coastal areas are being made and the topography shown on nautical charts is being brought up to date by this method, which makes possible surveying economically the almost impenetrable swamps and intricate waterways of our South Atlantic States, a large part of which was impracticable by the old ground methods. During this fiscal year such surveys were made along the Connecticut coast, the entire south shore of Long Island, the outer coasts of Maryland and Virginia, the coasts of North and South Carolina, the Georgia coast, the Mississippi Delta and westward along the Louisiana coast, the Texas coast between Galveston and Corpus Christi, in California from the Mexican border to Los Angeles, and also the deltas of the San Joaquin and Sacramento Rivers. In all, about 7,000 square miles were so surveyed during the year and the data compiled into base maps.

The Coast Pilot is a publication which furnishes the mariner a wide variety of information which cannot be shown on the charts, giving a complete description of the coast and waterways and innumerable data regarding all the ports of the United States and possessions. They are of inestimable value to the navigator, especially to strangers. The 14 Coast Pilot volumes are kept current by annual supplements and revisions, based on field examinations. During the past year examinations were made of the coasts of California, Oregon, and Washington, and field examination was made of the New Jersey inland waterways.

Although the Coast and Geodetic Survey for administrative purposes is a centralized bureau, in order to keep in touch with the public served and to have more direct information as to the charting needs and the requirements for surveys over the vast area covered, field stations are maintained in the United States at Seattle, San Francisco, New Orleans, New York, and Boston. The 56,000 calls for information made on these stations during the year are indicative of their usefulness to the public in supplying information, aside from their necessity in keeping the Bureau informed.

DIVISION OF GEODESY

The past year has been notable from the standpoint of geodetic work in the field and office. With emergency funds added to the annual appropriation, there were extended in the United States 8,520 miles of first- and second-order triangulation and 44,823 miles of first- and second-order leveling. Although this far exceeds the accomplishments for any similar year of its history, the work was held to the usual high standard of accuracy.

There has been a decided increase in the interest shown by Federal and State officials in the control surveys. Such surveys are indispensable for any comprehensive long-range planning of public works, as a means of conserving and developing natural resources by efficient and economical methods.

The increased application of high-grade control surveys to nearly all engineering operations and to many scientific problems is gratifying. It is recognized that they are essential for the completion of the topographic map of the United States and for all large-scale surveying projects; the results of these surveys are of the utmost value in irrigation, drainage, flood control, highway, and other engineering problems, and in the establishment and perpetuation of State, county, city, and private property boundaries; in the determination of the size and shape of the earth; in furnishing knowledge of the density of the earth's crust, useful in the search for oil-bearing strata and bodies of ore; and in determining the extent of the horizontal and vertical movements of the earth's crust in regions subject to earthquakes.

Control surveys consist of determining the latitudes and longitudes of monumented stations and the distances and directions between them, and of the accurate determination of the elevations of bench marks. They make it possible for various and widely separated surveys to have perfect junction when the projects meet.

An outstanding piece of fieldwork during the year was the completion of first-order triangulation from St. Augustine to Miami and from Naples to Port Inglis, Fla., and from Port St. Joe, Fla., to Mobile, Ala. These arcs were among the long-delayed needs for coordinating a large number of less accurate surveys of various dates and extent, required immediately for charting purposes. Similar arcs of less extent were completed along the Delaware River and Bay and along the lower Mississippi River from New Orleans to Buras, and from the river westward to Thibodaux, La. Another important arc was extended from Pittsburgh, Pa., westward to the Mississippi River.

At the request of the Tennessee Valley Authority, both triangulation and leveling were extended in the Tennessee River Basin, with the triangulation more than half completed and the leveling being practically completed to the 25-mile intervals by the end of the year.

Additional triangulation was extended in the vicinity of New York City for the complete coordination of a number of different projects.

