MAPPING THE LOW-WATER LINE OF THE MISSISSIPPI DELTA

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NOTE ON AUTHORS

Mr. William SHOFNOS, a native Washingtonian, graduated from the University of Maryland in 1924 with a B. S. degree in Civil Engineering. He also attended Georgetown Law School and received his LL. B. degree in 1929 and has been a member of the District of Columbia Bar since 1929. Mr. SHOFNOS entered the Coast and Geodetic Survey as a mathematician in 1925, assigned to the Division of Geodesy. In 1931 he was transferred to Tides and Currents Division and is at present the Chief of the Tides Branch. He is a member of the American Congress on Surveying and Mapping, American Geophysical Union, Washington Society of Engineers, and Tau Beta Pi Fraternity.

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INTRODUCTION

The Submerged Lands Act of 1953 (Public Law 31) which confirms and establishes titles of the States to lands beneath navigable waters within their *historic boundaries* has again brought into focus the importance of adequate tidal-boundary determinations. The Act stipulates that the base-line for the measurement of seaward boundaries of the states where no indentations exist is the *line of ordinary low water*. The term *ordinary low water* lacks the technical precision that is required in the establishment of tidal boundaries. However, *ordinary low water* where used is usually considered to be synonymous with mean low water.

The establishing of boundaries determined by the course of the tides involves two engineering aspects : a vertical one predicated on the height reached by the tide during its vertical rise and fall and constituting a tidal plane; and a horizontal one relating to the line where the tidal plane intersects the shore to form the boundary desired. The first is derived from tidal observations alone and once derived (on the basis of long-period observations) is for all practical purposes a permanent one. The second is

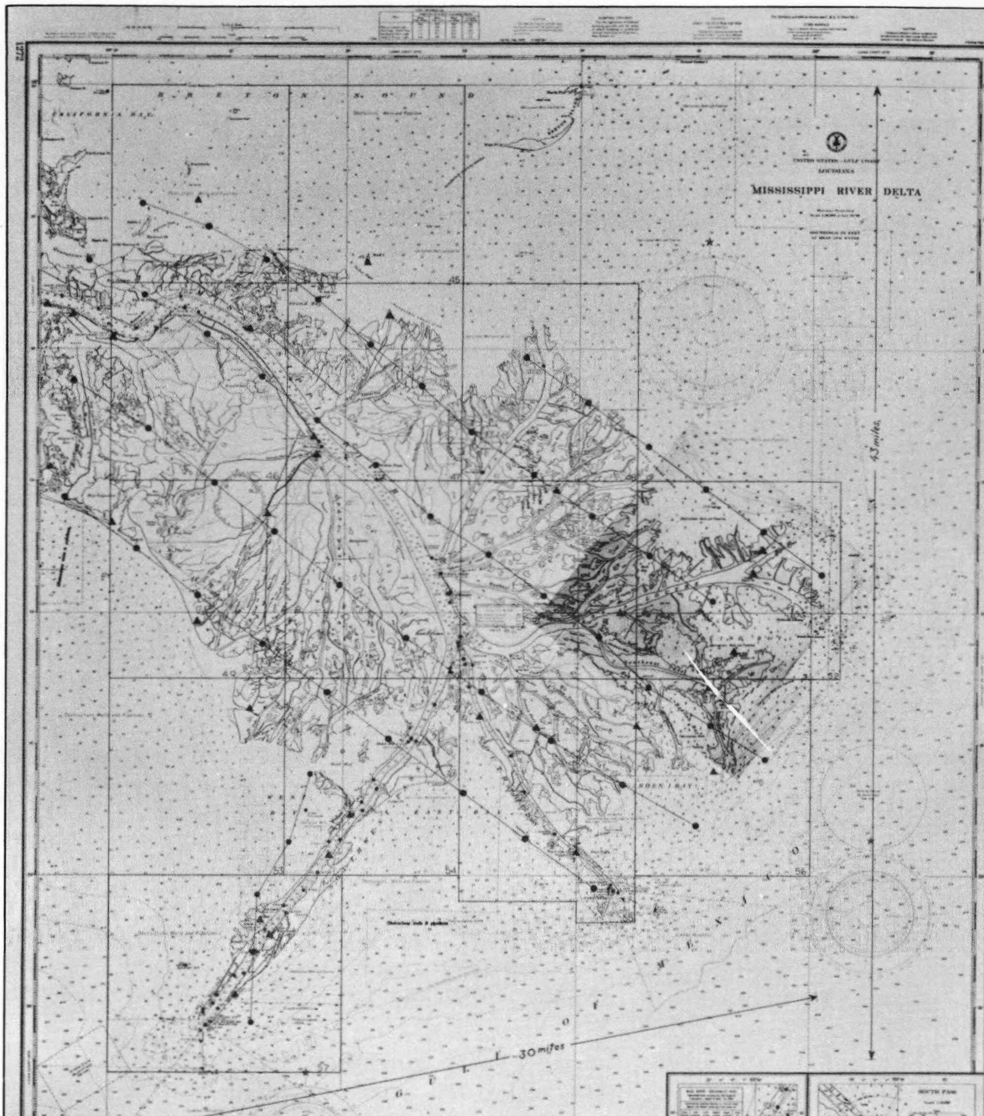
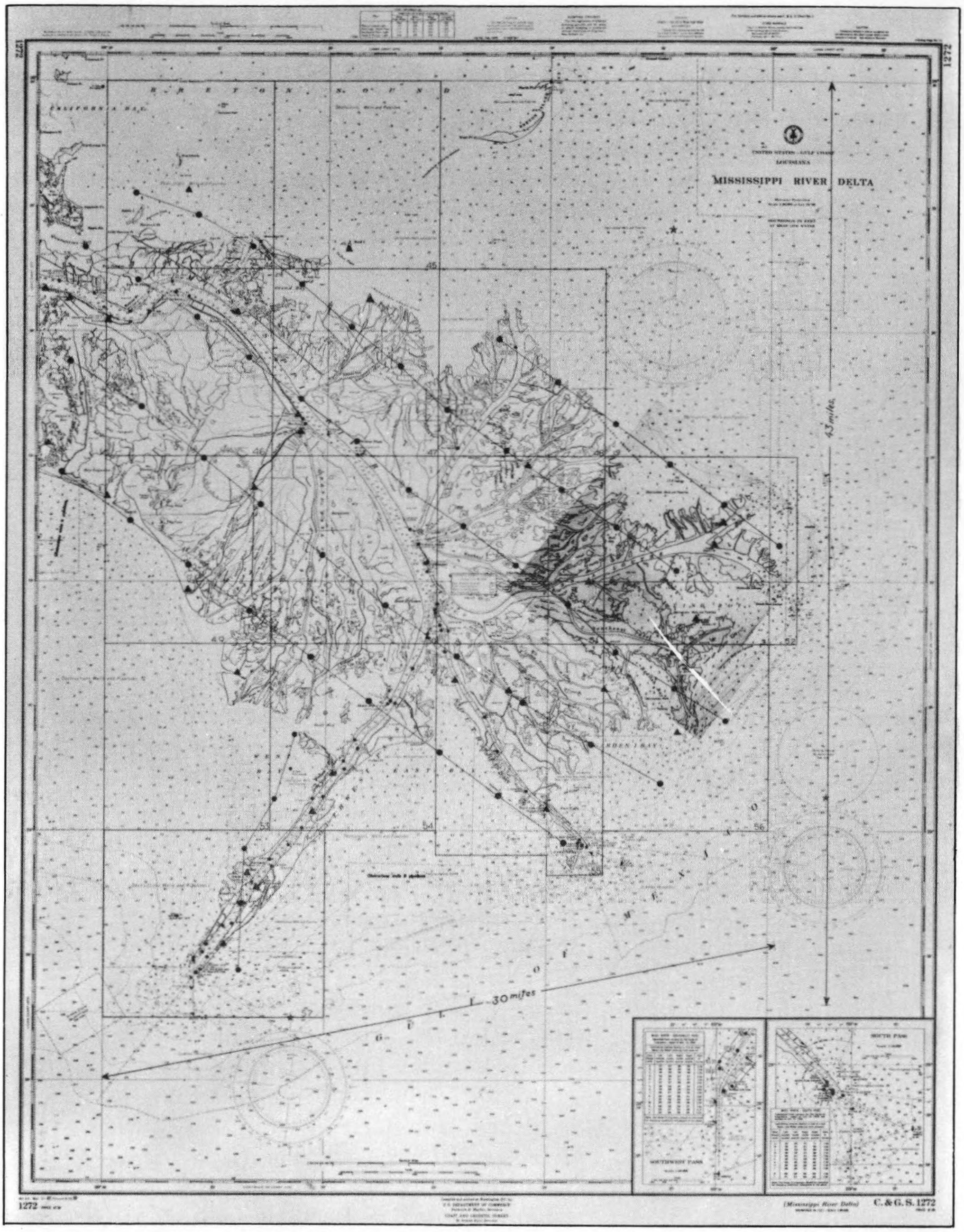


