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PHILIPPINE SURVEYS

by the

UNITED STATES COAST AND GEODETIC SURVEY.

[E. R. Frisby]

[Washington, 1921]

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ORIGIN OF WORK.

Nature of Problem:

The United States Coast and Geodetic Survey has played a pioneer part in the development of new regions coming under American jurisdiction. Each successive addition of territory has presented a new problem in the extension of scientific geographic knowledge. The acquisition of the Philippine Islands involved many unique features of exploration and surveying not previously encountered.

The Pacific Coast region was a thin, sparsely-settled region forming a continental rim in the temperate zone. Alaska was a little-known continental area fringed with islands and situated in sub-polar latitudes. Hawaii and Porto Rico were well-known and settled tropical islands of relatively small area, and easily accessible from the United States. In contrast to all these regions, the Philippine Islands presented a great tropical archipelago on the opposite side of the earth, densely peopled with diverse tribes of a race then unknown to Americans. As in California, there was a strong impress of Spanish culture in the centers of population. The internal geographic relations presented the picture of a sea area roughly equal to that part of the United States east of the Mississippi River, thickly strewn with islands to a number now known to exceed 7000. These islands ranged in size from mere rocks to an area equal to that of the State of New York. A total area equal to that of all the New England states with New York and New Jersey added was broken into fragments and scattered from the

Gulf of Mexico to the Great Lakes. These islands contained rugged mountainous interior regions covered with dense hardwood forests, and coastal fringes of swamp or coral reef. This, in brief, was the problem presented for surveying and charting. No more difficult combination of the adverse factors of distance, climate, language, sanitation and geography could be found. And, to multiply discouragements, the early parties viewed a hostile population in a state of insurrection.

Surveys in the Philippine Islands began shortly after military occupation by the United States. At first conceived to assist the movement of vessels in the campaign to suppress insurrection, they were rapidly expanded to fit the foreseen permanent commercial needs.

<u>Demand for Surveys</u>:

The American occupation of the Philippine Islands began with the naval battle of May 1, 1898, and the subsequent arrival of troops which forced the surrender of the City of Manila on August 13, 1898, by the Spanish forces. For the next six months army activity was confined to peaceful policing of the city. In February 1899, however, this routine duty was suddenly converted into an active campaign by the outbreak of insurrection in the native Filipino forces surrounding Manila. As these forces were pushed back from the city and the campaign spread into the adjacent provinces, the military need for accurate maps became acute. The extension of the campaign to other islands of the archipelago demanded the establishment of numerous detached army posts, which resulted in the organization of an inter-island transport service. The operation of this service reinforced the earlier experience of the Navy in demonstrating the inadequacy of the then-existing Spanish charts. These two agencies caused the first demand for modern surveys.

On the Spanish charts a few well-traveled routes and frequented harbors were shown with an appearance of completeness superior to that of the Russian charts of Alaska. Large areas were, however, devoid of soundings. Positions in the less known regions were subsequently found to have frequent errors of four or five miles and a maximum displacement of as much as 14 miles was found.

Under military exigency deep-draft transports began to appear in the remotest unknown corners of the archipelago and to seek anchorage in harbors hitherto used only by fishermen. These conditions forced realization of the need for comprehensive marine surveys based on mathematical control and so planned with a view to future commercial needs as to ultimately cover the entire vast water area of the archipelago.

EARLY ORGANIZATION.

Organic Agreement:

This need for new work was quickly grasped by the Coast and Geodetic Survey and, in consequence thereof, an officer was ordered to Manila in the early part of the year 1900 for a brief inspection and preliminary report.

Actual field work was inaugurated in December 1900 with the arrival of a party in charge of Assistant G. R. Putnam. The preliminary steps included the usual official visits for presentation of credentials; the negotiation of a working agreement with the Philippine Government; and the assignment and outfitting of office quarters. The broad provisions of the joint agreement with the Philippine Commission, as later ratified by the Secretary of the Treasury of the United States, contained the following features:

Equal division of expenses
Administration by U. S. Coast and Geodetic Survey
Records and sheets to be property of United States
Accountability to Philippine Government for Philippine funds and property.

The United States to provide:

- One large surveying vessel
- All technical officers
- All instrumental equipment.

The Philippine Government to provide:

- Two small surveying vessels
- Minor office employees
- Office quarters and furniture
- Specified classes of expenses.

One of the first steps was the assignment of office quarters in the Intendencia Building; and while these were being furnished and equipped, field parties were also being organized and set to work. Active field operations were in progress less than two years after the outbreak of insurrection; about one year after the beginning of regular military interisland transportation; and several years before the final termination of military operations.

Plan of Work:

While the early history of the Survey was controlled by military needs and limited by campaigns in various regions, it was foreseen that these conditions would soon be replaced by an era of reconstruction and peaceful commercial expansion. Plans for the survey were, therefore, adapted to these expected changes in conditions by providing for the immediate survey of harbors and anchorages and the subsequent gradual extension of surveys along the intervening coasts. This program promised quick relief to shipping at the points most critical to navigation; and the small separate surveys involved in starting the program lay within the ability of the limited technical force then available. The compelling factor, however, which alone would have dictated this method of work was the existing state of war. Extensive interior surveys would have been impossible, whereas the regions around the various harbors were already pacified.

ASTRONOMIC CAMPAIGN.

Program of Observations:

A corollary to the determination to institute widely scattered harbor surveys was the necessity to observe initial astronomic positions and azimuths at each harbor to properly coordinate the various surveys in a temporary manner, pending the execution of continuous triangulation. This led to the formulation of a program for the astronomic measurement of latitudes, longitudes and azimuths over the entire archipelago as preliminary to harbor surveys; although in practice the two were simultaneous. Astronomic work was carried on from 1901 to 1906 by shore parties organized for that sole purpose. From one to three parties were constantly engaged. Each party consisted only of one survey officer and a Filipino recorder. Such labor as was needed was hired at each locality and transportation from station to station was furnished by army transports or by commercial steamers.

Latitudes were observed by zenith-telescope, and longitudes by meridian-telescope time-determinations in connection with telegraphic exchange of signals. Azimuths were not at first separately observed, but were secured as incidentals to the time observations. While the weakness of such azimuths was well-known, they were nevertheless of adequate strength for preliminary use on the short lines of local surveys. Subsequently, all these azimuths were discarded as soon as the continuous main triangulation made available superior azimuths observed on Polaris.

Distribution of Stations:

The astronomical campaign located 39 fundamental positions which served to fix all original separate surveys during the period they remained detached. These positions were well distributed over the west coast and central portions of the archipelago, but were sadly deficient along the east coast where lack of telegraphic facilities made longitude determinations impossible.

The attempt to execute surveys simultaneously with military operations, while involving serious drawbacks in some respects, was at least of considerable advantage to the longitude work. As Army detachments occupied various towns they were promptly followed by military telegraph lines which finally spread into a network linking all important places and many minor towns. In subsequent years commerce has not warranted the maintenance of many of these lines which have consequently fallen into disuse. The longitude work was done during the period of maximum extension of the telegraph system and thus permitted the location of stations not now accessible. The lack of east coast stations is, however, fundamental. Few such points were reached even by the military system, since the topography is such that few important places can exist on that coast and these few are small and difficult of access. As soon as portable field radio equipment is adapted to longitude work, additional stations should be established on the east coasts of Luzon, Samar and Mindaneo in order to properly balance the available geodetic data.

Initial Astronomic Longitude:

All astronomic longitudes were at first based on that of Manila as brought from Hongkong by U. S. Navy determinations in 1881. In 1903, however, the Coast and Geodetic Survey measured the trans-Pacific longitude arcs from San Francisco to Honolulu, Midway I, Guam and Manila, thus completing the longitude circuit of the globe. The difference between the two values for Manila was only the small amount of 0.ˢ09. As the new trans-Pacific value was the stronger, it has since been adopted for Manila and is hence the present basis for all Philippine astronomic longitudes.

Interisland longitudes north of Manila were measured as single, independent differences from Manila. South of Manila they combine to form two interlocked circuits. The adjustment of these circuits and the addition of various spurs give the final astronomic longitudes.

HARBOR SURVEYS.

General Plan:

Harbor surveys involving the combined operations of base-measurement, triangulation, topography and hydrography were undertaken simultaneously with the above described astronomic work. The first such surveys were at the harbors of Santo Tomas, Sual, and San Fernando in Lingayen Gulf; but these were immediately followed by others in various regions. The organization of the parties was simple. The personnel usually consisted of the Chief of Party, an American aid or extra observer, a Filipino recorder and crews and laborers hired locally. Quarters were secured in rented houses or with army or constabulary messes.

The first transportation available was the crudest - such as native sailing craft hired at interisland ports. Shortly afterward, however, launches became available by charter, and were in extensive use between 1901 and 1908. During this period, the Survey was acquiring a permanent fleet, so that after the latter date all surveys were made by the regular vessels.

Each harbor survey depended on a short base measured on the sand beach and on a small net of tertiary triangulation connected to the astronomic station. Topography and hydrography were added by the usual Coast Survey methods.

Philippine Hardships:

During these surveys, the observers obtained their first introduction to the full range of vagaries embodied in the peculiar difficulty and interest of Philippine conditions. The picture exhibited the whole range of civilization from modern luxury to sheer savagery. The astronomic parties had taken the first step, but had still remained in touch with the Spanish culture of the provincial capitals. The harbor survey parties ventured into the hills and along the coasts where the sole human contact was with Malay peoples and where the physical conditions of life were a complete reversal of American experience.

One raised in the temperate zone, educated in the high average social culture of America and not inured to the bodily hardships of tropical exploration, little conceives the first shock of contact with aboriginal life. Reconnoissance was often on all fours behind a gang of knifemen slashing a tunnel through matted underbrush; at other times, it was in stifling fields of giant grass so dense and tall as to exclude all views except that of the blazing overhead sun; and again, it was a problem of waist-deep slimy swamps. Physical effort in the warm and humid air bathed the body in perspiration; and contaminated water demanded that the torments of thirst be met with self-denial or with an unbearable load of canteens.

Station clearing in dense hardwood forests turned the teeth of cutting tools and elicited amazement when severed trees refused to fall. Days of cutting were followed by days of disengaging the lacework of vines tangled in the tree tops.

Camp life was a struggle against the personal discomforts caused by insects, skin infections and diseases, primitive lack of sanitation, and the prevalence of intestinal disorders and fevers. There was a pervading sense of helplessness in dealing with native inhabitants and in securing efficient work from native employees. Irritations were multiplied by the failures of language, the inertia of the people, and their inability to comprehend either the haste of the foreigner or the intricacies of occidental methods. A sense of isolation and loneliness completed the undoing of all but the strongest spirits. It was natural that reports of these conditions, exaggerated by distance and repetition, should cause apprehension in the United States, with the result that numerous resignations occurred in the early days of the Survey as an alternative to three years of Philippine service.

Fortunately, however, there are individuals of the pioneer type who delight in discomfort and revel in the curiosity and humor of strange and novel situations. Such men flocked to the original organization of the Philippine Government - officers of the army and constabulary, engineers, teachers and provincial officials - and the similar elements in the Coast Survey enthusiastically carried its work through the early crucial and formative stages and pointed the way to its successful continuation.

The above disheartening conditions have now been largely overcome. The element of loneliness has been relieved by larger parties domiciled on ships. The difficulty of language has been mitigated both by the spread of English among Filipinos and by the acquisition of Spanish and native dialects by Americans. Transportation has been greatly improved by new roads, bridges and harbor facilities. Health conditions have been advanced by artesian wells, modern markets, and improved hospital facilities and medical technique. And above all there has been mutual growth of appreciation between the psychologies of the orient and the occident.

MANILA OFFICE.