The arc from Newport Beach to San Bernardino, Calif., was entirely reobserved for the purpose of making studies of any horizontal movements in the earth's crust as the result of the Long Beach earthquake of 1933. This work was done originally in 1928 as part of the program of extending triangulation into regions of seismic activity. First-order leveling was also extended in the San Jose, Calif., area at the request of engineers and scientists, to study the effect of recent settlement of the earth's crust in that region.

The Bureau has cooperated with numerous Federal and private organizations in the extension of control work in many areas during the past year. There was the usual cooperation with the United States Geological Survey in the extension of arcs of triangulation and lines of leveling to meet its needs for control in areas in which

topography is being executed. Stations and lookout towers of the United States Forestry Service in Oregon, Texas, and New Mexico, were also determined.

The State of North Carolina contributed $27,500 toward a 2-year program for priority in the extension of triangulation and leveling to the 50-mile spacing within that State. This work was completed with the exception of the publication of the results, now in process.

First- and second-order triangulation, base-line measurements, reconnaissance, and leveling activities, together with gravity observations, were carried on in various other areas. The following statement itemizes the work done by the Division of Geodesy during the year ended June 30, 1934:

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

Locality	Length of scheme	Area
TRIANGULATION, FIRST ORDER		
	Miles	*Sq. mi.*
Moyock to Weldon to Kinston, N. C. and Va	180	1,620
Washington to Pamlico Sound, N. C	85	1,360
Newport to Core Sound, N. C	25	215
Asheville to Murphy, N. C	80	1,800
Delaware River, N. J., Pa., and Del	100	1,200
Laramie to Pocatello, Wyo. and Idaho	390	12 870
Uniontown to Wellsboro, Pa	185	2,220
Newport Beach northeastward (reobservations), Calif	45	720
Bristol to Charleston, Tenn., Va., Ky., and W. Va	130	3,120
Klamath Falls to Bend, Oreg	125	3,375
Prineville to Burns, Oreg	100	2,600
Washington to Freeland, D. C. and Md	95	850
Washington to Greenville, Pa., W. Va., and Ohio	255	3,060
Murdo to North Platte, S. Dak. and Nebr	185	2,960
Ogallala to Sharon Springs, Nebr. and Kans	150	1,950
Russell Springs to Perryton, Kans. and Okla	165	1,980
Inyokern to San Bernardino, Calif	140	2,380
Tonapah to Las Vegas, Nev	240	4,080
Vicinity New York City, N. Y. and N. J	30	150
Chesapeake Bay, Md	40	400
Hermann to Lonoke, Mo. and Ark	245	2,940
Charlotte to Augusta, N. C., S. C., and Ga	130	1,300
Louisville to Nashville, Ky. and Tenn	175	1,925
Nashville to Corinth, Tenn. and Miss	140	1,540
Newberry to Georgetown, S. C	145	1,450
Dunnellon to Naples, Fla	205	2,460
Las Cruces to Belen, N. Mex	180	5,400
Las Vegas to Niland, Nev. and Calif	160	2,560
Langtry to Hot Wells, Tex	305	3,050
Hot Wells to El Paso, Tex	110	2,460
Lordsburg to Grand Junction, N. Mex., Ariz., Utah, and Colo	540	26,400
St. Augustine to Miami, Fla	320	2,560
Crowley to Ruston, La	160	1,440
McIntyre to Mobile, Fla. and Ala	235	2,115
TRIANGULATION, FIRST ORDER—continued		
	Miles	*Sq. mi.*
Niland to Calexico to Yuma, Calif. and Ariz	130	1,950
Hot Wells to Santa Rosa, Tex. and N. Mex	265	3,710
Union City to Quincy, Ind. and Ill	295	2,850
Havana to Jacksonville, Ill	45	400
Hartshorne to Lawrence, Okla, and Kans	270	2,970
Topeka to Nebraska City, Kans. and Nebr	110	1,100
James River to Washington, Va., Md., and D. C	135	1,215
Johannesburg to Bishop (Owens Valley), Calif	110	2,200
Hanna to Rosebud, Wyo. and Mont	285	4,845
Total	7,440	127,750
TRIANGULATION, SECOND ORDER		
Winchester to Lynchburg, Va	215	3,650
Smithville to Huntsville, Tenn. and Ala	95	1,045
New Orleans to Buras to Houma, La	115	690
Lebanon to Florence, Tenn. and Ala	130	1,430
LaFayette to Bristol, Ga. and Tenn	245	2,940
Boone to Bluefield, N. C., Tenn., Va., and W. Va	95	950
Clarksville to Corinth, Tenn. and Miss	160	1,280
Saulsbury to Silerton, Tenn	25	200
Total	1,080	12,185
BASE LINE, FIRST ORDER		
Lewellen, Nebr	6.8	-------
BASE LINE, SECOND ORDER		
Oceanside, Calif	2.8	-------
RECONNAISSANCE, FIRST ORDER TRIANGULATION		
Newark to Quincy, Ohio, Ind., and Ill	425	4,410
Washington to Freeland, D. C. and Md	95	850

