K 13.

SURVEY OF THE BRAZOS RIVER IN TEXAS, FROM EIGHT MILES ABOVE ITS MOUTH DOWN THROUGH ITS MOUTH, TO THE OUTER EDGE OF THE BAR IN THE GULF OF MEXICO.

This work was commenced on the 30th of September, 1878, under the following instructions sent by telegraph because of quarantine against New Orleans:

NEW ORLEANS, *August* 10, 1878.

Send Mr. Ripley, with Mr. Talfor as assistant, and with suitable instruments and party, to make a survey of the Brazos River from its mouth to a point 16 miles above.

The survey ordered is to form basis for a report upon the Brazos River as a harbor of refuge and naval station.

To make it for either purpose, our present knowledge of the river suggests three things:

1st. Deepening of the channel across the bar in the gulf at the mouth of the river.

2d. Enlargement of cross-section of the river both by widening and deepening.

3d. The excavation of basins, connecting with the river, without interposition of locks, and surrounding these with embankments having their crest above the level of storm tide, and so built and protected as to resist the waves of the gulf during the most severe storms.

The survey is to furnish accurate data for plans and estimates as above indicated.

1st. The survey of the bar is of the least importance, and should not be allowed to delay completion of the work. Days may be selected for it and if not enough favorable offer before the other work is completed, then it may be left incomplete. One reason for this is that the allotment is very small, another is that I do not wish to keep Mr. Ripley and party very long away from Galveston.

2d. The 16 miles of the river should be carefully and closely sounded, the shore-line accurately run, and its height above the plane of reference noted on either side of the river at intervals of 100 feet. This will give data for deepening and widening of the river-bed. Character of bottom should be noted frequently—same of banks.

3d. The survey should include a strip of land on either side of the river about half a mile in width, giving levels, character of surface, soil, and topographical features generally, so as to guide in selection of locations for basins and in making estimates for excavation and embankment.

4th. A permanent monument should be erected at Velasco and another at the upper limit of survey on which the station plane of survey should be marked for future reference. All gauges kept should be properly connected with one or the other of these and their stations marked.

5th. Velocities of currents may be noted if the labor does not interfere with the other operations of the party and delay completion.

The work need only be commenced when you can without too great inconvenience spare Mr. Ripley and party for two or three or four weeks from Galveston Harbor work. It should be completed and report rendered before the opening of the next session of Congress.

HOWELL,
Engineers.

Captain DAVIS,
U. S. Engineers.

For some reason that I am unable to explain the instructions directed survey of 16 miles of the river instead of 8, as provided for in the act of Congress.

The field-work was suspended on November 13, 1878, in accordance with my telegraphic order to that effect, given because of small balance of allotment remaining to the credit of the work, and under the impression, also, that the work had been prosecuted from the mouth upstream.

Chart and report of survey were completed February 17, 1879, and forwarded to me.

This work was performed by Messrs. Ripley and Talfor, while employed on surveys of Galveston Harbor and entrance, and during their spare time, so that it did not cost anything beyond the willing labor of these gentlemen, but was necessarily a long time in progress.

On receipt of the chart and report, I found that the survey had been commenced at the upper end of the section to be surveyed and that suspension had left about 1½ miles of the section near the Gulf—the most important part—incomplete as to hydrographic work.

Under date of March 1, 1879, I directed return of the party to complete the survey. This latter work was completed on March 12, and plotted on the chart.

But few soundings were taken over the bar, which is of sand, very shoal, and only at rare intervals smooth enough for such work. I could not afford to keep the party longer in the field to wait for a suitable time to sound the bar all over, and I could not go to the expense of boring to ascertain depth below the sand of the underlying blue clay. The chart, of which a tracing will be forwarded when completed, gives all information that may be necessary for the purpose of report on the Brazos River as a harbor of refuge.

The following is Assistant H. C. Ripley's report of the survey:

REPORT OF MR. H. C. RIPLEY, ASSISTANT ENGINEER.

BOLIVAR POINT, TEXAS, *February* 15, 1879.