Treatment of Field Work:

All records and sheets of Philippine surveys have always been forwarded to Manila for computation, plotting and chart construction. For about the first five years, charts were also printed in Manila at commercial lithographic plants; but after the sizes of charts passed those of the available stones and presses the finished chart-tracings were forwarded to Washington for printing. This method of publication is still in force, but in 1920 funds were provided by the Philippine Legislature for the purchase of a modern photolithographic plant. This plant is now in course of erection and it is expected that the publication of charts at Manila will be resumed in 1922.

At the outset, it was recognized that work carried on at a distance of 13,000 miles from Washington involving an average round trip mail time of two and a half months could not be done under the usual field station methods; but would require a large degree of independence, both in the campaign of field work and in the treatment of results. The interests of commerce demanded the promptest methods of publication. The original plan of work hence provided for the organization of a Manila office capable of handling all phases of work.

Quarters:

Office quarters were assigned to the Survey in the Intendencia Building, which is the Philippine Treasury. The first assignment was two rooms on the ground floor at the northwest corner of the building. These rooms were then not very desirable quarters. Since Spanish custom assigned an inferior status to the ground floor, they were roughly finished and had been in previous use as storage space. Gradually, however, the office has been extended, altered and improved until it is now an extremely desirable unit covering the entire western half of the building. The front portion was entirely rebuilt with concrete in 1908, and is hence fireproof and waterproof, as was amply demonstrated during the fire in 1920 which entirely destroyed other portions of the building. Other portions also have been extensively remodelled for the special needs of the Survey. These various changes have made the quarters so desirable that on three occasions bureaus of the Philippine Government have attempted to secure possession of them. Two of these attempts were foiled by the intervention of the Secretary of War on appeal from the Survey. The reconstruction of the building now in progress will make the quarters fireproof throughout, and even more suitable than ever for survey purposes. It is to be hoped that permanent retention may be assured.

<u>Early Organization</u>:

After the furnishing and outfitting of the office had been completed and the clerical work organized, the next step was the selection and training of a force of Filipino draftsmen to constitute the drawing division. An expert draftsman from

Washington accompanied the party of Assistant Putnam to manage this division. Early in 1902, the writer was sent from Washington to organize a computing division.

The office procedure for the treatment of the early harbor surveys after the receipt of records in Manila was to immediately check the unadjusted field computation of the triangulation scheme and to reduce tides and soundings in the computing division; to plot smooth sheets, compile working chart drawings, and to make finished chart tracings on lithographic transfer paper in the drawing division; and to then turn these transfer tracings over to private lithographic plants for printing from stone. As these plants were engaged almost wholly on commercial work for cigar factories, they had no previous experience in chart printing and hence considerable difficulty at first arose in such details as registration, coloring,and drying of transfer ink before completion of tracing. However, these difficulties were overcome and published charts of the early surveys were placed on sale in Manila within a few weeks after the office work and within a few months after field work.

First Director:

During this early period of the Survey, the greatest credit must be given to the energy and organizing ability of the first Director, Mr. G. R. Putnam, now Commissioner of Lighthouses. During the first year, in addition to the multifarious details of equipping an office and selecting and training a staff and in addition to the administrative direction of field parties constantly encountering new problems in a strange land, he personally made all office computations of astronomy, triangulation, tides and soundings and supervised all the details of publication. During the second half of this year, he also personally managed the entire force of Filipino draftsmen, on account of illness which compelled the return to the United States of the first American draftsman. Mr. Putnam also personally verified all chart drawings during his entire term as Director.

Permanent Organization:

In March 1902, the arrival of a computer and a new draftsman from Washington enabled the corresponding divisions to be organized on a permanent basis and to permit more systematic prosecution of work. About the same time a nautical expert was appointed and began the collection of nautical information and the preparation of sailing directions. This last work developed into the present nautical division and left the office with the three divisions which constituted its organization until 1908. In that year, the Philippine Government provided funds and additional space for a division since known as the "Geographic Division," which has compiled and published topographic maps of the interior land areas by assembling information from all available sources. About the same time the appointment of a bookkeeper and a property clerk led to the expansion of the work of the chief clerk into a clerical division. In 1920, the Philippine Legislature provided funds for the purchase of machinery and equipment for a photolithographic division, thus completing the present office organization of six divisions.

V E S S E L S

Acquisitions

The preceding description gives an outline picture of the field and office organization during the early years of survey work which overlapped the later years of military campaigns. Two factors soon tended to place the survey on a more permanent basis and to enable continuous surveys to be undertaken. These factors were the subsidence of hostilities, permitting shore parties to operate with greater freedom; and the acquisition of vessels, permitting hydrography in more exposed places outside the harbors.

In 1901 the steamer Research was purchased in Hongkong by the Philippine government for the use of the Coast Survey. After some necessary alterations she was placed in commission and accomplished a large amount of valuable work at extremely low cost. She was in continuous service from 1901 until the time of her sale in 1917. In the fall of 1901 the steamer Pathfinder, then the largest vessel of the Coast Survey fleet, was detached from duty in Alaskan waters and was assigned to the Philippine Islands where she has remained continuously until the present time. In the year 1903 the Philippine Commission provided legislative authority for the construction of a new vessel to be designed for the use of the survey. This vessel, the Fathomer, was built in Hongkong and was completed and placed in commission in 1905. In 1908 the Philippine government assigned the former coast guard steamers Romblon and Marinduque to the Coast and Geodetic Survey, thus completing the full complement of five vessels which carried on continuous work for ten years.

Reductions

At the end of 1917 the Research was given up and sold by the Philippine government. This action had been under contemplation for several years since the small size and low freeboard of the vessel permitted only work in sheltered localities which were then mostly surveyed.

The urgent demand was for larger vessels of considerable coal capacity able to work in more exposed regions. At the end of 1920 the shortage of field officers in the United States following the war became so acute as to prevent the assignment of sufficient officers to the Philippines to properly operate the four remaining vessels. This condition most unfortunately occurred at a time when ample funds for operation were available from Philippine revenues, so that it was with the greatest reluctance that it became necessary to admit the facts to the Philippine government and to surrender the steamer Romblon. At the present time the reduced fleet consists only of the Pathfinder, Fathomer and Marinduque.

Change in Character of Work

With the advent of the Research, Pathfinder and Fathomer as permanent equipment, all acquired previous to 1905, the character of survey took on a new aspect. Coast surveys connecting the separated harbor surveys became possible. From 1902 to about 1907 the prevailing type of work gradually changed from the early harbor surveys by shore parties using chartered launches, to continuous surveys by fully organized parties on vessels. During this transition period the two types were in simultaneous use,but after 1908 the acquisition of additional vessels, the Romblon and Marinduque, permitted the suspension of shore parties. Thereafter, practically all surveys have been designed in large units to cover the water areas and coast lines continuously.

It is a noteworthy fact that in the twenty years of operation in imperfectly charted and in uncharted waters abounding in reefs, and in a region visited by the most destructive typhoons, there has been no case of the loss of a vessel or even of serious damage; apart from a few minor groundings inseparable from marine surveying.

COAST SURVEYS.

Junctions of Surveys.

The first connection between harbors occurred as early as 1902, in Lingayen Gulf. The party which executed the previously mentioned first harbor surveys subsequently carried triangulation and topography around the shore of the gulf and thus joined Bolinao and Sual with Santo Tomas and San Fernando. In 1903 and 1904 two shore parties starting from Vigan carried triangulation and topography in both directions, joining on the south with Lingayen Gulf at San Fernando and extending to the north to Cape Bojeador and thence eastward to Aparri. This secured continuous coast line over the entire northwest coast of Luzon for a distance of 300 statute miles. Hydrography was later added by ship-parties.

Plumb line Deflections

This first continuous work joined the seven astronomical stations between Sual and Aparri and thus gave the first glimpse of the magnitude of the difficulty to be later encountered with deflections of the vertical and with the consequent discrepancies in the graphic junctions of shore-lines of surveys based on different astronomic positions. The first actual connection was between Sual and San Fernando, two harbors only 35 miles apart. The resulting discrepancy in position was ----------------4"-- in latitude and ---------------25"--- in longitude.

In other parts of the archipelago much greater discrepancies were subsequently found and caused great confusion in chart making during the period preceding the connection and adjustment of all triangulation and the adoption of a standard datum. Frequent discrepancies of from 15" to 30" in each co-ordinate were found, resulting in graphic breaks in shore lines of from one-quarter to one-half a mile. Iba, Zambales, was found to give a maximum eastward deflection of the vertical of 42" relative to the subsequently adopted datum; and there is indication that stations on the east coast of Samar and Mindanao will give over 60" westward relative to the same datum; as soon as telegraphic or radio longitudes are observed on those coasts. The entire width of the archipelago may thus be expected to produce a relative deflection of 2 minutes of arc in the plumb-lines or 2 miles in position of shorelines plotted astronomically.

Triangulation on Northwest Coast of Luzon.

The triangulation along the northwest coast of Luzon was the first venture in continuous surveys and as such was subject to the usual limitations of experiment. It was a thin chain covering only the narrow , densely-populated strip between the beach and the first foothills. Its average width of only four or five miles necessitated frequent stations and gave little strength in a chain of this length, although reinforced by a number of bases. It was, however, the scheme best fitted to the topography and was in fact the only scheme possible at that time when the mountain districts were still infested with bandits carrying on guerilla warfare, after the collapse of organized resistance. This triangulation connected seven astronomic stations which showed such large discrepancies as to require the recomputation of geographic positions on a uniform basis before the results could be published. The triangulation was not then adjusted; and it was also evident that any geodetic datum derived from astronomic results on one corner of the land mass would be far from the true value and could have only temporary use.

Vigan Datum

Precision in the initial position was hence needless. The latitude of Vigan, the central astronomic station in the series, was a rough mean of the seven latitudes and was hence adopted as standard; and a correction of 10" to its astronomic longitude resulted in a mean position used as the initial of a system called the "Vigan Datum".

This system was merely a rough temporary device used for a few years before the adoption of the "Luzon datum". It is described here since it appears in early computations and had considerable use in the first editions of some charts on the west coast of Luzon.

Main Scheme of Triangulation.

Experience with the work on the northwest coast of Luzon and with simultaneous surveys being then extended over Manila Bay and around Iloilo showed that the period of harbor surveys was drawing to a close. As early as 1903 preparations were under consideration for triangulation on a large scale preliminary to surveys over extended areas. This involved planning for many years in advance. It also involved limitation of the freedom of field parties in reconnoissance, and the previous office determination of the broader features of the triangulation schemes. It also involved the decision to concentrate effort in certain previously selected areas and to prosecute work on the continuous basis of engineering construction. An inevitable corollary was the necessity to deny the greater part of the requests for scattered surveys. A full explanation of the working program was usually sufficient to postpone such requests. Although this general method of work caused temporary difficulties to be described later, its ultimate soundness has been amply demonstrated by the abundant benefits now evident in the present connected and continuous system of surveys based on a uniform set of geographic positions.

An important feature of the plans for continuous triangulation was the decision to make complete least-square adjustments at Manila following as closely as possible on the heels of each piece of completed field work.

Central Luzon

The first actual steps in the program of expansion were the measurement of a base on Pasay beach near Manila with a length of 3.3 kilometers and the execution of secondary triangulation covering the entire area of Manila Bay with large figures. A base of 8.9 kilometers was next measured at Lingayen and a chain of figures with 50 kilometer sides was run through the central valley of Luzon, to connect Lingayen Gulf with Manila Bay by the direct overland route through the interior plain. This latter work had no immediate bearing on hydrography and was executed solely for its future value in bringing the northwest coast into accurate relation with the interior of the archipelago. It did, however, have an immediate result in furnishing the first correct location for many populous towns in the main agricultural region of central Luzon. Geographic positions from this work later furnished the basis of control for the military topographic surveys of this region executed between 1908 and 1913 and for the resulting splendid series of 40 lithographed maps showing 20 foot contours on a scale of one inch to the mile.

Verde Island Passage.