Geodetic triangulation, base lines, reconnaissance, leveling, and gravity observations—Continued

Locality	Length of scheme	Area
RECONNAISSANCE, FIRST ORDER TRIANGULATION—continued		
	Miles	*Sq. mi.*
Hardin to Missouri River, Mont	160	2,720
Brooksville to Lexington, Ky	55	600
Murdo to North Platte, S. D. and Nebr	185	2,960
Vicinity New York City, N. Y. and N. J	30	150
Prineville to Burns, Oreg	100	2,600
Hermann to Monroe, Mo., Ark., and La	430	5,170
117th Meridian, Nev	160	4,320
Owens Valley, Calif	190	3,700
Ruston to Crowley, La	160	1,440
Ashland to Hanna, Mont. and Wyo	255	4,335
Havana to Belleville, Ill	125	1,250
Wykoff to Hermann, Minn., Iowa, and Mo	360	3,860
Chesapeake Bay, Md	140	1,400
Inyokern to San Bernardino, Calif	140	2,380
Tonopah to Niland, Nev. and Calif	400	6,640
Niland to Calexico, Calif	55	500
San Diego to Yuma, Calif. and Ariz	120	1,200
Charlotte to Augusta, N. C., S C., and Ga	130	1,300
Newberry to Georgetown, S. C	145	1,450
Langtry to Hot Wells, Tex	305	3,050
Hot Wells to El Paso, Tex	110	2,460
Hot Wells to Santa Rosa, Tex. and N. Mex	265	3,710
Colorado River, Ariz., Calif., and Nev	375	6,630
St. Augustine to Miami, Fla. (revision)	320	2,560
Catesby to Anthony, Okla. and Kans	120	1,200
Hartshorne to Lawrence, Okla. and Kans	270	2,970
Topeka to Blair, Kans. and Nebr	170	1,700
Potomac River, Md and Va	50	600
RECONNAISSANCE, FIRST ORDER TRIANGULACION—continued		
	Miles	*Sq. mi.*
Des Moines to Antonito, N. Mex. and Colo	150	2,730
Grand Canyon to Boulder, Ariz., and Utah	135	3,375
Crisfield to Elkton, Md	190	1,520
Ashland to Opheim, Mont	220	3,300
Alma to McAllister, Wis	220	2,640
Blair to Sioux City to Adrian, Nebr., Iowa, and Minn	140	1,540
Towanda to Owego, Pa. and N. Y	20	200
New Freedom to Lebanon, Pa	50	500
Total	6,970	93,920
RECONNAISSANCE, SECOND ORDER TRIANGULATION		
Christiansburg to Beattyville, Va., W. Va., and Ky	200	2,700
Pennington Gap to Huntington, Va., Ky., and W. Va	140	1,960
Winchester to Lynchburg, Va	215	3,650
Smithville to Huntsville, Tenn. and Ala	95	1,045
Florence to Lebanon, Ala. and Tenn	130	1,430
Clarksville to Corinth, Tenn. and Miss	160	1,280
New Orleans to Buras to Houma, La	115	690
Saulsbury to Princeton, Tenn. and Ky	155	1,550
Paducah to Martin, Ky. and Tenn	50	450
Union City to La Fayette, Tenn. and Ga	240	2,400
La Fayette to Bristol, Ga. and Tenn	245	2,940
Boone to Bluefield, N. C., Tenn., Va., and W. Va	95	950
Total	1,840	21,045