CAPTAIN: I have the honor to submit the following report of the survey of Brazos River, Texas:

FIELD-WORK.

Preliminary arrangements having been made, the field-work was commenced on the 30th of September and suspended on the 14th of November, 1878. The details of the survey having already been given in my weekly reports at the time, it seems only necessary in this report to give a general description of the method of conducting the work, with just enough of detail to show the degree of accuracy attained and to contribute to a thorough understanding of the charts.

TRIANGULATION.

A careful triangulation, commencing with a base-line of 4,375$\frac{4}{10}$ feet from △ A to △ B, was carried from the Gulf to △ X V. The measurement of distances was continued from this point to the upper limit of the survey by a carefully chained line. The base-line was measured with a 100-foot Chesterman steel-tape and the chaining was done with a 100-foot steel chain. Angles were measured with a Stackpole transit reading to half minutes. By repetitions of the angle to about 360 degrees the triangles closed to within 5 to 15 seconds.

OBSERVATIONS.

Observations for true meridian were taken at the base-line, near the upper limit of the survey, and at numerous intermediate points. No extended series of observations for magnetic meridian was taken. But the mean of a number of readings taken at different times of the day and at different places gives the magnetic variation 8° 21′ east.

TOPOGRAPHY.

An azimuth and stadia line was carried along the river-bank, connecting whenever practicable with the triangulation or channel-line stations. From this line the topography was taken either by stadia readings or by intersections.

LEVELS.

Independent level-lines were run on either bank of the river, determining the elevations of points along the banks at intervals of about 100 feet.

Distances were determined by pacing, the length of a pace being found by the number of paces between known points of the stadia line. Where the banks are bluff (caving banks) and level on top, the elevations show the height of the bank. But where the bank is sloping the line was run sometimes on the side of the slope and at other times on the top or crest.

The general character of the slope in this case was determined by sections normal to the river at intervals along the main line. Where a batture occurred the line was generally run on the batture to avoid timber, and elevations of the high bank taken occasionally.

At the mouth of the river, where the land is more uneven, numerous lines were run to determine contours and ascertain the height of the ridge along the Gulf beach, upon which Velasco and Quintana are situated. With regard to the degree of accuracy of the levels, it affords me much satisfaction to be able to state that from bench A (where the continuous timber begins) to the upper limit of survey, out of 13 connections of the two lines the greatest difference was $\frac{7}{100}$ of a foot. Below this point the connections were not so good, and some levels had to be rerun for want of agreement. But even in this portion the greatest error will not exceed 1 or $\frac{2}{10}$ of a foot, which in elevations of the bank is of little importance. In addition to the elevations of the bank, the elevation of the water-surface at 120 places as the line was carried up the river was taken. A comparison of these with the records of gauges, showing their close agreement, gives an additional assurance of the accuracy of the level-lines.

HYDROGRAPHY.

The soundings were taken with a lead-line marked to feet, soundings being called to the nearest $\frac{1}{2}$ foot.

Locations were made by means of two transits sighting to the lead-line at intervals of about 1 minute, which gives an accurate location of every fourth sounding. In running the lines of soundings an effort was made to have each line crossed by another line to serve as a check. This was accomplished by running lines diagonally from side to side of the river, and trying them all by one long line running up and down the river. This proved very satisfactory, as giving a visible verification of all the hydrographic work both as regards location and soundings. Any line which would not stand the test thus imposed was discarded.

The imperative importance of a rigid check in work of this kind will be appreciated when it is remembered that in taking sights for locations as often as once a minute there is time to read but one vernier, and in the haste necessary to accomplish this when the observer keeps time and records for himself there is great liability to mistakes, and the most careful observer is not infallible in this respect. In the absence of a check, therefore, there would be a greater or less danger of uncertainty about any part of the work, and any peculiarity not anticipated or unexplained would be looked on with suspicion.

In taking cross-sections each sounding was located.

TIDE-GAUGES.

A record of the tide at the mouth of the river was kept for a period of 45 days, gauge readings being taken every hour during daylight.