By 1906 a main base-line had been measured at Calapan, Mindoro, and a chain had been constructed through Verde Island Passage connecting Manila Bay with Marinduque. The resulting complete chain from Lingayen Gulf to Marinduque formed a main backbone of 300 miles around which the entire subsequent triangulation of the archipelago was built. Although designed only as secondary triangulation the adjustment showed that certain sections approached primary grade.

Luzon Datum

By this time the main scheme contained three main bases and three main azimuths. The previously mentioned tertiary extension northward to Aparri and a subsequent scheme along the Zambales coast together with the various harbor

Schemes linked together by these several chains brought nineteen astronomic stations into geodetic connection. As all this triangulation was then in process of adjustment the time seemed ripe to adopt a geodetic datum to replace the early approximation called the "Vigan datum" and to suppress the numerous conflicting sets of positions based on the several astronomic stations. At one time there were 51 charts on Luzon based on 19 different positions. By 1908 the confusion had become a severe obstacle to chart production. The number of projections appearing on original survey sheets was so great that the minutest attention was needed in assembling and errors were not infrequent. Charts of the same area either showed different positions or else unsightly breaks in the graphic shorelines requiring arbitrary connection. This dilemma had long been foreseen as an inevitable consequence of the working plan enforced by the early conditions of the survey. It was a necessary penalty paid for departure from the ideal plan of maintaining continuity by outward expansion of surveys from some central starting region. Initial gain in immediate availability of results from different regions had now to be paid for in confusion and disorder. The only escape lay in the speedy adoption of a permanent datum. It was recognized that while the available astronomic stations were well distributed in the latitude coordinate they were seriously unbalanced in the longitude coordinate, since nearly all lay along the well-settled west coast of Luzon. It was also recognized that delay would improve the datum by linking in additional astronomic stations in the central portion of the archipelago and by thus strengthening the longitude. On the other hand the pressing demand for uniform chart positions was reinforced by urgent appeals from the Army for uniform positions for extensive topographic surveys then in progress and by similar appeals from the Bureau of Lands for correct connection of extensive traverses.

These three features made the immediate adoption of a standard datum imperative and the work was undertaken with the nineteen stations then available. The details of the computations extending over several years are so voluminous and involved as to require separate presentation.

Topographic deflections of the plumb-line were computed and applied to the observed values. An attempt was then made to so treat the remaining residuals for sub-surface variations of density as to predict a value applicable to the Philippine Islands as a whole, despite the fact that the available

stations were mostly on Luzon and hence determined the name "Luzon datum". Without further details, it suffices to say that all subsequently acquired data indicate that the resulting positions then adopted are within 1" or 2" of the true geodetic latitude for the Philippine Islands and within 3" to 5" of the corresponding longitude. The initial point for the "Luzon datum" system is station "Balanacan" on the northwest side of Marinduque. Immediately after the initial values were adopted geographic positions were recomputed over the whole area of the then-adjusted triangulation, giving uniform results from Aparri to Marinduque. The foundation was thus laid for the broad treatment of surveys in other parts of the archipelago.

Triangulation in the Visayas and Mindanao.

Work has always been prosecuted in so many regions simultaneously that a history accurate in detail can only be secured from the successive annual reports with their included progress sketches. The northeast monsoon is a salient feature of Philippine surveys which compels a semi-annual change of working ground. Parties are thus frequently shifted great distances, but dealing only with tendencies of broadest scope it may be said that from 1900 to about 1907 or 1908, work was principally centered in Luzon; from the latter dates to about 1912 in the Visayas and Mindoro; and from 1912 to the present time the main effort has been in Palawan and the Sulu Sea. Mindanao has not had a definite and continuous compaign as its survey has been built up of work distributed mostly through the two latter periods. The main outline of the work on Luzon has already been described. While this was in progress surveys on a limited scale were started in various parts of the Visayas and Mindanao. Some of this work partook of the small-scale reconnaissance character which was typical of the post-military period and which had already proved a source of trouble and confusion. Experience in the north with the larger triangulation of the main scheme had demonstrated the need for more comprehensive treatment of work in the south. While the need was evident there were, however, certain economic and administrative factors based on party and survey organization which delayed the needed change and which ultimately modified the ideal results sought to be attained. Comment on these factors should precede description of the work.

Administrative Difficulties

In the north the control system was constructed by small shore parties economically operating with land-transportation or with launches. In the south the geographic distribution of the broken land areas made water transportation an essential feature of the triangulation. The acquisition of the Romblon and Marinduque concentrated all officers and expenditures in vessels and left no opportunity for the operations of separate triangulation parties. A large vessel is an expensive operating unit to devote solely to triangulation and yet this branch of the work often makes excessive demands on time and effort. The problem then presented was that of execution of large scale triangulation with ships doing combined operations.

Large Scale Control

Trips on foot to high interior stations involving long and uncertain travel caused ship delays which rapidly mounted into high overhead costs and caused constant pressure from field officers to confine stations to the vicinity of the shore line. In some cases work done on this basis later proved incapable of extension and was virtually lost. Reconstruction in these cases produced ultimate costs higher than those temporarily evaded and led to an office demand for work better fitted to the topography and hence to future use.

This conflict with its inevitable compromises moulded the entire course of work. The writer frequently urged that the conflict be avoided by the assignment of the Research, the smallest and most economical vessel, to triangulation exclusively; but although several directors assented in principle the merits of this vessel for hydrography always seemed to prevent the consummation of the plan.

After about 1908, however, the previous tendency to thin coastal chains was replaced by a concerted effort to at least span all the principal interisland channels with adequate figures. Circuits were planned as complete units even though necessarily broken into seasonal sections. Instructions were prepared with a view to the needs of future years in regions outside that under immediate survey. At this point, however, other administrative difficulties intervened.

Lack of Inspection in Field.

After the issuance of instructions the office was practically powerless to enforce their provisions and was obliged to accept and use such results as were actually submitted. This statement is not intended as criticism of a large volume of excellent work accomplished under the most trying tropical conditions little realized by those who have not personally encountered them.

It refers only to occasional lapses permitted by the system of organization. The Director has been rather rigidly tied to his office without opportunity to visit field parties, and no machinery for inspection of work in progress has ever been provided. Mail service is so slow as to preclude frequent consultation by letter. The result has been that all matters of judgment in reconnoissance and execution have rested in chiefs-of-parties who are often and naturally reluctant to incur immediate expense for the benefit of some future party. It is to be expected that such a condition would be more noticeable among the less experienced officers; and it is at this point that the criticism is most valid since the Philippine Islands have to a considerable extent served as a training ground for new officers. The short term of two or even three year details with the consequent incessant changes in both chiefs-of-parties and subordinate field officers has produced great variation in the quality of work. In the same circuit both low and high grade work is found interspersed, depending largely on the personal qualities and experience of the observers.

Despite these economic and administrative difficulties the several circuits covering the main interior channels and surrounding the various islands of the Visayas were gradually completed and built up into the present triangulation network. These circuits represent long planning and measurably approach ideal conditions, within the limitations imposed by combined ship operations, rapidly changing field personnel and seasonal changes in working ground.

Geographic Advantages

The geography of the Visayas imposes frequent circuit closures which add vastly to the labor of office adjustment but which at the same time add great internal stiffness and strength to the resulting net. The interior of the archipelago is thus rigidly controlled by a system of closed and interlocked circuits which at the present time are mostly adjusted and furnish uniform control by positions computed on the "Luzon datum".

Practically all positions based on the original astronomic stations are now discarded, so that the latter retain only their scientific interest.

Descriptive Outline.

Apart from numerous harbor-surveys the main triangulation of the Visayas may be said to have grown from two principal centers - Iloilo and Ormoc - with a later independent origin at Dumaguete. The first work was a tentative expansion from Iloilo in 1903 with a scheme which later surrounded Guimaras Island and extended northward through Guimaras Strait to the northern end of Negros. A subsequent development followed, however, by more rapid expansion was the growth of the work around Ormoc which soon covered the entire area between Leyte, Cebu and Bohol. Shortly thereafter work was extended northward from a base at Dumaguete and covered the southern half of Tanon Strait. This was followed by a minor scheme starting at the northeast corner of Bohol and running along the north coast to the west end of that island where it was expanded into a larger scheme covering the area between Bohol and Cebu. This work effected a junction with Tanon Strait near Dumaguete and was then carried along the south coast of Bohol, closing the circuit of that island. A block of work south of Masbate, accomplished by several parties at scattered intervals, finally connected the Ormoc work with that from Iloilo and also provided the basis for a southward spur in Tanon Strait which completed the circuit of Cebu. This furnished the main structural nucleus of the Visayan work. Incidental spurs extended southward to cover the north coast of Mindanao; eastward through Surigao Strait and thence northward and southward over the east coasts of Leyte and Samar and over the east coast of Mindanao respectively; andwestward over the south coast of Panay and thence northward over the west coast. Another small chain closed the south coast of Negros.

All this Visayan block remained detached from the Luzon system by a large area covering the Sibuyan Sea. It was also detached from surveys of the south coast of Mindanao reaching from Zamboanga to Cotabato. A long interval of detachment from Luzon delayed the introduction of final "Luzon datum" positions into the Visayas; but meanwhile the figure adjustments of angles and lengths in the triangles making up the circuits were being computed. When the physical connection with Luzon was completed final positions were immediately carried through a previously adjusted net.

The Visayan figure adjustment originates in two base-nets. One of these covers the area between Bohol and Cebu and Negros, and contains in itself a length equation connecting the two closely-adjacent bases at Dumaguete and Tagbilaran. The other is a figure covering the area north of Cebu and is dependent wholly on the length of a base at Bantayan. The principal Visayan figure, called"Cebu, Leyte and Bohol", covers the area between these islands and connects the two base nets with each other and also with the base line at Ormoc. Another figure, called "Tanon Strait", also connects the two base nets by this route and thus includes the equations for length, latitude, longitude and azimuth arising from the closure of the circuit of Cebu.Another figure called Mindanao, Bohol and Leyte, closes the circuit of Bohol and connects the Dumaguete-Tagbilaran base-net with previously adjusted work in Canigao channel and with measured bases at Iligan, Mindanao, and at Camp Keithley on Lake Lanao in central Mindanao. Another figure, called "East Coast of Leyte" is based on the preceding figure at Surigao Strait and carries a length equation northward to a measured base near Tacloban and another length equation southward to a measured base at Cantilan, Mindanao. These figures made up the main framework of adjustments in the Visayas previous to the connection with Luzon. Minor chains have not been mentioned.

Throughout the Visayas and Mindanao there was the same confusion from multiplicity of positions based on separate astronomic determinations as existed on Luzon. The possession of a large block of adjusted circuits in the heart of the Visayas was too tempting to be ignored; and hence while it was neither possible to await the field connection with Luzon nor to duplicate the vast amount of effort expended on the derivation of the "Luzon datum" to compute a "Visayan datum", it was still possible to secure some benefit to chart construction by the temporary use of uniform positions based on an arbitrary datum. The system of positions thus used had its initial point at Escalante on northeast Negros and was thus called the "Escalante datum".

It was an arbitrary adoption and was used for several years more as a device to facilitate computations in graphic assembling of different areas than as an actual chart basis.

Connection with Luzon

The connection between the Visayas and Luzon was accomplished in the following manner:

A large figure was constructed in the center of the archipelago with its center near Sibuyan Island and its perimeter extending from Luzon to Panay and from Masbate to Tablas. A southward extension of the Verde Island Passage work along the east coast of Mindoro was integrally connected with it and slightly preceded it in point of time. A new base line was measured at Ibajay on northwestern Panay. The figure around Sibuyan was considerably the largest then observed and involved long delays due to the exceptional length of lines which ran as high as 85 statute miles. While this length is not excessive in dry interior mountain altitudes it presented difficulty in the humid, sea-level atmosphere encountered. The maximum station-elevation was only somewhat over 3000 feet, but one line was so low that it was only visible at low tide.