Locality	First order	Second order
LEVELING		
	Miles	*Miles*
Alabama	160	1,410
Arizona	570	500
Arkansas	25	230
California	710	30
Colorado	580	----------
Florida	730	1,430
Georgia	250	1,580
Idaho	890	830
Iowa	360	----------
Kansas	970	1,390
Kentucky	50	290
Louisiana	250	190
Maine	18	680
Maryland	20	----------
Massachusetts	----------	40
Minnesota	210	310
Mississippi	290	940
Missouri	170	1,230
Montana	1,070	960
Nebraska	700	260
Nevada	660	180
New Hampshire	70	345
LEVELING—continued		
	Miles	*Miles*
New Jersey	40	80
New Mexico	820	270
New York	270	520
North Carolina	70	610
North Dakota	410	1,740
Ohio	90	----------
Oklahoma	780	1,750
Oregon	60	135
Pennsylvania	140	----------
South Carolina	----------	805
South Dakota	1,050	660
Tennessee	120	1,440
Texas	890	3,730
Utah	660	1,150
Vermont	----------	15
Virginia	30	1,180
Washington	600	480
West Virginia	290	820
Wisconsin	110	----------
Wyoming	970	460
Total	16,153	28,670

Geodetic triangulation, base lines, reconnaissance, leveling, and gravity observations—Continued

Activity	Stations	Miles	Activity	Stations	Miles
SUMMARY			SUMMARY—continued		
Triangulation:			Leveling:		
First order		7,440	First order		16,153
Second order		1,080	Second order		28,670
Base line:			Gravity observations [1]	118	
First order		6.8			
Second order		2.8	Total	118	62,162.6
Reconnaissance:					
First order triangulation		6,970			
Second order triangulation		1,840			

[1] Gravity observations were made in Colorado, Connecticut, Florida, Kansas, Montana, Nebraska, Ohio, Texas, Wyoming, and Hawaii.

Splendid progress was made in the office computation and adjustment of the results obtained from field observations. The computation and adjustment of 21 arcs of first-order and 38 arcs of second- and third-order triangulation were completed, with computations of 17 arcs of first-order and 14 arcs of second- and third-order triangulation in progress.

Computations and adjustments of the leveling results were kept as current as possible, considering the great mass of field data received. Information concerning descriptions and elevations of bench marks for 153 lines of levels were distributed to engineers and surveyors in the areas covered and manuscripts prepared for 6 triangulation and 5 leveling publications. The geographic positions of 30,000 triangulation stations were prepared for ready distribution. Manuscript for the publication Triangulation Along the Mississippi River from Cairo, Ill., to Headwaters, Minn., was sent to the Chief of Engineers, United States Army. Prepared by personnel detailed to the Washington office by the Chief of Engineers, it covers data for 2,900 triangulation and traverse points.

DIVISION OF TIDES AND CURRENTS

During the past year there has been an increase in accomplishments in every field of activity covered by the Division of Tides and Currents, made possible by the allotment of recovery funds in addition to the regular appropriation.

During the year, 32 primary tide stations were in operation: 18 on the Atlantic coast, 4 on the Gulf coast, 7 on the Pacific coast, 2 in Alaska, and 1 in the Hawaiian Islands. Twelve of these stations were conducted on a cooperative basis, to reduce operating costs, with the aid of the following agencies: The Army Engineers at Southport, N. C., Miami Beach and Mayport, Fla., and Mobile, Ala.; the Navy Department at Newport, R. I., Annapolis, Md., Portsmouth, N. H., Hampton Roads, Va., and San Diego, Calif.; the Woods Hole Oceanographic Institute at Woods Hole, Mass.; the Harbor Department at Los Angeles, Calif.; and the Surveyor of the Territory of Hawaii at Honolulu.