In addition to this, wherever the schooner happened to be moored a gauge was put down and readings recorded, so that a nearly continuous record was kept by means of these supplementary gauges. These gauges being connected with the level line, served as a check upon that line during progress of the work, also as a check upon the gauge readings at the mouth of the river and for the purpose of reducing the soundings, and, as we shall see hereafter, served an admirable purpose for determining slopes. In order to determine the mean low-tide, the gauge at the mouth of the river has been connected with the gauge at Bolivar Point, a distance of 40 miles. The result of this connection is so satisfactory that I have thought it would be interesting to give somewhat in detail the method by which it was accomplished. Then, too, the details being given, the accuracy of a connection at so great a distance cannot be questioned.

The gauge at Boliver Point is a self-recording float-gauge of which the mean low is known, and which gives the stage of tide accurately to $\frac{1}{100}$ of a foot.

The gauge at the mouth of Brazos River was an ordinary staff-gauge graduated to tenths of feet and read to the nearest half-tenth. The comparison is made by means of the maximum and minimum tides.

The following table shows the comparison:

Table of maximum and minimum gauge readings at Brazos River and Bolivar Point.

September and October	30.	1.	2.	3.	4.		5.		
Maximum or minimum	×	×	×	×	⊕?	×	× ?	⊕	×
Brazos River	3.20	3.00	2.60	2.75	3.70	2.65	3.60	3.75	2.70
Bolivar Point	1.00	.....	.40	.30	.....	.22	1.25?	.....	.15
Difference	2.20	.....	2.20	2.45	.....	2.43	2.35	.....	2.55

October	6.		7.		8.		9.		10.
Maximum or minimum	×	⊕	×	⊕	×	⊕	×	⊕	×
Brazos River	3.55	3.70	3.50	3.75	3.65	4.35	3.65	4.50	3.45
Bolivar Point	.97	1.12	.95	1.15	1.20	1.77	1.40	1.95?	1.02
Difference	2.58	2.58	2.55	2.60	2.45	2.58	2.25	2.55	2.43

October	10.		11.		12.		13.		14.	15.
Maximum or minimum	⊕	×	⊕	×	⊕	×	⊕	×	×	×
Brazos River	4.45	3.10	4.40	2.85	4.60	2.75	4.35	2.80	2.80	
Bolivar Point	1.78	.83	1.67	.43	1.77	.40	1.66?	.47	.57	
Difference	2.67	2.27	2.73	2.42	2.83	2.35	2.69	2.33	2.23	

October	16.	17.	18.	19.	20.	21.	22.	23.	24.
Maximum or minimum	×	×	×	×	×	⊕	⊕	⊕	×
Brazos River	3.00	2.30	2.95	3.20	3.25	4.10	3.60	3.75	2.60
Bolivar Point	.....	.....	.25	.65	.77	1.70	.85	1.05	0.00
Difference	.....	.....	2.70	2.55	2.48	2.40	2.75	2.70	2.60

October	24.	25.		26.	27.	28.	29.	30.	31.
Maximum or minimum	⊕	×	⊕	×	×	×	×	×	×
Brazos River	3.95	2.00	3.85	2.60	1.90	2.75	2.75	2.40	2.70
Bolivar Point	1.50	.40	1.40	.10	−.55	.25	.25	.00	.00
Difference	2.45	2.40	2.45	2.50	2.45	2.50	2.50	2.40	2.70

November	1.	2.	3.		4.		5.		6.
Maximum or minimum	×	×	⊕	×	⊕	×	×	⊕	×
Brazos River	3.20	2.90	3.35	2.70	3.50	3.20	3.25	4.00	3.15
Bolivar Point	.60	.40	.75	.10	.95	.45	.60	1.45	.60
Difference	2.60	2.50	2.60	2.60	2.55	2.75	2.65	2.55	2.55

November	6.	7.		8.	9.	10.	11.	12.	13.
Maximum or minimum	⊕	×	⊕	×	×	×	×	×	×
Brazoz River	4.20	2.85	4.20	2.70	2.70	2.80	2.00	1.80	2.20
Bolivar Point	1.55	.35	1.60	.15	.15	.25	.50	−.80	−.35
Difference	2.65	2.50	2.60	2.55	2.55	2.55	2.50	2.60	2.55

SIGNS USED IN THE TABLE.—× indicates minimum tide; ⊕ indicates maximum tide; − indicates below mean low-tide.