This figure was adjusted immediately and thus carried "Luzon datum" positions to the west coast of Masbate where they first came into contact with Visayan positions based on the arbitrary "Escalante datum". Complete junction was not effected, however, until some years later when new field work was carried through Ticao Pass and covered the area between Samar and Luzon and the north coast of Masbate. Added to previous work south of Masbate this completed the circuit of that island. This circuit was immediately adjusted as a new figure with a measured base at Bulan and provided a rigid and complete junction between Luzon and the Visayas. Immediately thereafter new geodetic positions were computed throughout all Visayan adjustments and hence extended "Luzon datum" positions to the center of Mindanao and to the east coasts of Leyte and Mindanao.

A spur situated between Samar and Leyte and extending from the Masbate circuit to San Juanico Strait afforded the means for closing the circuit of Leyte. Since three-quarters of this circuit had previously been adjusted it was necessary to force closing errors, reasonable for the entire circuit, into the remaining one-quarter; and thus to impose large corrections on an excellently observed scheme.

Within the past two years field work on the west coast of the Zamboanga peninsula has closed a circuit embracing the western portion of Mindanao. This work in now in process of adjustment. The circuits of Samar, Negros and Panay are still unadjusted.

Triangulation of Southwestern Philippines.

The southwestern section of the archipelago comprising Palawan, the Calamian Islands, Busuanga and Mindoro was undertaken after the connection of the Visayas with Luzon. The span from Mindoro and Panay to Palawan, by utilizing the Calamian and Cuyo Islands, necessitated the use of figures larger than any hitherto observed and involved lines up to 95 statute miles in length. Observers were stationed on Mt. Tinayunga for a total time of five months. Previous experience with large scale work proved most beneficial. Not only did the bridge to Palawan demand the highest grade of work but the tradition of early reconnoissance methods had long since died. For years officers had seen only the infectious examples of excellent work and when this new project was launched they vied with each other in enthusiasm to excel, not only where the geographical feature of great sea areas demanded the best but throughout the entire length of Palawan where there was strong temptation to lower the standard.

Mindoro, Calamianes and Cuyo.

The first advance toward Palawan started from the passage between Mindoro and Panay and comprised a large polygon with a central point on Quiniluban and its perimeter resting on Cuyo, Busuanga and two small groups of islands off the north end of Palawan. A large side spur extended northward along the west coast of Mindoro and closed the circuit of that island by connection with Verde Island Passage. The adjustment of these figures with their subsidiary minor chains provided final positions over the south and west coasts of Mindoro and throughout the Cuyo and Calamian groups of islands. It also provided a fixed length which was used as the base for the chain subsequently constructed for a distance of 250 miles throughout the entire length of Palawan, to Balabac at the southern limit of the Philippines.

Palawan

Palawan presented the problem of securing adequate control from a thin straight chain unsupported at its outer end. The island itself is narrow, but has its high summit ridge close to its western edge and thus presents its wider slope toward the eastern coast facing the Sulu Sea, which it was first proposed to survey. This condition dictated triangulation spanning the whole eastern slope from coast stations to interior points on the ridge. It was planned that the subsequent survey of the west coast should utilize the same summit stations for the addition of new figures on the western slope, thus securing the full width of the island. The drawback to this plan lay in the height of the summits which ranged from 4000 to 7000 feet and thus encountered frequent cloud; and in the long journeys by foot through dense forest. The final accomplishment of this work as originally planned is highly creditable to the energy of the field officers charged with its execution.

Work was started at the northern end of Palawan in 1913, but to expedite progress a separate base was measured on Mantangule Island off the south end of Palawan and work was independently started in that region by a second party which worked northward. The two parties effected a junction in 1917 near Puerto Princesa after the measurement of a new base in that locality at Iwahig, and thus completed the main triangulation of the island. The survey of the east coast of Palawan was not finished until 1921 when the topography and hydrography were completed.

Topography

The foregoing description of surveys in the Philippines has been roughly chronologic and has been expressed in geographic rather than in technical form. It has, moreover, been expressed in terms of triangulation rather than in terms of topography or hydrography because the three were nearly always simultaneous and the former more closely fits the geographic relations used in description. Topography and hydrography, however, have of course formed the great bulk of the routine work in the Philippines, as elsewhere. As the historic and geographic features have already been described only those features of topography and hydrography peculiar to the Philippines need mention.

A constant feature is extreme diversity of language among numerous tribes, making the problem of communication with the inhabitants and with hired labor one of frequent change. Even Filipino members of ships crews are often helpless in this respect

Characteristic features of topography which influence the work of the survey are:

Extensive coral reefs
Mangrove Swamps
Heavy Forest
Cliffs undercut by surf

Along many stretches of coast are wide reefs bare at low tide. These reefs are full of deep, treacherous holes and are covered with irregular masses of sharp, broken coral. Walking is seriously impeded and access to boats slow and difficult. One life was lost in approaching a boat across a reef at dusk. In some cases the low water line at the edge of the reef has been located by rod-readings; in others it has been partially fixed by intersection cuts locating conspicuous rocks or breakers; and, in many others it has been developed or corrected by the inshore ends of the sounding lines terminating at the reef edge. These reefs are most extensive off the north coast of Bohol. They will be a conspicuous feature of work in the Sulu archipelago. They are, however, found in smaller units very widely scattered over the entire archipelago.

Mangrove swamps are also frequently found features. Here an interlaced network of roots forms the only standing ground over large areas of deep mud. The bushes grow in water several feet deep and blanket the coast so that the topographer is forced to skirt their outer edge by working waist-deep in mud with his plane-table supported on deep driven stakes. It is frequently difficult to determine even approximately the outer edge of such a swamp since the solid mass shades away by insensible gradations of smaller and smaller clumps as deep water is approached.

A different variety of swamp less frequently found is that produced by the growth of the nipa palm in estuaries where salt and fresh water meet. Forest-covered slopes have their most serious effects on topography in obstructing the views over the interior necessary to sketch contours. The shore stations are at times completely blocked by a solid wall of foliage, demanding expedients of various grade to see the interior. In the absence of offlying islands, jutting peninsulas, or accessible tree-tops, the topography has as a last resort been sketched from the ship at anchor in determined positions. This condition of dense forest is most pronounced in parts of Mindanao, Palawan and Mindoro.

Cliffs facing exposed areas of sea and undercut by the action of surf along their bases are common in certain regions. In such cases the height of the cliffs or the wooded summits usually prevent placing the traverse above the cliff and compel work at low tide to secure standing room. Such regions demand continuous ingenuity on the part of the topographer. The principal regions showing this feature are the entire Pacific Coast of the archipelago including the Babuyan and Batan Islands north of Luzon, the west coast of Palawan, and the Calamian and Cuyo Islands.

Despite the foregoing and other difficult features of Philippine topography, sheer persistence has overcome all obstacles of nature and of personal discomfort and has produced sheets which will rank well with the average of similar work under more favorable physical conditions. Practically all the work has been done by the customary method of short traverses between closely situated triangulation points and corrected by intermediate three-point locations.

In only a few cases of the most exceptional difficulty have traverses as long as 20 miles been used as a last resort.

Hydrography

The hydrography of as vast an area as that covered by the Philippine Islands is so diverse that its detailed description, as it actually has been written in the descriptive reports accompanying the hydrographic sheets, is the equivalent of several volumes. The total number of topographic and hydrographic sheets so far completed is about 1500, of which nearly two-thirds are hydrographic. These 1000 reports cover hydrography of all possible classes from deep-sea sounding to the shallowest mud-flats, the survey of creek channels, and the intensive development of deep-draft dredged harbors.

The predominating feature of hydrographic surveying is the northeast monsoon. From November to April this blows with such severity as to prohibit work on coasts exposed to that direction. From May to October the monsoon is replaced by a tendency toward southwest winds. During this latter season typhoons to an average of eleven per year rage with great intensity. Surveys are therefore in constant danger of interruption not only by the actual passage of storms but by justifiable precautions in seeking shelter on the slightest indication. The navigational element in surveying is moreover enhanced by the wide prevalence of dangerous reefs often rising abruptly from deep water. Wire drag work has never yet been instituted, so the routine of work has followed the usual course of development by hand-lead, pressure tubes or vertical wire casts with incessant watch for the various surface indications of danger.

Throughout most of the interior passages of the islands high land is in sight so that shore signals or peaks are always visible. Practically all interior sounding lines are therefore located by continuous three-point fixes. Around the borders of the archipelago a few cases arose in which lines crossed wide areas where shore-fixes were lost but were soon recovered on the opposite side. Such cases were the deep lines crossing the Moro Gulf in the Celebes Sea south of Mindanao and deep lines in the China Sea west of Mindoro. These rare cases were adjusted wholly by graphic treatment of the short unlocated sections.

In the early part of 1919 a new problem arose. The hydrography around the Cuyo Islands had then been completed down to the northern edge of the Sulu Sea. The previous completion of the main triangulation of Palawan, with the location of mountain peaks along the sky line of the island, paved the way for off-shore hydrography in the Sulu Sea; and since the corresponding mountain locations on Panay and Negros were already available, it became possible to run long continuous east and west sounding lines across the entire Sulu Sea between accurate shore fixes adjacent to either end. The unsupported sections of these lines promised to be too long for the simple graphic adjustments previously used in similar cases. This condition required deep-sea work by astronomical positions and by dead-reckoning with such occasional support as might be secured from fixes or bearings on located reefs. This deep-sea work has formed an important part of the survey since 1919 and has developed depths as great as 2800 fathoms in this enclosed body of water. The northern half of the Sulu Sea is now completed as far south as the eighth parallel of latitude.

Tides and Currents.

A necessary adjunct of the hydrography has been the observation of tides at widely distributed stations. At the moment of writing this report in Washington the exact number of these stations is not accessible but it is roughly in the vicinity of 300, of which about one-third are automatic gauge stations and the remainder are auxiliary tide-staff stations. At Manila there is a series of automatic gauge observations covering nearly 20 years.The first half of the period was somewhat broken by changes in location due to the construction of harbor improvements and by occasional damage due to the temporary character of the tide gauge structure. In 1910 the structure was demolished by a typhoon but was rebuilt in permanent manner on the heavy concrete foundation of Pier 5, with float-tube and all fittings of heavy bronze and with adequate housing on the concrete deck of the pier and inside its steel superstructure. Frequent level lines have connected the gauge with permanent bench marks in Intramuros and have left no doubt as to its stability. Moreover, the second half of the series has been characterized by excellent instrumental operation so that there is at least a ten year period of continuous record. In 1920 the permanent structure was wrecked by the collision of a vessel which inflicted great damage on the pier structure. Preparations are now under way to incorporate a new gauge structure into the design of Pier 7 which is now under construction. The ordinary course of hydrography has maintained other gauges in one location for considerable periods - a number of records extending for 2 year periods and many for one year.

Co-Tidal Chart

Two specific problems have recently been presented for the consideration of the Division of Tides. The first is a consolidation of the mass of accumulated data by the construction of a new co-tidal chart of the Philippine Islands. This is needed to graphically illustrate the manner of wave propagation through the various inter-island channels and to assist in the interpretation of current observations.

Seiches at Puerto Princesa.

The second problem presented was one of scientific interest in the analysis of the tide at Puerto Princesa, Palawan, to determine the cause of the remarkable seiches there observed. These seiches have a range of over two feet and a period of less than an hour. Several successive oscillations of this type give a startling aspect to the tide curve. The regular recurrence of the phenomenon at definite periods of the lunar month together with similar manifestations on a smaller scale at adjacent stations in the Sulu Sea indicates that the origin of the disturbance is not meteorological but is inherent in some component of the tidal force. It seems likely that the free period of oscillation of Puerto Princesa bay is an exact multiple or an integral quotient of the period of some tidal component and that the repeated application of this impulse to the free boundary causes resonance. A number of stations around the shore of the bay were observed simultaneously in order to provide data for the motion of the surface. The complete elucidation of the causes and mode of oscillation promises not only scientific interest but practical local importance on account of the exceptionally great range of the seiches. Smaller seiches are frequent in many localities.