A number of secondary stations were operated for periods of a month or more to solve special problems and to secure fuller knowl-

edge of tides along the coasts. During the year, 58 such stations were occupied, cooperative stations being operated by the Army Engineers at Fort Worden, Wash., the University of Washington at Friday Harbor, Wash., the Biological Research Bureau at Bermuda, the Washington Suburban Sanitary District at Bladensburg, Md., and the California State authorities at Santa Monica, Calif.

In addition to the fieldwork falling directly within the purview of this Division, tide observations made by the Division of Hydrography and Topography are tabulated and reduced in this Division. The expanded program of hydrographic work has brought about heavy increases in the office work, as observations at approximately 375 tide stations made in connection with the year's hydrographic surveys were tabulated and reduced in the Division, and the datum planes derived and related to local bench marks. As illustrating the Division's expanded activities, 433 secondary tide stations were occupied, compared with 281 during the year previous.

From the various tide data received the Survey issues in advance yearly tide tables, for in modern commerce, with its deep-draft vessels moving on exacting schedules, it is a prime necessity to know the times and heights of the high and low waters. Commencing with the calendar year 1934 the three volumes of tide tables were consolidated into two under the titles Tide Tables, Atlantic Ocean, and Tide Tables, Pacific Ocean and Indian Ocean. They give daily predictions of the high and low waters for 97 of the more important ports and harbors of the world, and carry data which permit predictions at some 3,900 secondary stations. Although there has been a constant growth in the information furnished by these tables, due to demands of the Navy and merchant marine, it has been possible to supply the added information with but little additional work by the organization of international exchanges of predictions. At the present time predictions are exchanged as follows: England, 21 stations; Germany, 6 stations; France, 4 stations; Canada, 5 stations; and India, 5 stations.

Another field activity of the Division relates to special tidal surveys. Various sections of our coasts have been lacking precise tidal information which in the majority of cases is derived as a byproduct of hydrographic surveys. To remedy this situation in the interests of navigation and engineering, special tidal surveys are conducted. This type of survey is a relatively recent development, necessitating a coordinated plan of operations to make possible the determination of mean values from relatively short periods of observations. During the year such a survey was completed for the coast of Oregon and for the Gulf coast of Florida.

Annual current tables are issued as navigational aids, giving information with regard to the times and velocities of the tidal currents. They give daily predictions of the current for 23 of the more important North American waterways and for one in the Philippine Islands, and furnish data which permit predictions to be made for 1,300 other stations.

In regard to currents, the primary field activity consists of surveys of important harbors and waterways to bring out in detail the features of the current movement, a matter of prime importance to navigation and harbor engineering. The specialized technique developed

has made the survey the recognized authority in this matter and requests for such surveys are received constantly. During the year the waterways of the St. Johns and Savannah Rivers were covered by such surveys. Valuable cooperation was rendered by the Army engineers of the Savannah and Jacksonville districts, the latter office loaning the tugboat *Fulton* for this work.

Requests were received during the year from various scientific and research organizations and expeditions for the loan of tidal instruments. The Louise A. Boyd expedition to Greenland was supplied with gages, the records from which have been received and tabulated, and the Byrd second Antarctic expedition was furnished with a portable tide gage and deep-sea thermometers for observations at Little America.

DIVISION OF TERRESTRIAL MAGNETISM AND SEISMOLOGY

Aside from expenditures under the regular appropriation and that for the International Polar Year, Public Works funds permitted additional needed magnetic and seismological observations, important repairs to buildings and the installation and operation of additional strong-motion seismographs.