It will be seen from this table that there are 40 minimum and 18 maximum tide comparisons.

The mean of the minimums is	2.481
The mean of the maximums is	2.608
The total mean is	2.544

Which shows that the mean low-tide reads on the Brazos gauge 2.544 feet.

The disagreement of the maximum and minimum comparisons shows that the high tides were higher and the low-tides lower at Brazos River than at Bolivar Point by an amount equal to $\frac{4}{100}$ of a foot. This is as we should expect from the positions of the gauges. At Bolivar Point the gauge is 6 miles from the bar, while the Brazos River gauge is but 1 mile, and hence would feel a small tide that would not show itself at Bolivar Point. This circumstance is seen in the table, where on several occasions maximum and minimum tides occurred at Brazos River which did not appear at all at Bolivar Point. A further inspection of the table shows that the extreme differences differ from the mean difference by quantities as great (in one case) as $\frac{34}{100}$ of a foot. These can reasonably be accounted for by local disturbances or errors of gauge readings, due to swell or other causes. The mean result has been expressed to the third place of decimals. Of course no such accuracy can be obtained from gauges graduated to tenths with a possible error of 1 or more tenths in reading. But it must be evident from an inspection of the table that a connection close enough for all practical purposes can be made in this way, especially in view of the fact that more than $\frac{1}{2}$ of the comparisons differ from the mean by less than $\frac{1}{10}$ of a foot.

On previous occasions I have connected gauges with Bolivar Point and Sabine Pass, a distance of 60 miles, and with Pass Cavallo, a distance of 110 miles, with approximately if not equally good results.

In the same manner have the supplementary gauges been connected with the gauge at the mouth of the river. This became possible on account of the low stage of the river, so that during flood-tide there was always a current from the Gulf. These connections, giving the same result as the levels, show that there is no water-surface slope in that portion of the river embraced in this survey at low river except that due to tide.

CURRENTS.

No measurements for the velocity of the current in the river were taken; but from the gauge records we are able to get the slope of the water-surface, from which an approximate idea of the force of the current may be obtained. The following table gives the greatest difference in elevation of water-surface observed at the mouth of the river and at points above, whose distances are given from the gauge at the mouth and the slope per mile as observed from simultaneous gauge readings:

Distance.	Slope.		Slope per mile.	
	Flood.	Ebb.	Flood.	Ebb.
3 miles	.2	.1	.04	.02
9.5 miles	.5	.3	.053	.033
13.6 miles	1.0	.55	.073	.04
15.3 miles	.4	.7	.026	.045

From which it will be seen that the greatest observed slope is 1 foot in 13.6 miles, which corresponds to a slope of .073 of a foot per mile. This occurred when there was a range of tide equal to 2.6 feet, which is nearly $2\frac{1}{2}$ times the range of the mean daily tide. It is evident, therefore, that little scouring effect can be expected from the current during a low stage of the river. We had no means of determining the slope, which does not exist at high river.

PERMANENT MARKS.

At stations A and B (the extremities of the base-line), I, II, III, and 124 (the upper limit of the survey), boiler-tubes about 4 feet in length are driven to within a few inches of the surface of the ground. These tubes serve to mark the positions of each station, and also serve the purpose of bench-marks.

The tide-gauge at the mouth of the river is referred to a bench made by driving one of these boiler-tubes to within $\frac{1}{2}$ inch of the surface of the ground at the northwest corner of chimney to Captain Lyon's house. The elevation of the top of the tube is 3.052 feet above the plane of mean low tide. Another bench to which the same gauge is immediately referred is on a forked tree, 15 feet west of the same house. The bench-mark is a nail driven in the top of east branch, and its elevation is 4.657 feet above the plane of mean low-tide. In addition to these there are numerous other benches established on trees along the river's banks, whose positions and elevations are shown on the charts, and which may readily be found and made available for future reference.