Currents

Currents have been observed to some extent in various parts of the islands. Considerable velocities exist in such important navigable channels as San Bernardino, San Juanico and Surigao Straits; to the extent of impeding full powered vessels and in the case of San Juanico Strait of preventing passage during maximum current. Lesser but still troublesome velocities exist in many other inter-island channels and even in the open Sulu Sea. Observations of currents have not yet been adequate to explain even the most simple facts. For example, the direction of the current in San Bernardino Strait is not even known in its relation to tidal phases. Fragmentary observations at various times and in different parts of the channel are contradictory. It is hoped that the construction of the co-tidal chart will at least supply a solid basis for estimates of level differences to permit more intelligent planning of current observations. As soon as the pressure for new surveys relaxes, considerable effort should be devoted to a comprehensive study of currents.

Magnetics

Complete magnetic observations for declination, dip and intensity were made by the early astronomic parties at each astronomic station. In the year 1912 an observer detailed from Washington made a special trip to the Philippines and reoccupied all recoverable stations for the determination of the annual variation of each of the magnetic elements. Other parties engaged on triangulation or combined operations observed declination in all parts of the islands. Additional observations of declination of lower accuracy are available from large numbers of ship swings.

Accurate observations of declination, dip and intensity have been made in many localities by members of the Jesuit order. A permanent magnetic observatory was maintained in Manila by the Jesuits until the opening of the electric street railway in 1905, after which it was removed to Antipolo where it is still operated.

Gravity

A set of instruments for the measurement of the intensity of gravity was received in Manila during the early part of 1921 and observations have just been begun by experimental work at the Manila observatory. This location was chosen as it was the site of the only known previous observations for gravity. This previous work was done by an Italian party. The result was almost identical with the value computed from the usual formula for variation with latitude. It is expected to redetermine the value at Manila and thereafter to make observations at various provincial stations. It is hoped that as soon as wireless receiving sets are perfected and are available for distribution that one may be sent to Manila for use by this party in receiving the daily time signals from Cavite.

UNFINISHED WORK

The foregoing description completes a general picture of the broader outlines of the survey up to December 31, 1920, as shown completed on the accompanying blue-print progress sketch. A discussion of the work remaining to be done will now be in order. The yet unsurveyed regions may be divided into the following areas, each of which is a distinct geographical unit in which the work is of approximately homogeneous character. The order of arrangement of the areas is that which in the judgment of the writer should be followed as a general survey program, as influenced chiefly by the commercial importance of the several regions.

The first three areas are in and around the Sulu Sea and are a continuation of work already begun. A fortunate coincidence is that the cheapest present coal supply is at Sandakan, Borneo, which is close to these areas and can be used as a base of supply. Some years hence when the surveys of this region are complete it is to be expected that the restoration of normal commercial conditions will depress the present excessive cost of coal at Philippine ports to a point where it will be feasible to undertake the survey of other regions. For the present it would be impossible with the existing appropriations to purchase all coal within the Philippines, and hence all conditions combine to prescribe continuation of work adjacent to the Sulu Sea.

The suggested order of work is as follows:

1. Sulu Archipelago
2. Sulu Sea, southern half
3. Palawan, west coast
4. Mindanao, south coast
5. Luzon to Formosa
6. Luzon, east coast
7. Ocean Hydrography.

In addition to the above large areas there are a number of smaller sections such as resurveys of southeastern Luzon now in progress, needed resurveys on the south coast of Samar, and other minor sections requiring additional development which are not specifically mentioned as they are relatively incidental. In practice it is not expected that work should be concentrated wholly on each area in succession, but rather that at least two should be in progress simultaneously.

Sulu Archipelago.

By this term is meant the entire region from Basilan Strait to the limit of American jurisdiction in Alice Channel adjacent to the coast of Borneo. The survey of this area necessarily precedes that of area No. 2, or the southern part of the Sulu Sea. It is an intricate region consisting of many groups of islands, extensive coral reefs and numerous dangers to navigation. It contains about 10,000 square nautical miles, all requiring detailed hydrographic development. The islands are well-populated, there is considerable local traffic and steamship lines to foreign ports pass through the region. Except for a small harbor survey at the town of Jolo,no surveys have yet been made in this large area.

Political Conditions.

The reason for this neglect of an important region at first lay in the prevalence of disorder and piracy. At the present, however, these conditions have subsided to a point where, in the opinion of the writer, the Survey is no longer justified in shirking its obvious duty to chart the region. For over ten years there has been no general condition of disorder. Occasional and isolated instances of violence still occur but they are nearly always traceable to small bands engaged in smuggling opium from Borneo. It is only the remote chance of encounter between such rovers and the isolated triangulation or topographic party which requires attention. Scientists from the Bureau of Science at Manila have assured the writer that they have made collecting trips throughout this region alone in small boats with native crews. They also state that no fear need be felt of the residents of the various islands(except perhaps Balanguingui) and that the only danger to be apprehended is from chance collision with a roving band which might happen to land on some island where a small party was at work. This contingency should be amply secured by a small military or constabulary guard carried on the ship and detailed to shore-parties. Triangulation was carried across the more dangerous country in Central Mindanao around Lake Lanao with the assistance of military guards and without untoward incidents. At the present time the work in Sulu is believed to be not only entirely practicable but a duty incumbent on the survey.

Program of Surveys.

Work has already been done on the north and west coasts of Basilan, on which island conditions are now secure. The first step should be the completion of the small local triangulation circuit of Basilan with the adjacent topography and hydrography. Following this a large scale triangulation scheme should be projected for one figure toward the southwestward as the basis of control for subsequent extension into the Sulu Archipelago. Experience gained in the execution of these two preliminaries will furnish information as to the character of country and number of guards probably needed for the subsequent survey. Economy in timber cutting as well as strength of figures requires a large scheme spanning the entire width of the chain of islands. This will require only a few main occupied points,but numerous minor intersection points for the control of individual small islands. Topography will be a difficult but relatively small fraction of the entire survey.

Hydrography will prove by far the largest element of work and will be extremely slow on account of the numerous islands and extensive reef areas requiring detailed development.

Sulu Sea (Southern half)

Work in this area will consist largely of deep-sea lines of sounding run out of sight of land and controlled by astronomical navigation. It will necessarily be dependent on the completion of the Sulu archipelago for the location of islands and peaks needed to fix the eastern ends of the sounding lines. It should be undertaken immediately after the preceding area in order to continue the work of the northern part of the Sulu Sea now in progress and to complete this entire geographical unit.

Preliminary Surveys.

Before the deep-sea work can be undertaken, however, two extensive preliminary sections of detailed inshore work must be surveyed. Each of these is of about 1000 square nautical miles. The first is a southward extension of the Palawan survey to include Balabac Island and Strait and all adjacent waters to the limits defined by the Treaty of Paris adjacent to the north end of Borneo. This involves shoal development on a wide bank east of Balabac Strait as well as all the intricate detail of a group of islands. The second preliminary section is that surrounding Cagayan Sulu, Bancoran, Bancauan and adjacent islands. These islands form a connected shoal area in the Sulu Sea about 80 miles from Palawan. The location of points throughout these two preliminary sections is needed to provide accurate shore-fixes for the western ends and central portions of the deep-sea lines. The connection of the several islands in the second section with each other and with Palawan by triangulation is within the range of possibility.

It requires careful study and reconnoissance to determine its feasibility and cost as related to the more unsatisfactory condition which would result from the use of several independent astronomical positions to separately control these closely adjacent groups of islands.

As soon as the two preliminary areas are surveyed the deep-sea lines may be run in with comparative ease to complete the entire Sulu Sea. About 20,000 square nautical miles of deep hydrography is involved.

Circuit Closure.

A final consideration in this area is the possibility of supporting the long parallel chains of triangulation along Palawan and the Sulu archipelago by means of a cross connection along the Borneo Coast. Certain islands along this coast are claimed by the United States.Without attempting to prejudge the issue of pending diplomatic proceedings, the claim is probably sufficient to warrant the use of funds for the small amounts needed for triangulation points. Utilizing these islands in this way and securing the cooperation of the Government of British North Borneo for the establishment of a few mainland stations, the connection is feasible and would encircle the Sulu Sea.

Palawan, west coast.

The importance of this region cannot be said to surpass that of the region between Luzon and Formosa but it should be undertaken first in order to utilize the existing triangulation stations before they have suffered damage. All the difficult interior stations are already established on peaks close to the west coast. The triangulation will therefore be only the relatively simple addition of new points. Topography in many sections consists of very bold cliffs. The hydrography consists of the usual inshore work followed by a shelf some twenty to thirty five miles wide.

This shelf is covered with water of from 20 to 50 fathoms and is thickly sprinkled with dangerous reefs to its extreme outer edge. It covers an area of about 8000 square nautical miles.

Palawan Passage.

Immediately outside this shelf is a wide and deep channel parallel to Palawan. This channel is about 40 miles wide and 1000 fathoms deep. It covers about 7000 square nautical miles. This deep hydrography may prove to be slow because of the difficulty in securing proper positions. The difficulty arises from the fact that the channel and the outer edge of the shelf are so far from land that signals and peaks will be visible only in exceptionally clear weather. The channel must be well developed as it is the direct foreign steamship route between Manila and Singapore; and the coastal shelf must be developed in detail for local traffic to ports on Palawan. This coast is so far from coaling stations that the success of the work depends on the establishment of coaling facilities for the use of survey vessels. Ulugan Bay is the logical site for such a coal pile. Topography involves about 400 statute miles of shore line.

Mindanao, south coast

This area is of considerably smaller extent than any other unfinished area, but it is treated separately as it is a distinct geographic unit. Its main difficulty lies in the triangulation through the very heavily wooded country from Cotabato to Davao Gulf. This triangulation has been started and carried some distance south of Catobato, but it was allowed to degenerate into such a thin coastal chain that excessive cutting at its numerous stations caused its abandonment. It will be necessary to reconstruct the entire scheme on a larger scale and hence with fewer stations in order to secure progress and to connect with the triangulation of Davao.

About half the topography was previously done -much of it in advance of the triangulation. If the marked stations are recoverable some of this work can be utilized. The remaining topography presents no unusual difficulty. Hydrography along this coast is a simple matter of a narrow inshore belt as the coast is bold, clean and steep-to. Some development will be needed in Sarangani Bay and around the Sarangani Islands.

Luzon to Formosa

The entire sea area lying between Luzon and Formosa is unsurveyed. Even the Spanish information is extremely meager.The area is of importance in that it lies in the direct track of transpacific liners plying between the United States and the Philippine Islands via Japan and China. It is also in the direct track between Honolulu, Guam and Manila. This route was formerly in use by the U.S.Army Transports but was later abandoned in favor of the better known route through San Bernardino Strait. That portion of the area lying between the north coast of Luzon and the center of the Bashi Channel falls within the Treaty of Paris limits. This portion contains the Babuyan,Balintang and Bashi Channels and several groups of islands arising from very deep water - a condition which justifies the belief that dangerous reefs will be found to be even more numerous than those already reported but not adequately located. Navigation is particularly dangerous in this vicinity because of strong currents and the prevalence of stormy weather. The United States Cruiser "Charleston" was wrecked here in 1899 and was a total loss.

Weather Conditions.

Work in this area will doubtless prove to be one of the most difficult tasks in the survey of the Philippine Islands. For the five months from November to March the northeast monsoon sweeps through this region with unchecked violence sufficient to prohibit hydrography.