The extension of the strong-motion program has had an important bearing on all Public Works projects in California. This program involved the construction of buildings, bridges, dams, and other structures, in the design of which resistance to earthquakes is now a recognized factor.

Active cooperation with State civil works organizations has resulted in securing reports on the present condition of some 400 magnetic stations and declination observations, with compass declinometer observations at some old stations.

TERRESTRIAL MAGNETISM

The earth's magnetism continuously changes in a complicated manner, so that the future cannot be predicted from the past. Observations in the United States are made at 5-year intervals at about 175 places for information regarding these changes and in this way it becomes possible to keep current the observations made at some 6,000 places.

The points where these observations were made, including the determination of the true direction of one or more objects from the point of observation, are known as "magnetic stations" and are usually marked in some permanent manner, as with a concrete monument. Magnetic stations where observations are made at regular intervals to determine changes are known as "repeat stations." Observations were made during the year chiefly at repeat stations in the extreme southern and western tiers of States. There has been a continuation of the policy of using triangulation stations as magnetic stations, thus substituting stations in the open country for those heretofore established in cities and towns which are subject to many disturbing and destructive forces.

Observations of declination were continued along the coasts to assure proper values on nautical charts and, especially in Alaska, to define areas where the magnetic compass is affected by magnetic

deposits. In a number of cases old stations have been replaced to meet the needs of local surveyors.

Magnetic observations were carried on in the following States during the fiscal year ended June 30, 1934:

State	Complete observations at repeat stations		Observations for declination	Total	State	Complete observations at repeat stations		Observations for declination	Total
	Old	Added				Old	Added		
Alaska	2	-------	23	25	New Jersey	1	2	-------	3
Arizona	3	-------	3	6	New York	3	1	2	6
California	9	3	45	57	North Dakota	-------	-------	2	2
Colorado	3	-------	4	7	Oregon	1	-------	11	12
Connecticut	1	-------	-------	1	Philippine Islands	-------	-------	15	15
Idaho	1	-------	3	4	Puerto Rico	1	-------	-------	1
Kansas	1	-------	-------	1	Rhode Island	2	-------	-------	2
Maine	5	2	-------	7	South Dakota	1	-------	2	3
Maryland	1	-------	-------	1	Vermont	3	-------	-------	3
Massachusetts	2	1	2	5	Washington	3	4	1	8
Montana	1	-------	-------	1	Wyoming	2	-------	2	4
Nebraska	3	-------	1	4					
Nevada	2	-------	2	4	Total	52	13	118	183
New Hampshire	1	-------	-------	1					

The five magnetic observatories continued their function of recording the day-by-day changes in the earth's magnetism, those at San Juan, Puerto Rico; Sitka, Alaska; and Honolulu, Hawaii, carrying on this work as their principal function. The Cheltenham, Md., station also carried on a standardization and comparison of field instruments, and at Tucson, Ariz., measurements were made of atmospheric electricity and earth currents, related to magnetism and to telegraph and cable transmission, with the cooperation of the Carnegie Institution of Washington and the Mountain States Telegraph & Telephone Co.

The variation building at Cheltenham was saved by replacing the foundation and taking special antitermite precautions. The maintenance of routine observations during the period of building repairs was made possible through the cooperation of the department of terrestrial magnetism of the Carnegie Institution of Washington. A La Cour magnetograph was loaned and installed in the comparison and test building, providing a continuous record during the time when the other instruments were too disturbed to give a satisfactory record.

The Second Polar Year of scientific observations in the polar regions and elsewhere throughout the earth was successful, and was brought to a close at the time scheduled for the northern hemisphere on August 31, 1933. This applied to most of the activities of the College-Fairbanks station, where many cooperative efforts were carried on with this Bureau in administrative charge. The work included measurements in terrestrial magnetism, atmospheric electricity, earth currents, aurora, radio transmission, and related fields, carried on by the cooperation of the Naval Research Laboratory, Signal Corps, Rockefeller Foundation, Carnegie Institution of Washington, and Alaska Agricultural College and School of Mines. In addition, a broad program of meteorological investigation was car-

ried on by the Weather Bureau. With the close of the regular period, observations in terrestrial magnetism and in earth currents were continued until March 31, 1934, by the Bureau at the request of the International Polar Year Commission. Auroral work and radio investigation also continued under other auspices.