Fig. 1. — Project diagram showing layout, nine-lens photographs, and control stations.

dependent on the first and can be determined therefrom by leveling from tidal benchmarks, or by photographing the shore at the proper instant of the tidal cycle, i.e., at mean low water, or mean high water, etc. The boundary line thus determined and mapped on the national horizontal datum is permanently recorded in horizontal position as the boundary on the specific date of the survey. However, this boundary, the actual line on the



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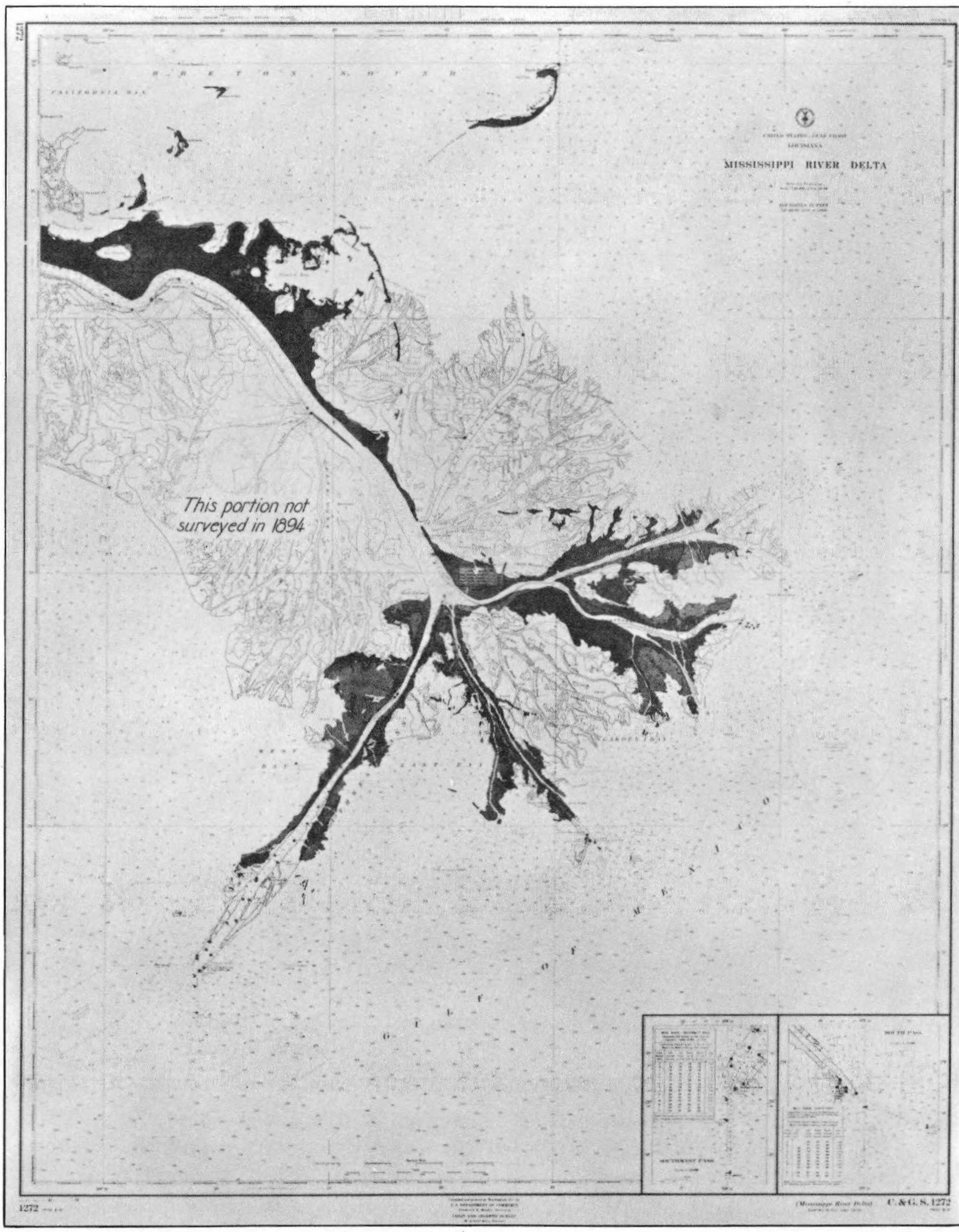

Fig. 2. — Comparison of 1894 and current nautical charts.

ground, is subject to change by erosion, accretion, and the works of man.

This paper describes the application of modern methods of infrared photography and photogrammetry to mapping of the mean-low-water line of the Mississippi Delta country where ground survey methods are prohibitively difficult and expensive because of the swampy character of the terrain. Of particular interest are the tidal characteristics of this area and

Fig. 3. — Comparison of shoreline from 1922, 1932, and 1958 surveys.

the facility with which the low-water contour is captured by the infrared photography even in extremely shallow and muddy waters.

This is a cooperative project between the Coast and Geodetic Survey, the Federal Bureau of Land Management, and the State Mineral Board of the State of Louisiana. The purpose of the project is to provide additional basic tidal data and up-to-date planimetric maps for revision of Coast and Geodetic Survey nautical charts; and to provide the Bureau of Land Management and the State of Louisiana with a special set of these maps showing the mean-low-water line and the coordinates of turning points selected along that line by the State of Louisiana and the Bureau of Land Management. The maps from this project will be used to administer the development of the extensive offshore oil and gas fields in this area. Figure 1 shows the map layout of the project comprising 14 - 7 $\frac{1}{2}$ minute quadrangles and a land area of about 450 square miles.

Low-water-line mapping of most of the coast of Louisiana was completed about two years ago but the Mississippi Delta and the coastline around Atchafalaya Bay and Marsh Island, because of the more extensive foreshore areas and shoals, had to wait until arrangements could be made for detailed tidal surveys and the establishment of accurate tidal datums.

The changing nature of the Mississippi Delta and the consequent need for periodic remapping, or map revision, for the up-to-date maintenance of nautical charts is illustrated in figures 2 and 3. Figure 2 shows the limits of the Delta from an 1894 chart (shaded area) (surveys between 1859 and 1872) in contrast with the present limits (chart 1272). Extensive changes are apparent to the east and south; no comparison is indicated on the western shore as that area had not been surveyed and is not shown on the 1894 chart. The Coast and Geodetic Survey mapped this area with aerial photographs for the first time in 1922. Figure 3 shows the changes in the Garden Bay area between photogrammetric surveys of 1922, 1932, and the present.