During the four months from June to September the region lies at the heart of the typhoon belt and is on the direct track of nearly every storm which traverses the Far East. Only about three months of the year - two after the end and one before the beginning of the northeast monsoon can be classed as even reasonably good weather. This means that work must be continued throughout the typhoon season, taking advantage of each good spell and seeking refuge during the passage of storms. This also means long delays and exceedingly slow progress. These unfavorable conditions are aggravated by the absence of harbors and coaling stations. The recent erection of a wireless station at Santo Domingo de Basco will, however, be of assistance in giving timely warning of storms.

Triangulation.

On account of the distances separating the several groups of islands, the triangulation control must necessarily be derived from a large-scale scheme. Such a scheme cannot be based on the thin tertiary chain which now controls the northwest and north coasts of Luzon. It must be an independent construction with observations and a new base-line of secondary grade.

Cagayan Valley Scheme.

A corollary to the proposed secondary scheme is an additional similar scheme crossing the Caraballo Sur mountains and running the length of the Cagayan Valley to connect the new secondary work north of Luzon with that now existing in central Luzon. This will incidentally provide needed support for the present weak north coast chain by closing a new circuit. The Cagayan Valley scheme should be executed by a shore party as a preliminary to the work north of Luzon. It should also be designed to facilitate the survey of another large area designated "Luzon",east coast" to be described next. This object can be accomplished by locating minor intersection points along the summit of the ridge separating the Cagayan Valley from the Pacific Ocean and utilizing these for control of the outer coast in a manner to be described later.

Incidentally, the need for the interior triangulation is accentuated by the consideration that it affords the only means by which any reasonable standard of control for the east coast surveys can be secured. The Cagayan Valley triangulation should be terminated by the shore party on an adequate secondary base measured near the beach at some suitable site in the vicinity of Aparri. This base will do double duty by also providing lengths for the extension of the main triangulation northward toward Formosa.

Topography and Hydrography.

Topography in the Babuyan and Batan Islands will be a very small fraction of the total work north of Luzon. It will, however, prove difficult on account of the prevalence of undercut cliffs.

Hydrography will prove not only the largest element of work but one of great variety ranging from inshore development to deep-sea soundings and from clear navigable areas of large extent to detailed searches for dangerous reefs along the northern extensions of the axes of the Luzon mountain systems. The existence of pinnacle rocks is to be expected in this area. Tide-rips and overfalls are common features indicating strong currents which will require careful observation. The total area involved is about 8000 square nautical miles.

Luzon, east coast.

This is the last area which should be surveyed, as it is of the least commercial importance. The main divide of Luzon lies close to this coast leaving little possibility of agriculture on the steep slopes, and hence few settlements. The narrowness of these slopes will not permit triangulation of sufficient strength to warrant extension over the entire length involved, or 300 statute miles.

Control.

(see next page)

The most feasible basis for the control of this coast seems to be an occasional point on the summit of the ridge, located as a minor station by the previously mentioned Cagayan Valley triangulation. One such point every twenty or thirty miles will furnish sufficient basis. The character of this coast is such as to warrant the use of reconnaissance methods which would not be justified elsewhere. Hence along concave stretches of coast it will be permissible to carry a short thin chain from one fixed point to the next with possible strength added by a small local base line. Along convex stretches of coast it will be permissible to run plane-table traverses, supported where possible by graphic triangulation, between two adjacent fixed points. In short the detailed local control may be broken into short separate links, each one of which may be treated by some expedient adapted to the topography.

Topography and Hydrography.

Topography will form an important part of this survey, but little is known of the character of the immediate shoreline. About 400 statute miles are to be run.

Hydrography should prove relatively simple as the coast is bold and steep-to, and has no real harbors except the one at Casiguran Bay. The hydrography will therefore in general consist only of a narrow fringe of inshore work and a belt of ship soundings. Present indications are that the 1000 fathom curve will be found within 15 miles of the shore. While the absence of harbors simplifies development it will add to the difficulty of the survey in the same degree as in the region north of Luzon.

Ocean Hydrography.

The survey of the Philippine Islands cannot be considered complete from the scientific standpoint until the deep-sea areas surrounding the archipelago are explored. These areas promise unusual scientific and geologic interest. The deepest known sounding in the world has already been found by the German steamer "Planet" in the Pacific within 40 miles of the coast of Mindanao. Parallel to this coast lies the "Philippine Deep" - the deepest known submarine valley. This valley will probably be found to face the Pacific along the entire eastern edge of the archipelago. The proximity of this extensive deep to the main mountain masses is responsible for the tectonic displacements which are the origin of the most destructive seismic shocks felt in the Philippines - shocks far more widespread and violent than those of volcanic origin. South of Mindanao the Celebes Sea is known to contain great depths probably connected to those in the Pacific. On the west side of the archipelago the China Sea contains a similar but smaller submarine valley. On account of the rugged nature of the surrounding sea bottoms, results of more than routine interest are to be expected. Full knowledge of the adjacent depths will assist in interpreting the large anomolies now known to exist in many of the astronomic values.

To properly complete the survey of the Philippines exploration should be carried out to the boundary limits as defined by the Treaty of Paris. This program will not involve great cost or time, despite its considerable extent, since widely-spaced soundings will adequately cover most of the area.

ESTIMATE OF TIME OF COMPLETION.

The writer is reluctant to enter the field of prophecy and only does so in deference to the wish of the Director, U.S.C. and G. Survey, as expressed in his letter of March 23, 1921, No. 7, M.F.G. to the Director of Coast Surveys at Manila. As the subject is now a live issue a report of this character would be incomplete without some treatment of the question. As the basic factors in a time-estimate are highly variable the figures hereinafter given must be considered as the best present personal impressions of the writer.

Basic Element.

Topography and miles of shoreline to be run have ceased to be the correct measure of unfinished work. Similarly, triangulation is a relatively small part of the remaining field work, despite the fact that several important schemes are needed. The true measure of unfinished work is hydrographic area. Unfinished hydrographic areas may be divided into two classes - those for navigational surveys and those for scientific surveys. The former may be subdivided into two groups - shallow regions requiring detailed development and deep-sea regions. The latter consists of deep-sea regions solely.

For the navigational surveys the total areas of shallow and deep-sea work are about equal; but the time involved in the shallow areas is so greatly in excess of that of the deep-sea areas that for practical estimation the latter may be ignored. Navigational surveys will, therefore, be estimated on the basis of the three present ships operating in the shallow areas alone. For convenience it will be assumed that all three ships concentrate on each locality in succession.

For the scientific surveys of deep ocean areas there is only one ship - the Pathfinder - with sufficient coal capacity and seaworthiness. These surveys will hence be estimated on the basis of one ship only. As the Pathfinder will also be needed for navigational surveys the times for the two classes must be added.

Future Progress.

Future progress will be slower than past progress for three reasons:

1. Reduction from five to three ships.
2. Greater distances from coal and supplies.
3. Loss of time in exposed localities.

The third reason is perhaps the most serious of all since past progress has been continuous throughout the year by the simple expedient of change in location with change in monsoon; but future progress will more nearly approach the seasonal character of work in the United States and Alaska, since most localities suitable for work in the northeast monsoon have been completed. Only two large areas remain in which such work is possible, viz: the Sulu Archipelago and the South Coast of Mindanao. In all other areas the estimated times for three vessels working simultaneously must be summed.For the two areas mentioned only half the estimated time is added in the summation. The foregoing factors are exhibited graphically as follows:

Navigational Surveys

Shallow areas - 3 ships

Sulu Archipelago	-	annual
Sulu Sea	-	semi-annual
Palawan	-	" "
Mindanao	-	annual
Luzon to Formosa	-	semi-annual
Luzon,east coast	-	" "

Deep-Sea Areas

Omitted from estimate

Scientific Surveys

Deep-Sea Areas - 1 ship

Pacific Ocean	-	annual
China Sea	-	annual
Celebes Sea	-	annual

Table of Unfinished Work

The itemized results of the estimate are given in the table which follows hereafter. This table gives approximate amounts of unfinished work of each class in each area. Relative magnitudes are adequately shown without great accuracy. Hydrography is expressed in square nautical miles and topography is linear statute miles of general coastline as measured with 10 mile steps of dividers on Chart 4200. It is to be noted that a more careful estimate of detailed coastline by the Director of Coast Surveys at Manila under date of June 14, 1921 gives slightly over double the length used herein; but as above stated topography is no longer the controlling factor.

Time Estimates

The time estimates in the following table are based on actual recent times involved in the survey of the east coast of Palawan. This work began in 1912 and was only completed in 1921 after a total of ten seasons of continuous work. It was accomplished in half-year periods by one vessel for the first four years and by two vessels for the remaining six. It is assumed that two vessels in continuous operation would have completed the survey in 7-1/2 years and that three vessels would have required 5 years.

The west coast of Palawan requires about the same amount of topography as the east coast; considerably less triangulation; but a much greater amount of detailed hydrography. It is, however, assumed that three vessels working in half-year periods will accomplish the survey in the same time as the east coast, or say 5 years.

The Sulu Archipelago has somewhat more shallow hydrography which may be compensated by the absence of deep hydrography but it requires the construction of a large triangulation scheme. It is, however, also assigned the same time as for Palawan. Other regions are assigned times roughly proportional to their areas.

Areas and Times of
Unfinished Surveys

	Shallow Hydrography Sq.Mi.(naut)	Deep Hydrography Sq.Mi.(naut)	Shoreline (general) Lin.mi.(Stat)	Seasons (3 ships)	Years
Sulu Archipelago	10 000	---	600	5	2-1/2
Sulu Sea	2 000	20 000	75	3	3
Palawan, west coast	8 000	7 000	400	5	5
Mindanao, south coast	150	---	200	1	1/2
Luzon to Formosa	8 000	---	200	8	8
Luzon, east coast	1 000	3 000	400	2	2
	Navigational Surveys - Total Time				21
Ocean Surveys					
Pacific	--------	50 000	---------		2
China Sea	--------	50 000	---------		2
Celebes Sea	--------	20 000	---------		1
	Ocean Surveys - Total Time				5
	Completion of work				26 yrs.

Some slight saving in time may result from the execution of repairs during the northeast monsoon, leaving the other season wholly free; whereas in the past there has been some encroachment on it. It is, however, the opinion of the writer based on past experience, present conditions, and future indications, that the present program cannot be completed in less than 20 to 25 years.

RECOMMENDATIONS

Continuation of Survey.

The survey of the Philippine Islands was undertaken as a necessary consequence of the transfer of sovereignty from Spain to the United States. Although stimulated by military exigency, it was undertaken as a comprehensive plan carefully framed with a high regard for the duty of a sovereign power to advance the general interests of civilization in the backward portions of its jurisdiction. Duty, at first altruistic, now fortunately coincides with material interest. Twenty years of development by systematic inculcation of modern methods is now bearing fruit.

Importance of Philippine Commerce with the United States.

The total volume of trade between the Philippine Islands and the United States has been steadily increasing until in 1920 the total value of exports and imports exceeded 212 million dollars; an increase of over five times within a single decade and a growth from practically nothing in two decades. The present Philippine trade is over double the trade with Alaska, which reached only 97 million for 1920; and it is increasing at a more rapid rate as shown by the following table taken from reports of the U.S. Bureau of Foreign and Domestic Commerce.

Value of Merchandise Imported into and Exported from the United States.

	Philippine Islands			Alaska		
Year	Exports	Imports	Total	Exports	Imports	Total
1911	20 928 753	20 212 917	41 141 670	16 205 730	14 055 329	30 261 059
12	24 685 931	22 437 356	47 123 287	19 417 227	21 778 064	41 195 291
13	27 904 727	17 913 173	45 817 900	20 827 262	24 634 987	45 462 249
14	22 797 400	23 611 809	46 409 209	22 461 723	21 817 408	44 279 131
15	26 346 480	22 859 613	49 206 093	21 260 042	27 442 335	48 702 377
16	22 775 491	34 162 081	56 937 572	27 086 288	49 468 186	76 554 474
17	38 140 152	62 386 641	100 526 793	38 992 049	60 773 859	99 765 908
18	52 975 672	85 926 717	138 902 389	44 280 075	71 595 414	115 875 489
19	70 551 953	66 289 336	136 841 289	37 476 232	60 479 548	97 955 780
20	99 829 994	112 951 409	212 781 403	36 876 855	60 939 061	97 815 916

This comparison does not by any means represent the relative commercial importance of these two territories since the Philippine Islands carry on extensive additional commerce with Europe and Asis whereas Alaska confines its commerce almost entirely to the above exchange with the United States. The strictly American intercourse with the Philippines represents the greatest volume of trade between the United States and any unsurveyed portion of its jurisdiction.