There is an increasing demand for and dependence upon the Bureau's accumulated information regarding the change of the magnetic declination with lapse of time in retracing lines of old magnetic surveys, in some cases as much as 200 years ago.

Current magnetic observatory records are used in connection with the examination of geological formations by magnetic methods in the search for oil and minerals. They are also in demand by Federal and commercial agencies studying the relation of magnetism to radio transmission difficulties. Magnetic information for the daily broadcast of phenomena affecting radio transmission, carried on at the request of the International Scientific Radio Union, was furnished from Tucson until December 31, 1933, and thereafter from Cheltenham.

SEISMOLOGY

The trend of the Bureau's earthquake investigations was directed toward obtaining information necessary for the saving of life and property from earthquake damage. While this has many aspects, stress was laid on fundamental measurements needed by engineers and architects for the safe design of buildings and other structures. The work is all interrelated and coordinated with that of other organizations to form an effective attack on earthquake problems.

The work includes the immediate location of every major earthquake, no matter where it may occur; the collection of instrumental and noninstrumental information regarding all earthquakes in or near the United States or the regions under its jurisdiction; the measurement of strong earth motions, especially in California; and the investigation, just started at the close of the fiscal year, of building vibrations and other factors relating to resistance of buildings and other structures to earthquake stresses.

Through cooperation of many seismological stations, the Jesuit Seismological Association, and Science News Service of Washington, D. C., prompt determination of earthquake location is made. Forty-two epicenters were located during the year. Information regarding all earthquakes occurring in or near the United States or the regions under its jurisdiction was obtained by instrumental and noninstrumental means. Instrumental information comes from the seismological stations of the Survey at San Juan, Puerto Rico; Tucson, Ariz.; Ukiah, Calif.; and Sitka, Alaska; from the cooperatively operated stations at Columbia, S. C.; Chicago, Ill.; Bozeman, Mont., and Honolulu, Hawaii, and reports from a number of other stations. Noninstrumental information is obtained from the reports of many volunteer observers and through questionnaires distributed immediately after an earthquake. In the case of Pacific Coast States, the work is divided between the San Francisco field station and the Washington office. The information is published annually.

Additional strong-motion installations were made of 11 instruments at 10 places, bringing the total to 42 in 33 cities. Ten addi-

tional instruments were constructed incorporating improvements added to previous installations.

Twenty-two records were obtained for six earthquakes. These were carefully analyzed, in a manner which obtained all possible information from them. Some of these instruments were placed at top and bottom of buildings, thereby introducing a problem which required additional work for solution.

Accordingly, toward the close of the year a program was inaugurated as a result of an allotment of Public Works funds requested by California scientists, engineers, and architects. This included measurement of vibrations of buildings and other structures and of the ground, as well as the collection of other information, all intended to make the program more definitely applicable to securing information needed for better design. An instrument convenient for making building vibration records was designed and by the close of the year observations had been made in high buildings, on tall tanks, dams, and bridges.

In addition to publication of the results of these investigations to date, there were issued lists of the principal earthquake epicenters of the world for a 30-year period, and a list of destructive and near-destructive California earthquakes. Investigations of tidal waves were also made.

By means of a shaking table at the Bureau of Standards and by cooperative action of the two Bureaus, valuable tests were made of the characteristics of several types of seismometers in regular use.

Tiltmeters installed during the previous year were kept in operation at the University of California at Berkeley, through the cooperation of that institution, for the purpose of determining possible tilting of the surface stratum; information which might give indication of an impending earthquake.

U. S. GOVERNMENT PRINTING OFFICE: 1934