MAPPING PLAN

The Delta, as one would expect, is low lying and predominantly marsh with many bayous and shallow bays, some of the latter being very large. Except for fringes of trees along the river and main passes the vegetation is principally marsh and wild cane. The latter is found in places throughout the Delta but predominates along much of the coast. It is extremely dense and grows to a height of perhaps ten feet (figure 4). The coast area floods at high tide, and seen from seaward the apparent mean-high-water line is against the marsh and wild cane. The mean-low-water line is mostly along the mud banks and flats, but is rarely seen because only a very few of the low waters occur during daylight — a circumstance peculiar to this area and extremely important as regards aerial photography at low-water stages. Travel in this area must be by float plane, helicopter, marsh buggy, or boat. Boats are of little use outside of the main channels because of the extremely shallow waters. Ground survey activities such as leveling, traverse, and so on are extremely difficult in any case and next to impossible around much of the coastline. Consequently, the plan for the project called for maximum use of aerial photography, and a minimum of ground work. The project included these primary phases or activities :

(1) Nine-lens photography for basic planimetric mapping was taken in October, 1958. Figure 1 shows the layout of photographs and the horizontal-control stations identified to control the plot with those photographs. The photogrammetric plot and the subsequent mapping was at scale 1/20 000 and the illustration shows the area covered by a single nine-lens photograph. This photography was a very real advantage because of the relative scarcity of existing control and the difficulty of identifying control on the aerial photographs.

(2) Tidal surveys, to establish basic tidal datums, started in April, 1959 and were to be completed in April, 1960.

Fig. 4. — Typical growth of wild cane.

(3) Low-water infrared aerial photography controlled from the tide stations after establishment of the mean-low-water datum was taken in December, 1959. Infrared photography was selected for mapping the low-water line because it provides a sharp contrast between land and water and thus captures the tide-stage contour accurately.

(4) Field examination of the infrared photography was made at mean low water by float plane or helicopter in December 1959 and early January 1960.

(5) Completion of the basic maps and compilation of the low-water line from the infrared photographs were to be completed the summer of 1960.

Prior to this project very little tidal data were available for the Mississippi River Delta area. Tidal datum planes (mean low water, half-tide level, mean high water, etc.) had to be determined. While the plane of half-tide level could be assumed to be at approximately the same elevation along considerable stretches of the outer shore of the Delta area, the range in tide and consequently the elevation of mean low water below half-tide level could vary appreciably from place to place due to differences in hydrographic features. Consequently, observations had to be made at a sufficient number of places to determine the mean low-water datum for all places around the entire outer shore of the Delta.

After a careful and extensive reconnaissance of the area, eight tide stations were established. Their locations are shown in figure 8. Two of these are standard tide gauges set on semi-permanent structures of the

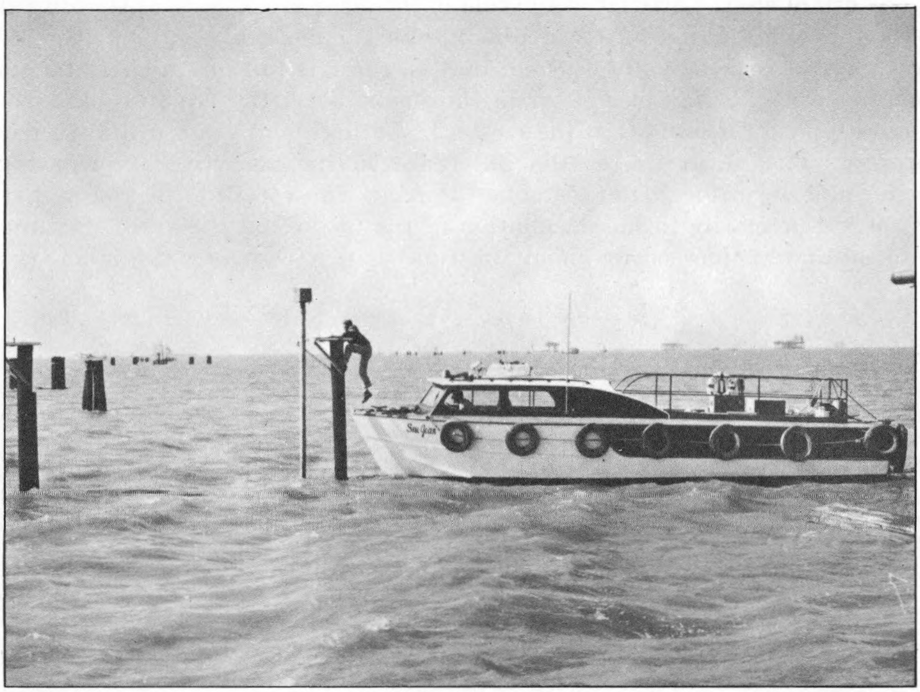

Fig. 5. — Portable tide-gauge installation.

Kerr-McGee Oil Co. at Breton Island and the U. S. Coast Guard at South Pass. The remaining six are portable gauges. These require servicing every three or four days. They had to be placed far enough offshore so that there would always be at least five feet of water at low tide. Consequently, many of the portable gauges and most of the tidal benchmarks (three to a station) are on wooden piles driven at least 20 feet into the Gulf bottom. A typical portable tide-gauge installation is show in figure 5.

Observations at all stations were started no later than April 1959 and were continued through April 1960.

A period of 19 years of tide observations is generally considered as constituting a full tidal cycle, for during this period of time the more important of the tidal variations will have gone through complete cycles. Tidal datum planes thus determined may be taken to constitute a primary determination. However, long experience and analyses have disclosed that good determinations of mean values can also be obtained by a direct comparison with simultaneous observations at some nearby place with similar characteristics and for which a 19-year series of observations is available. It became quite apparent when the tide observations at the various stations were examined that, without exception, the characteristics of the tide at the 8 tide stations were quite similar to those at Pensacola, Florida. Since a 19-year series of tide observations are available for Pensacola (1940-1958) mean low water and other tidal datums around the Delta will be determined from twelve months of observations compared with simultaneous observations at Pensacola.