PLOTTINGS.

The triangulation and principal topographical stations have been plotted by means of co-ordinates. Minor topographical stations have been plotted by bearings and distances, or by intersections. Where connections were made with the triangulation stations by the stadia line, the error found was distributed proportionately amongst all the stations of the stadia line back to the previous connection, and thus the accumulated error corrected at each connection. The work is plotted on three sheets. Sheets No. 1 and No. 2 show the river plotted in sections, to economize space, at a scale of $\frac{1}{2500}$. Upon them the original plotting was done. No effort at embellishment has been attempted. They are intended as the working-charts in case of contemplated improvement and for making estimates.

Outlines only of topography are shown and topographical features; character of the soil, &c., are only indicated. By careful inspection, however, most of the information obtained by the survey and presentable in this manner will be found upon them.

The hydrographic work near the mouth of the river and on the bar being incomplete, the charts have been left so that co-ordinate lines can be reproduced and that work plotted whenever it may be completed. It is very desirable, therefore, that the charts should be returned after the estimates are made, especially since no tracings of them have been retained.

Upon sheet No. 3 the river is shown at a scale of $\frac{1}{10,000}$. As with the other sheets, the triangulation and principal topographical stations have been plotted by co-ordinates, but the topography, shore-lines, &c., have been transferred from the other sheets by reducing squares. This sheet gives a comprehensive view of the river, and gives topography distant from the river which could not be shown upon the other charts for want of space.

GENERAL DESCRIPTION.

The survey embraces that portion of the river extending from its mouth to Buffalo Bayou, a distance by river of $16\frac{1}{2}$ miles. Along the Gulf beach there is a series of sand-hills sloping abruptly towards the beach, but merging on the back side into a more uniform ridge, covered with grass, and sloping gently back into a marshy region which borders the canal on the north side and West Union Bayou on the south side. Along this ridge south of the river can be traced the line of drift accumulated by the storm of 1875, and below this line another accumulation which was left by the storm of 1877. An intelligent citizen assures me that the drift did not cross this ridge during the highest water of either storm. But of the ridge on the north side the same cannot be true, as is evident from the accumulation immediately around △ I, where it is higher by 3 feet than the general height of the ridge. As soon as the beach is left the banks of the river become nearly level, rising gently as you ascend the river and sloping back from the banks into a marsh or wet prairie region at a distance therefrom of $\frac{1}{2}$ to $1\frac{1}{2}$ miles.

This feature holds true until we reach the timber, when a sudden elevation of about 3 feet occurs, and the slope instead of being from the river is towards it, and for a limited distance the elevation is increased by leaving the bank of the river, although it is generally quite level. Where the timber begins, about $3\frac{1}{2}$ miles from the mouth, the banks have an elevation of 8 feet. From this point ascending the river the increase in elevation is quite uniform and at the rate of about $\frac{6}{10}$ of a foot per mile. The banks are covered by a dense growth of timber (where not removed artificially), principally of live-oak, but interspersed with elm, ash, hackberry, pin-oak, Spanish oak, and willow, the latter being principally confined to battures along the river bank. The character of the soil is but little varied. It consists of a rich surface-soil of a reddish sand and clay or dark loam, with a substratum of tenacious reddish or bluish clay.

The bed of the river is generally "soft," but a careful probing of the bottom generally revealed the fact that underneath the soft mud carpet there is a floor of hard clay.

There are caving banks and battures to be met all along the river, but from the durable appearance of the banks generally great or rapid changes should not be expected. In this connection, it is worthy of remark that the dredging from the Galveston and Brazos Canal Company's canal was deposited close to the edge of the canal, the sides of which have a very steep slope (as great, I think, as 2 vertical to 1 horizontal), yet there seems to have been no slipping or caving of its banks.