Philippine Contributions

The per capita wealth of the Philippine Islands is very low from an occidental standpoint. It is therefore much to the credit of the Filipino people that they have appreciated the advantages of modern surveys to the extent of contributing two-fifths of the total cost. No other territory has made contribution to similar work financed wholly by the United States.

Political Status of the Philippine Islands.

It may be argued that Alaska, Hawaii and Porto Rico are permenent territories, whereas there is prospect of severance of the Philippine Islands from the United States. It is not within the province of this report to argue the political question of the future status of the Islands; but it must be remembered that foreign nations view them from the international standpoint as identical with other American territory and even from the domestic standpoint they are being administered under an organic act of Congress analagous to the charters of territories. In fact they are a territory in everything but name and there is no definite prospect of termination of this status. To the contrary, the most recent indications from reports of the Wood-Forbes Commission are to the effect that a long period of reconstruction under American auspices is in sight. As long as they remain American territory the survey should be actively prosecuted as planned.

A cessation of work would be hailed by radical agitators as a precursor of political abandonment and would be a blow to American prestige throughout the entire Far East. On the other hand the remarkable recent increase in trade is suggestive of the latent possibilities of ten million people, just emerging into commercial activity, when the full effect of the stimulus of American association shall have finally come into play.

The Coast and Geodetic Survey furnished one of the earliest American influences. It should continue to add its directive character to the present and coming epochs of development, in which navigation plays a controlling part.

Minimum Force

The question of a reduction in working force to meet present conditions of shortage of officers and demands for work in other regions has already been met. The sale of the Research and the surrender of the Romblon have already reduced the normal working force from five to three ships. The latter number is the minimum with which the program of unfinished work can be successfully prosecuted. It is therefore earnestly recommended that the complement of those ships now in commission be kept filled to maximum capacity; and that as soon as the field force in the United States shall have been restored to normal strength additional officers should be assigned for the organization of one or two shore parties to do needed work in triangulation, gravity and remarking of old stations.

Surgeons

A most serious condition now exists in a shortage of surgeons. Only one of the three vessels now carries a surgeon. Two more are urgently needed. The practice of carrying medical officers on Coast Survey vessels is so well established that the basic arguments need not be repeated. These arguments apply with extreme force to the present Philippine situation since the vessels are now working in regions distant from centers of population and hence distant from hospital facilities.

Minor injuries or indispositions which might be treated on board are apt to cause delay to field work by long runs to port. Moreover, infections are so much more frequent in the tropics than elsewhere that commanding officers are properly reluctant to take chances by applying amateur treatment. It is recommended that this shortage of surgeons be remedied at once.

Commissioned Officers.

In the commissioned force only a slight increase over the present complement is needed to properly provide for the present parties. A small additional number of assignments to the Philippines will make but little inroad on the considerable increase in the force expected as a result of its post-war rehabilitation in the United States.

For several years the field work has been carried on with the greatest difficulty and on several occasions has been on the verge of a standstill through depletion of personnel. The most recent tendencies give assurance that the low-water mark has been reached and that this particular phase of the situation is again receiving adequate attention.

Manila Office

In direct contrast to the favorable trend in assignment of commissioned officers the conditions of organization affecting the personnel of the Manila office are deplorable and have been steadily growing worse. They have long passed the point where mere efficiency is in question. They have been allowed to reach the point where normal operation is impossible. Lest this statement be considered alarmist the actual details will be first presented before reference to causes.

The office staff consists of two parts - a Filipino force of about forty draftsmen, clerks and recorders and an American supervising force. The Filipino force (admirably) executes the routine drafting and clerical operations, but requires much more and closer supervision than an equal number of similar employees at Washington. Moreover, for a given output, a larger number of employees is needed.

Depletion of Personnel

In the year 1914 supervision was provided by 14 Americans - a number determined by years of experience as a balanced proportion between proper treatment of field records and supervision of the Filipino force. At the time this report is being written the number has been allowed to fall from 14 to 3 * - a number wholly incapable of continuing work.

The original number of 14 was divided between the United States and Philippine payrolls as follows:

	U.S.	P.I.
Director	1	0
Computing Division	3	0
Drawing Division	3	0
Geographical Div.	0	2
Nautical Expert	1	0
Chief Clerk	1	0
Bookkeeper	0	1
Stenographer	0	1
Property Clerk	0	1
Total	9	5

Political changes in the Philippine Government caused the loss of all five Americans on that payroll. However, three of the five were in positions of clerical grade namely, bookkeeper, stenographer and property clerk - and were replaced by Filipinos who are giving satisfactory service. These three replacements involve some additional supervision, but may be dismissed as of little real moment. The remaining two Americans lost from the Philippine payroll were technical employees designated "draftsman-cartographer" and were in charge of the geographical division. This loss was serious, but as it was in a division wholly devoted to the production of maps for the Philippine Government it is not of direct concern to the United States.

*Note: This number does not include two photolithographic experts recently assigned to organize new activities. Their work is not comparable with the work of the 14 Americans in 1914.

The really serious feature of the present situation is the loss of six Americans, all of technical and supervising grade and all on the United States payroll. The fact that one - the nautical expert is now returning to the Philippines may in some measure relieve the future prospect but does not mitigate the seriousness of the crisis accentuated by his absence on leave for the past six months. Of the five remaining vacancies only one has been recently filled, and the appointee is not yet in Manila. Four vacancies still remain to be filled, as follows:

Computing Division	1 Chief 2 Computers
Drawing Division	1 draftsman

These vacancies require immediate attention because of accumulation of work due to the fact that two have existed for several years; the one just filled by appointment of a draftsman has existed for a year and a half; and the chief of computing division and the nautical expert have both been absent for six months. This accumulation of undigested field work should prevent a reduction of the office force for several years, although it may ultimately result from diminished field activity.

The condition of shortage in the Manila office has existed and has steadily been becoming more acute for five years. Directors at Manila have repeatedly called attention to it, but finding their urgent appeals fruitless and knowing the facts to be of record in Washington, they have been forced into an attitude of apathy. A reply, received six months after an appeal, stating that"there are no applicants for the position" is sore satisfaction to a helpless official marooned on the oposite side of the globe. The Panama Canal was not built by searching Civil Service files. The inducements were placed high enough to command applications. Until an adequate view is taken of the necessities of the Survey at Manila there will be no applicants.

It is feared that the situation of the Survey is not properly understood. No Director at Washington has ever visited the Philippine Islands. Despite the distance Congressional parties have done so on many occasions. A personal visit to the most important survey of recent years would be most helpful.

The Manila office not only plans the details of new field work and carries out administrative duties; but also reduces, computes and adjusts all field observations; plots and verifies sheets; compiles and traces charts; and is in addition now preparing to print the results. Sailing directions and notices to mariners are prepared and printed. In addition, topographic maps are prepared, extensive lists of geographic names are maintained and representatives cooperate with the Philippine Government by serving on official boards. Moreover, there is a steady stream of inquiry, not only for routine survey data, but also for a wide range of scientific subjects. Such inquiries arise from the U.S. Army and Navy, Bureaus of the Philippine Government, shipping and commercial interests and the general public.

Comparison with Washington.

The organization at Manila is thus parallel to that at Washington in nearly all essentials but on a smaller scale. A comparison of the ratios of administrative officers to field parties will prove illuminating. The Washington office is now directing the operation of eight vessels and two launches. The Manila office for ten years directed a force one-half this size and is now, under reduced schedule, directing one-third this force. Inclusion of geodetic parties might reduce the present fraction to one-fourth, but accumulation of past field work aggravated by the acute office shortage of the last few years means that one-third is a fair statement of actual needs.

At Washington and the several field stations in the United States there are 20 commissioned officers assigned to general administration. In Washington there is at least an equal number of technical employees of high grade in work comparable to that of the supervision required of Americans at Manila. One-third of forty is thirteen. The present number at Manila is five! and including two more enroute raises the number to seven, or only half the proportion found necessary at Washington. Detailed consideration of existing conditions in both the drafting and computing divisions will only emphasize this conclusion.

Drafting Division.

The drafting division is under a chief who has been continuously in the service of the Survey in the Philippine Islands for 19 years. His American assistants have been allowed to disappear. He is now directing a force of between 25 and 30 draftsmen without any assistance whatever. In addition he is also acting chief of the nautical division; with 3 employees charged with chart correction and sales, and with coast pilot work, notices to mariners and general hydrographic information. As if this were not sufficient, he is in addition also in charge of the geographic division with 4 employees charged with the construction of topographic maps and the maintainance and correction of lists of geographic names. Has any such condition ever existed at Washington, that one man unaided was obliged to manage three divisions with a total of 35 draftsmen and clerks? Does the administration adequately realize the danger in such a situation? What would happen in case of resignation or disability or in case needed and deserved leave were requested? Is there any one in Washington who could at once assume such responsibilities among foreign surroundings, peoples and languages; and among employees with the peculiar psychology of Filipinos?

If a man of this caliber is found, is it conveivable that he would accept this position under existing conditions and pay? The only possible answers to these questions are :

> that good administration requires the constant training of understudies;
>
> that another draftsman should be at once sent to Manila to restore the staff of the division to its normal need of three; and
>
> that the pay of the chief of division be made commensurate with his ability and responsibility

There has been incomprehensible official oversight with respect to this position. Faced with inability to continue support of his family in Manila on a base pay of $ 2400, which was fixed several years before the rise of prices due to the war, the chief of this division in conjunction with the writer arranged for the grant of a per diem of $ 2.50 from the Philippine Legislature. The Coast Survey took no initiative in the matter. It was arranged through private effort, but assisted by the kind and cheerful agreement of the Director of Coast Surveys to sponsor whatever documents might be prepared. The per diem was a grant made largely in recognition of special local geographic knowledge acquired through years of experience.

Since that time three individuals, two of whom had no previous Philippine experience, have been appointed and promoted to higher salaries reaching $ 3000. This places the United States in the position of taking refuge behind the skirts of the Philippine Government in the salaries of its own officers and humiliates an officer who has made Philippine chart production possible through 19 years of capable effort. At the present moment he stands fifth on the United States (account) out of seven Americans now in the Manila office and enroute thereto.

His salary should be at once raised to at least an equality with that of the highest, and his per diem should be left untouched in recognition of his much longer service and experience. Such action was indeed foreshadowed in a letter of the Chief of the Division of Hydrography and Topography to the Director of Coast Surveys announcing the terms of appointment of the two photolithographic experts; inquiring whether there would be objection to such appointments at the salaries found necessary; and suggesting the necessity for a general revision of salaries in the Manila office. To have objected at that critical time after orders for machinery had been placed and to have thus blocked the consummation of plans he had personally sponsored would have been ethically impossible; and assent was of course given. The tone of the inquiry seemed to warrant faith that the inequality would be remedied, but after more than a year no action is evident.