Certain characteristics of the tide in this area are of critical significance as regards the taking of aerial photographs at mean low water. The tide in this area is principally diurnal, that is, there is but one high water and one low water a day except when the moon is on the equator. Figure 6 shows typical tide curves at the western, southern and eastern limits of the project. The mean range (the difference in height between mean high water and mean low water) is about 1¼ feet. The variation in rise and fall is related primarily to the declination of the moon and the sun. Maximum and minimum tides occur about the time of tropics, when the moon is at

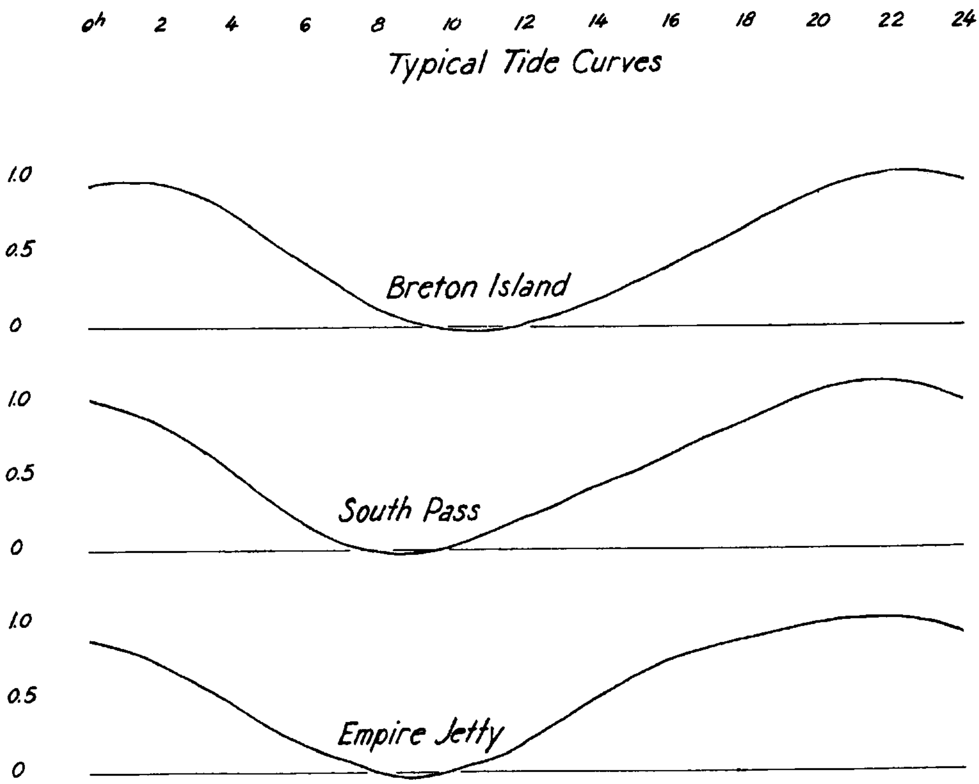

Fig. 6. — Typical tide curves.

maximum declination. Of more importance is the fact that most of the low tides reaching mean low water, or below, occur at night. This is due to a combination of factors which will not be discussed here. Daylight (photographic daylight) low waters occur almost exclusively during the period from late November to late January. Consequently our low-water aerial photography had to be taken during this period of 1959-60, after about six months of tide observations, or a year later in 1960-61.

The delay of one year was undesirable both from the standpoint of map needs and costs. Consequently it was decided to determine preliminary planes of low water at the tide stations based on about six months of tide observations, compared with the 1940-1958 series at Pensacola. This was done and it was on the basis of these tidal planes that the photogrammetric work was begun. It is very unlikely that the mean-low-water plane will change more than 0.1 foot when the complete year of observations is obtained. If there is a change, it now appears that the datums will be slightly higher than determined from the six-month series.

Several days of daylight low water and clear skies were needed for the aerial photography. From the foregoing it is evident that this is a rare combination on the Delta. It was not realized how rare until after arrival in the area. Tide predictions indicated some 25 low waters during photographic daylight (9:00 a.m. to 3:00 p.m.) between 28 November and 30 January. Long-term weather statistics indicated cloud cover of over 10 per cent for about 80 per cent of the time. Thus only five days for mean-low-water photography could be expected between 28 November and 30 January. Plans for the infrared photography had to be based on this estimate but there was still a wild card in the deck—the wind.

As previously stated the mean range of the tide is about 1¼ feet. Because of the extensive shallow waters surrounding the Delta, a continuing northerly wind can cause the tides to run as much as ½ foot lower than predicted and a continuing southerly wind can make them ½ foot higher than predicted, i.e., eliminate the predicted mean low water. Figure 7 illustrates this. This shows the predicted and actual tides for December 1, during a norther, and the predicted and actual curves for 16 December with fairly strong winds from the south. There was no way to predict what the winds would do to the plan of operations -- one could only hope, pray, and worry.

Now let us see what actually occurred. Due to the norther that started just when the aerial photography was undertaken there were four days of combined low waters and photographic weather between 29 November and 7 December. Tide and weather records show that only one such day occurred for the entire period after that, that is, from 8 December to 30 January. The infrared photography was finished by 7 December and it is well that it was because waiting in the area for another seven weeks would have provided only one good photographic day.

The aircraft was based at New Orleans — a distance of some 80 miles. The primary tide station for controlling the photography was at South Pass where telephone communications with the flight crew were available. Figure 8 shows the tide stations and the infrared flight lines to be covered at an altitude of 10 000 feet, that is, at scale 1/20 000. A tide observer was

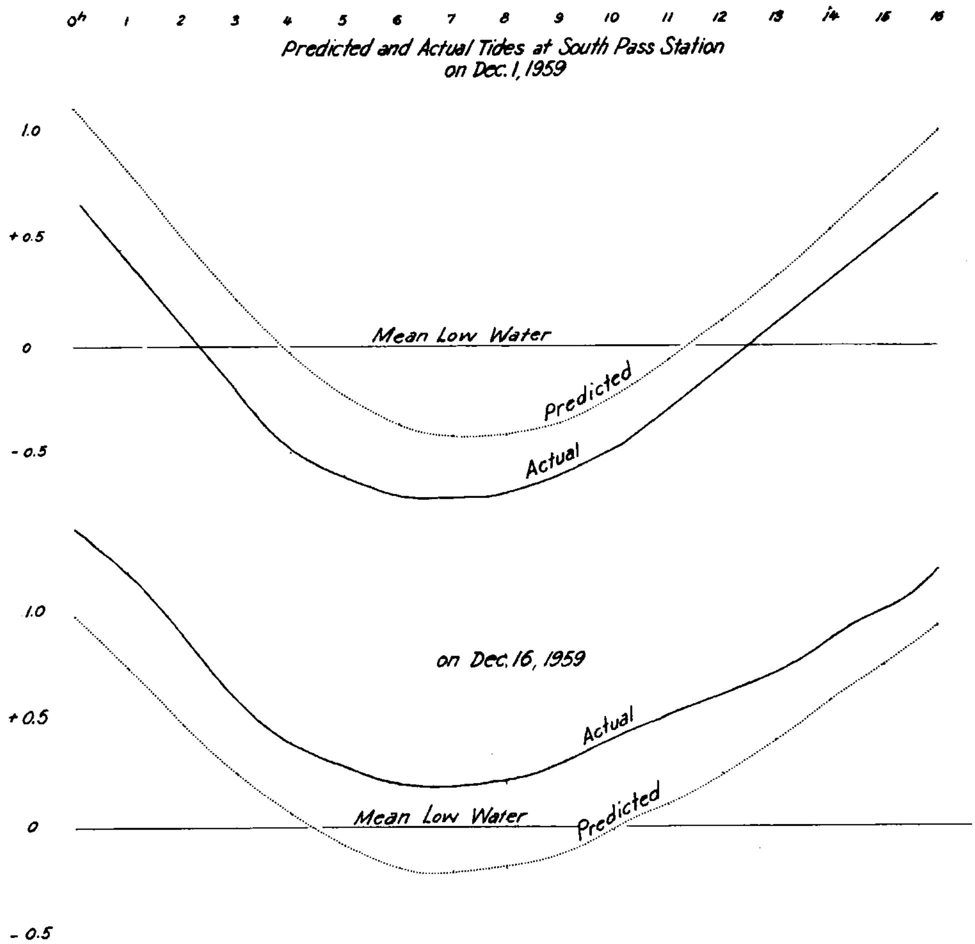

Fig. 7. — Tide curves for December 1 and December 16, 1959.

also quartered at Breton Island, this being the only other station where quarters were available for an observer. The remaining six stations in the project could be occupied only from a fairly large boat that could stand the weather and also provide protection for the observer. The Coast and Geodetic Survey launch was used to occupy first the Empire Jetty and later the Joseph Bayou Station. A launch, not equipped with radio, and observer loaned by the Texas Company through the good offices of Mr. Martin Standard also occupied the Lonesome Bayou Station for several days to read the staff in case of a gauge failure.

Communication between the tide observers and the aircraft was by handy-talkie radio and after installation of a proper aerial in the aircraft this communication worked very well.

At about 5:00 a.m. each morning, the observer at South Pass would plot a tide curve for the preceding eight or ten hours and then project this curve to determine the approximate time of mean low tide for that day. He would then call the flight crew telling them whether to come to the area and, if photography was to be attempted that day, when to arrive on