Computing Division

In the computing division conditions exist parallel to those in the drafting division. The chief of the computing division arrived in Manila in April 1902 on the same steamer with the present chief of the drawing division, and has remained continuously in the same position. For many years after the full organization of the division he had two American assistants. During these years excellent progress was made on the adjustment of the triangulation, as herein before described and as shown on existing progress sketches of completed work. During the past five years, however, resignations have been replaced so irregularly that at times he has had one assistant and at other times none. At the present time he is absent in Washington writing this report and his single assistant has left Manila enroute to the United States and the division is thus abandoned, so far as direction is concerned. There are left five Filipino employees not one of whom is a computer! Only one is a high school graduate!. What would be the effect on the work of the Survey at Washington were the division of Geodesy filled with sixth and seventh grade graduates, even though these had had years of experience in copying and simple figuring and were faithfully and diligently doing their best? It is feared that the administration fails to appreciate the seriousness of the facts. Ostensibly the Survey is maintaining an office in Manila for the dissemination of information; in reality it is either unable to reply to certain classes of requests or, should the Director be reluctant to publicly admit this fact, it incurs grave risk of officially spreading misinformation.

All Philippine bureaus have one or more assistant directors, even though they are headed by men of long local experience. The Coast Survey has made no provision for an assistant director at Manila, and hence considerable work connected with administration falls on the chief of the computing division. This condition has been accentuated by the short two-year terms for directors. How much in the nature of effective adjustment of difficult triangulation circuits can be expected of a division consisting of a chief with divided duties and either one computer or at times none; even though clerical assistance is available? This division is in urgent and immediate need of a chief and two computers.

Continuity of Service.

Continuity of service is even more vital than number of employees. The geography of the Philippine Islands is an intricate subject. A recent count gives 7083 islands. The list of geographic names in use at Manila runs well over 100,000. A two-year term of service is barely sufficient to acquire technical working knowledge of essential details of geography. It requires this amount of time to acquire reasonable familiarity with the 1500 topographic and hydrographic sheets or with the 10,000 field records on file.

Least square adjustment is an intricate mathematical process compared to the simple requirements of geography and filing systems. Few computers are able to learn its effective use in less than a year, and to handle the more complex cases of circuit closures requires two. Circuits are frequent in Philippine work and hence urgently needed work has to be postponed pending education.

Failure of present system

Every computer sent to Manila has been either wholly untrained or has been given a hasty smattering of two or three months in preliminaries. The writer has labored for twenty years laboriously teaching the details of triangulation adjustment to ten different individuals. Of this number only two ever returned for a second detail and no one for a third. Effort at Manila has been rendered futile through inability at Washington to appreciate the true economy of considerable salary increases for subsequent details. At the end of twenty years what organization has been built up? Not a single individual of technical grade! Could anything be more destructive to morale?

Responsibility

The ultimate reason for these conditions goes back to the organization of the Philippine work in 1900. Computers and draftsmen were not given statutory positions but were placed on a temporary basis payable from party expenses. Granted this plan as fixed, the present reason for these conditions lies in divided authority. Responsibility for work rests in Manila while salaries are fixed in Washington.

How much more than the past twenty years is needed to demonstrate that men will not remain in Manila at salaries current in Washington,? The occasional individual who responds solely to the lure of travel is not a permanent asset.

It is feared that the examples of the chiefs of the computing and drafting divisions has had a damaging effect. That these have continued so long on nominal salaries cannot be construed to mean that others will likewise; as in fact is vividly proved by present conditions. Appeals for remedy have been overlooked for so long that a state of indifference has been engendered.

Remedy

It Is again recommended that the salary schedule of the Manila office be reorganized on a more liberal basis; that no terms of office service be for less than three years; and that a substantial increase be granted to induce the return of desirable employees for subsequent terms of service. An entrance salary of $ 2400 would attract experienced men. An increase of $ 400. to secure a second term is real economy when considered in the light of the enormous overhead expense involved in travel and training.

An excellent solution would be to remedy the original organic flaw by providing for the transfer of computers and draftsman between Washington and Manila by placing them all in the same status. On several occasions experienced and capable individuals have assured the writer that they would welcome an opportunity to serve in Manila if their positions in Washington could be assured them on final return. Recommendations for this reasonable solution have not yet been adopted. It is again repeated. It must, however, be accompanied by an adequate bonus for foreign service.

Allotments

The recommendations made heretofore reduce ultimately to terms of expense. It has been suggested that no further allotment of funds to the Philippine Islands can be made, because of the advanced state of that work and the backward state of work elsewhere. It is hoped that parts of the foregoing discussion may have adequately pictured the extent and the importance of work yet undone. Recent assignments of commissioned officers are hopeful auguries that no further reduction in field work is contemplated but rather that reorganization is again in progress. The office is therefore the critical factor. No appeal is being made for expansion but only for restoration. In the selection of appointees to Manila the idea of cost should not control. There is no point in the whole organization of the Coast Survey where greater results are assured for slight expense.

A quarter of a million dollars is being spent by both governments on the Philippine work. Ten thousand means the difference between an effective organization and a helpless one. Is it good judgment to paralyze output for a saving of 4%? The field work has already been reduced two-fifths. Is it not wise to restore a fraction of the saving to convert unused records into publications?

The United States is obligated by its agreement with the Philippine government to supply the technical officers for the Survey in office positions as well as in the field. If conditions are such that it has become impossible to fulfill the agreement representations to that effect should be openly made to the Philippine government with a view toward abrogation.

Term of Director.

The arguments favoring continuity of service may be held inapplicable to field officers subjected to the daily stress of severe physical effort. They do, however, apply with added force to the position of Director. Intimate knowledge of people, customs, business and language are desirable in addition to technical knowledge of geography, geology, meteorology and similar local features. To formulate future policies long residence and acquaintance with the spirit of the community are essential. The acquisition of scientific knowledge is a plant of slow growth and its digestion must be at leisure. How would the service prosper with a New Director at Washington every two years? How much of the valuable scientific work of Col. Burrard, now Surveyor-General of India, was accomplished during his first two years of service?

There is no physical excuse for such frequent changes at Manila. American business men reside there over long periods of time without danger to health and the same thing is true of Americans in the Insular service. Such recuperation as may be needed is supplied by vacation trips to Baguio, China, Japan or the United States; but complete disruption of business is avoided by the return of the individual.

Organization

The Philippine Survey has a wide variety of functions. Nearly all the activities carried on in the United States have some counterpart there. Its status as a field party on the basis of a vessel under the direction of a single division at Washington has always seemed somewhat anomalous. Inasmuch as its functions cover those of several divisions it would seem to be a more rational plan of organization to constitute it a separate division reporting immediately to the Director. It is suggested that the possibilities of this plan be given consideration.

Relations with the U.S. Army

Army relations with the Coast Survey involve two features of personal concern to both field and office forces. These are the privileges of purchase of supplies from the Army commissary and of admission to the Army hospital.

Commissary Privilege.

The commissary privilege has been enjoyed both by messes and by individuals since the beginning of operations, or for over 20 years. This enjoyment has been uninterrupted except for a brief period in 1903 when they were erroneously withdrawn by the Chief Quartermaster at Manila; but they were immediately restored on appeal to the Secretary of War. This privilege has been enjoyed for so long that it has come to be a prerequisite of office and hence its withdrawal constitutes a real reduction in salary. In March 1921 the Chief Quartermaster at Manila gave notice of termination of the privilege on the ground that the

Coast Survey was not mentioned in recent War Department regulations as among the organizations entitled to its benefit.

In the case of an employee maintaining a family in Manila an increase in living expenses of fully $ 25.00 a month is involved. It also means a proportional increase in the ship mess accounts on all stores bought in Manila, where the vessels usually stock their food-supplies. It is recommended that this matter be fully investigated with a view toward taking such steps as may be needed to restore this long standing privilege with a precedent of 20 years; or else to provide equivalent compensation.

Hospital Privilege

Admission to the Sternberg General Hospital, maintained by the Army at Manila, was secured about two years ago. This privilege is of very great benefit in the existing situation at Manila where hospital facilities for the use of Americans are now seriously limited. At the outset all technical employees (this term being used to distinguish Americans from Filipinos) together with members of their families were admitted without distinction. Subsequently members of families were denied admission.

The writer drafted the original letter suggesting the need for this privilege. He had "members of families" conspicuously in mind; but through inadvertance did not make use of the specific expression. In fact this distinction did not occur through the unconscious impression that extension of hospital facilities to the Coast Survey would automatically extend to " members of families ". This impression apparently extended throughout the subsequent correspondence and even to the hospital authorities themselves during the first year of operation. As the distinction appears to be somewhat artificial it is thought that the attention of the Secretary of War would be sufficient to remove the anomoly.

Publication of Results.

Publication of work at Manila has heretofore been confined to charts, maps, sailing directions and notices to mariners. A large amount of data on triangulation and astronomy has been accumulated, but no provision for its publication has ever been made. This valuable information should not be indefinitely withheld. Between 1909 and 1912 the writer prepared complete manuscript and typewritten copies for the publication of all triangulation results on Luzon and adjacent islands from Aparri to Marinduque and Lamon Bay. This copy treated the details of adjustment, geographic positions and descriptions of stations; and in addition described the observed deflections of the vertical, computations of topographic deflections and all other considerations leading to the adoption of the fundamental position and azimuth of the "Luzon datum".

When inquiry was made as to the manner in which the work might be published the only response from Washington was a statement that no funds for publication could be used outside the government printing office at Washington. As the writer and all essential data were in Manila and as it did not seem feasible to read and correct proof and supervise the details of publication at a distance of thirteen thousand miles the matter was left in suspense. After the lapse of ten years so much additional data has been accumulated that thorough revision, rearrangement and extension is necessary. This work is of such value to the Philippine government that it is quite likely that Insular funds may be secured for publication at the Bureau of Printing in Manila, an organization well equipped to do excellent work. This suggestion has not been previously made because in this case the seal of the Philippine Islands should appear on the title page.

There would, however, seem to be little valid objection to the joint use of two seals - those of the Coast and Geodetic Survey and of the Philippine Islands. It is therefore recommended that consideration be given to this as a feasible program for the publication of results at Manila as fast as they may become available.

CONCLUSION

Results Accomplished

In conclusion attention is invited to the fact that for 20 years the Philippine Survey has operated semi-independently. It has operated so smoothly that Washington has been relieved of many of the details of administration. When finished chart-tracings have regularly arrived for publication the multifarious preceding steps have not been conspicuously evident.

The Philippine Survey has executed 1500 topographic and hydrographic sheets and has acquired 10,000 volumes of records and computations. The present chart catalogue shows 150 publications, many of which have been through several editions. A complete set of sailing directions for the entire Philippine archipelago has been published. In addition to actual surveys an extensive collection of collateral geographic information has been acquired.

The work has been comprehensively planned for years in advance; and while the severe limitations imposed by previously described conditions have caused the results to fall short of expected ideals nevertheless the final outcome is a connected system of reasonably strong and complete work based on a single uniform set of positions.

Requirements

The only requirements of Washington are men and money. The reduced program of field work will demand smaller drafts on each. But it is essential that the present three ships be kept filled to capacity with field officers and that the office force be restored to normal strength and be maintained in continuous long-term service by more liberal treatment and by greater diligence in filling vacancies. Irrespective of cost men are a necessity.

If they are provided the Philippine branch of the service will continue to produce the results.

Respectfully submitted

E. R. Frisby

To the Director,
U.S. Coast and Geodetic Survey,
Washington, D.C.

Through

The Chief, Division of Hydrography and Topography.

Washington, D.C.
October 15,1921.

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PHILIPPINE ISLANDS
COAST AND GEODETIC SURVEY
PROGRESS SKETCH
SHOWING
ADJUSTMENT OF TRIANGULATION
TO DEC. 31. 1920.
Scale, 1:1,600,000
Heavy lines show completed adjustments.
Light lines show unadjusted field work.
Broken lines show field work incomplete.
Principal Astronomical Stations with telegraphic longitude.
" " " " chronometric "
Base line.
Uniform geodetic positions based on the "Luzon Datum" have been computed for all adjusted work.
LUZON
MINDORO
SAMAR
LEYTE
NEGROS
BOHOL
MINDANAO
SULU ARCHIPELAGO