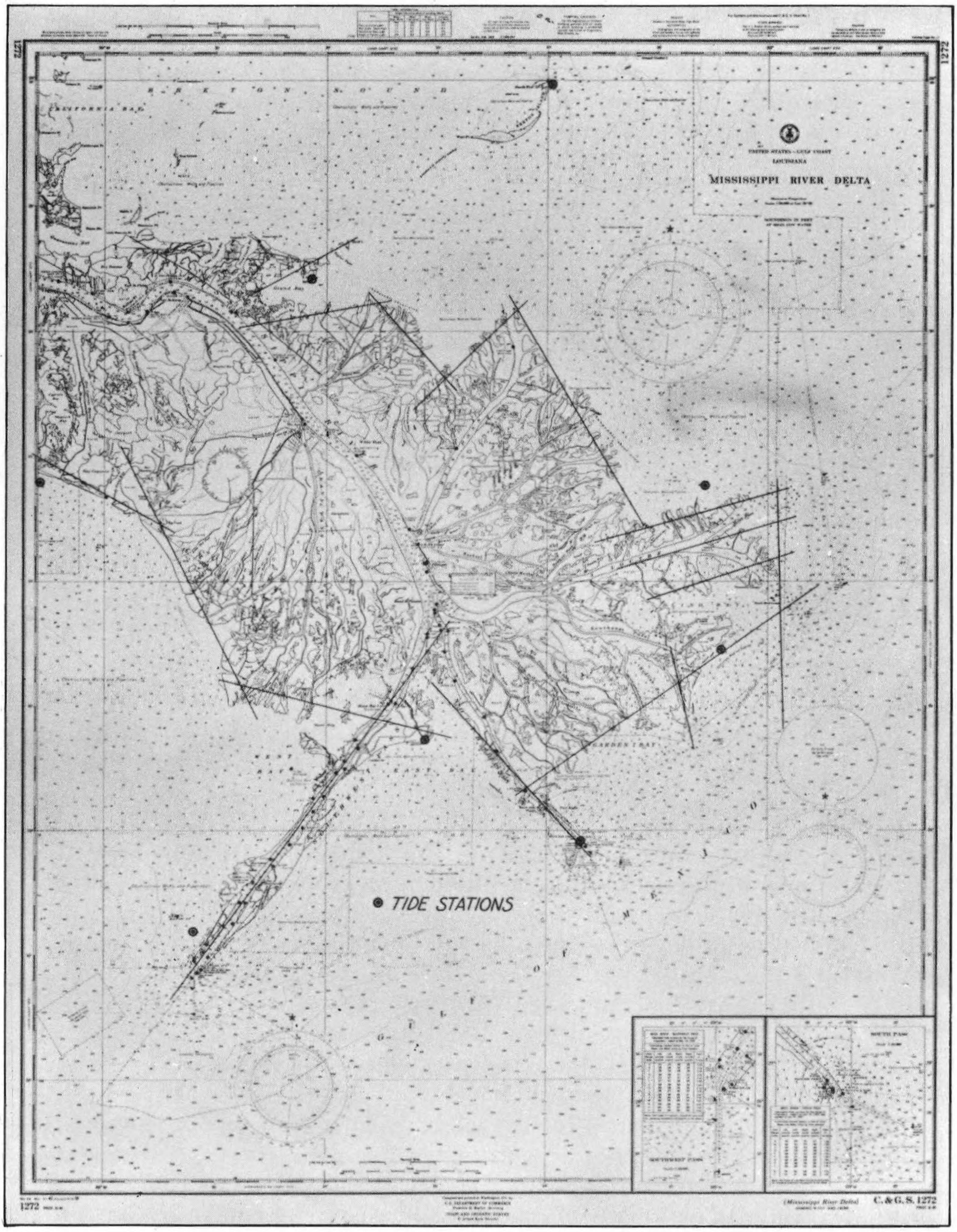

Fig. 8. — Tide stations and infrared flight lines.

the project. The latter was necessary because when strong winds were blowing the time of the tide might vary an hour or more from the predicted time. Once in the area the plane was directed by radio, that is, was told what line to fly at what time.

A preliminary flight inspection around the entire outer coast was made at low tide early on 29 November. This inspection was considered essential since there were a number of unknowns critical to the project. For example, it was essential to know whether the low-water line was generally just inside or outside of the edge of the marsh and wild cane; where the shores were steep and represented an easy mapping job; and where the more extensive mud flats existed since these would be the more difficult to map. This inspection proved to be invaluable. The western shore was found to be generally steep and the more extensive flats on the eastern shore that had to be given particular attention were spotted. Needless to say, the field crew was delighted to find that the mean-low-water line in most instances, was outside the edge of the grass and wild cane.

Taking all of this photography exactly at mean low water would have required more flying days than could be expected even with extreme good luck. This is because of the obvious fact that the tides don't go exactly to mean low water and stand there, or at least only rarely. The tide will usually either not go as low as mean low water or it will go below mean low water. Figure 7 illustrates the conditions under which the infrared photography had to be taken. Because of the early morning occurence of mean low water, it was necessary to work on minus tides and to photograph the coastline as nearly as possible at the time the rising tide crossed mean-low-water datum; the rate of rise being about 0.2 feet per hour. The time difference between the occurrence of mean low water at different stations helped somewhat, that is, the tides could be followed, but these differences are small for most of the project.

The field crew had to assume that one good day might be the only and last day. Consequently, photography was started with the tide as much as 0.4 or 0.5 feet below mean low water on the less important lines, that is, on the west side where the shore was steep; then moved over onto the most important lines just before or at the time of mean low water; photography was then continued on other lines until the tide was up to 0.1 or 0.2 feet above mean low water. This latter photography might never be used but then again it might be better than nothing.

On subsequent days the same procedures, more or less, were followed, cleaning up the more important lines close to the mean-low-water datum and repeating those that had been flown slightly off. On the flat shores lines were deliberately repeated at slightly different stages of the tide so as to have a means of interpolation in cases where the photography couldn't be taken at exactly mean low water.

As mentioned previously the norther that blew into this area about 28 November continued more or less unabated for about a week. It held the water off the shore making the tides go lower than predicted and causing mean low water to occur later in the day. It was accompanied by generally clear skies providing four days of photography in the first nine days on the job.

In summary, the outer coastline, with the exception of a small section of the west shore, is covered with infrared photography taken between zero and —0.3 feet of tide. All lines on the project have been photographed from two to four times with coverage ranging between + 0.2 and — 0.4 feet for interpolation of the mean-low-water line. Figure 9 is a fair sample of the infrared photography.

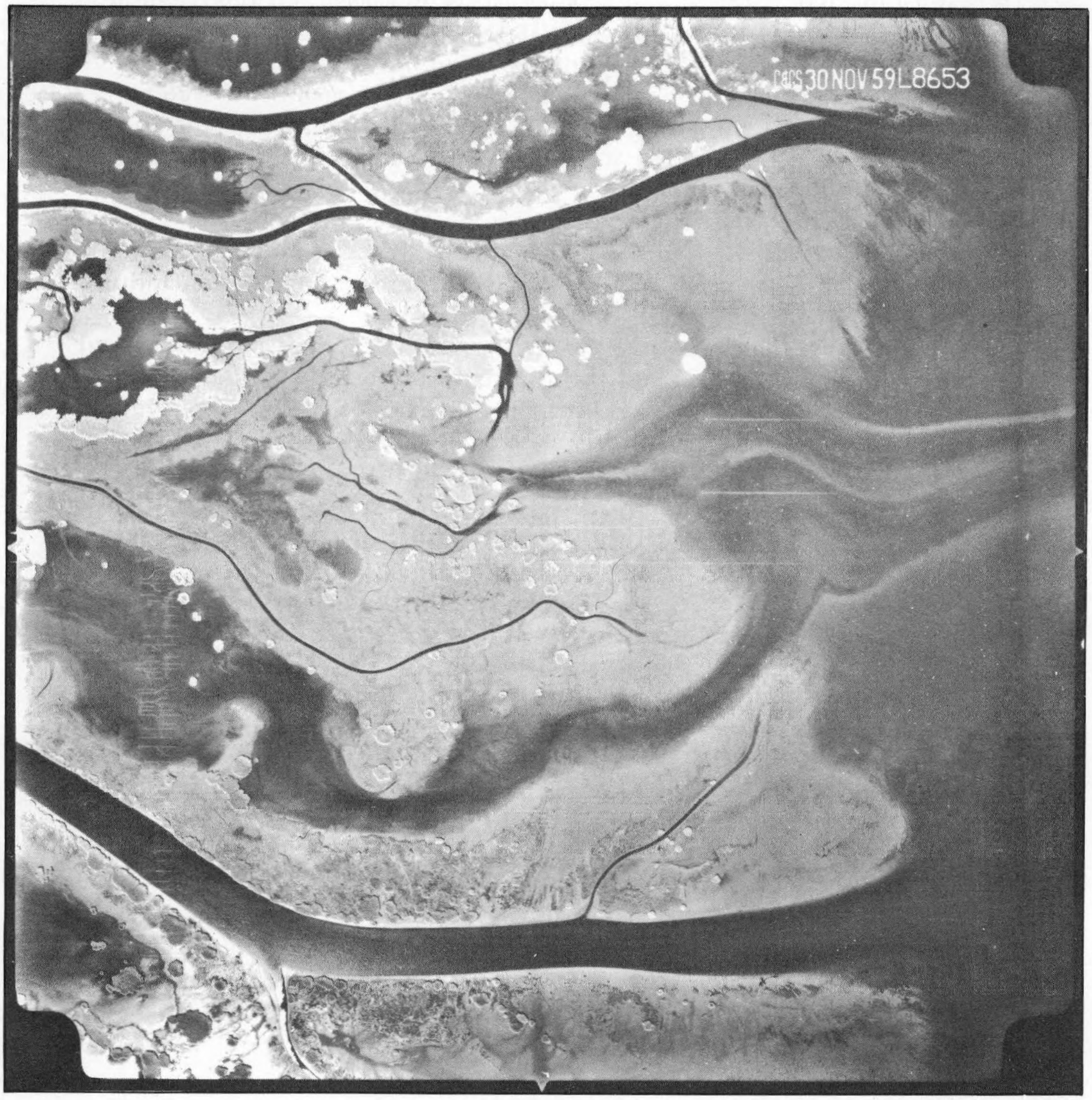

Fig. 9. — Infrared photographs.

FIELD EXAMINATION

The next step after completion of the photography was to inspect the photographs, that is, compare them with the shoreline at, or very nearly at, the mean-low-water tide stage. This was done by float plane and helicopter, mostly by helicopter.

Such an inspection was necessary to, first, be certain to find small off-lying mean-low-water islands or spots that might not be detected from an office examination of the photographs. Examples of this are the numerous mud lumps off Pass A Loutre and Southeast Pass and the tops of shell reefs in Grand Bay. Secondly, it was necessary to search out the mean-low-water line in the few instances where it occurs just inside the edge of the wild cane; and third, to check the interpolation of the mean-low-water line when the photographs had not been taken at exactly mean low water.

The practice was to fly to and read a staff at the controlling tide station and then to inspect that section of the shoreline reading the staff again upon completion of the inspection.

As regards the accuracy of the mean-low-water line, all the evidence indicates that it is located within about 0.1 feet vertically, and that this is about all one should expect in this area with any reasonable expenditure of time and money.

Color photography was used for the location of aids to navigation and for interpretation of natural and cultural features on the planimetric maps. Color photographs provide a wealth of detail not visible on panchromatic photography, and save a considerable amount of field time that would otherwise be necessary to clarify details on the photographs. It was relatively easy to identify the many aids to navigation on these photographs, and thus to locate them with very little ground examination and no real ground surveying.