AM. PHOTO-LITHO.CO.N.Y. (OSBORNE'S PROCESS.)

The improvement of the Saint John's Bar on the scale above indicated, should be accompanied by a deepening of the shoalest places in the river between the bar and Jacksonville, for which not less than $120,000 would be needed.

A practicable high-water depth on the bar equivalent to and probably somewhat exceeding the greatest draft that can ordinarily be carried between the bar and Jacksonville, on the flood-tide about 12½ feet, could in all probability be established by a single jetty carried out to the 15-foot curve, or a little beyond. If this jetty be projected from the north shore, it should be built in conjunction with a short, open jetty on the northeast point of the south shore to protect it from further erosion.

This plan, if completed within three years from the time of commencement would cost about $800,000.

Should the time come when it failed to afford the needed relief, it could then be converted into a two-jetty project by the extension of the spur.

In the execution of either of the foregoing projects, the sum of $400,000 can be profitably expended within twelve months after it is made available.

The following named papers are transmitted herewith:

1. A chart showing the results of the soundings and borings upon the Saint John's Bar.
2. The report of George Daubeney, assistant, with 15 sheets of drawings.
3. A chart of Saint John's River, made December 24, 1791, copied from one furnished by Dr. A. S. Baldwin, of Jacksonville, Fla.

Very respectfully, your obedient servant,

Q. A. GILLMORE,
Lieutenant-Colonel of Engineers, Bvt. Maj. Gen. U. S. A.

Brig. Gen. H. G. WRIGHT,
Chief of Engineers, U. S. A.

REPORT OF MR. GEORGE DAUBENEY, ASSISTANT ENGINEER.

PILOT TOWN, FLA., *March* 19, 1879.

GENERAL: I have the honor to make the following report, as to the carrying out of your instructions, to measure the discharge of the Saint John's River, in the vicinity of Mayport. It was at first contemplated (being guided by the rule that the mid-depth velocity of all rivers bears a certain proportion to the mean velocity given by a curve constructed on the velocities at the surface, bottom, and intermediate depths) to divide the section of the river into certain divisions, in each of which floats, gauged to the half depth of such division, were to be run between certain ranges on shore. I found this method inapplicable to the Saint John's near its mouth, the velocity of the ebb-current being so great that, in the thick of the tide and in mid-stream, no row-boat, after letting go the float at the upper range, and picking it up at the lower one, could pull against the current and regain, without great loss of time, a position above the upper range so as to start another float.

Under these circumstances, I concluded to obtain the measurements from a boat anchored on the range lines, the upper being used for the ebb and the lower for the flood observations, the velocity being measured by a fine line run off a log-reel, and made fast to the under side of the surface float.

The floats used were as follows: The lower or measuring float was a keg 16 inches high, 12 inches bung-diameter, and 10½ inches head-diameter, with the top and bottom knocked out, weighted on its lower edge and suspended from center of its bung-diameter, at any required depth, by a cork surface-float, measuring 6 by 7 by 3 inches.

The line connecting lower and surface floats was ⅛ inch in diameter. This was also the dimension of the recording line running off the log-reel.

The locality selected for the gauging was about 1,400 feet above Pilot Town wharf. The width of the river, from low-water mark to low-water mark, was 1,735 feet. This was divided into 8 divisions, viz: 6 of 230 feet in width, and 2 of 180 feet and 175 feet, respectively, the latter being the inshore divisions, and were made of less width than the others to adapt them to the cross-section of the bottom, and also on account of their being affected by eddies. These cross-sections are shown on sheet F, and they show that since 1868 the middle ground in that locality has worked down stream.

At starting, the velocity was measured at surface, bottom, and each intermediate 4 feet in depth. I then noticed that the velocities at these different depths varied so greatly, so irregularly, and so quickly, that when plotted they gave no curve, but formed, instead, a broken line. These pulsations in the movement of the water were plainly visible, and forced me to the conclusion that any observations, to be of value, should be made in rapid succession, and that in taking measurements at different depths, the interval between measurements at the same depths became too long. Under these circumstances, knowing that in regular rivers the mid-depth bore a proportion to the mean velocity, I thought it worth while testing it in this instance, although well aware that the velocities at varying depths formed no curves. Station 3 (sheet F) was selected to test this proportion, if such existed. Two boats were anchored side by side, and the velocity was measured at the surface, bottom, and every intermediate 4 feet of depth. One boat took the surface, 4 and 8 feet depths, the other one the 12, 16, and bottom. The measurements were made as rapidly as possible, each having a duration of 10 seconds, and the greatest number that could be made was 3 in 5 minutes, making that the interval between measurements at the same depth. This test was applied to two ebb-discharges. The velocities were then plotted to a scale of distance and time, and horizontal curves constructed thereon, as shown on sheets A and C. From these horizontal curves vertical ones were constructed, as shown on sheets B and D. These verticals were obtained by plotting the velocity of the surface, and each successive 4 feet in depth to the bottom as given at any one minute by the horizontals. For instance, take 11 hours and 10 minutes on sheet A and it will be seen that the surface had a velocity of 42 feet in 10 seconds, 4 feet depth 41 feet, the 8 feet depth 38, the 12 feet depth 39½ feet, the 16 feet depth 35½, and the bottom 31 feet, and that the depth of water at that time was 20½ feet. These points were then connected (see same hour on sheet B) forming a broken line, and half the perpendicular height between the surface and the bottom was taken for the mid-depth velocity. These vertical curves were constructed at intervals of 5 minutes from the horizontal, and show the mid-depth and mean discharges for a period of 10 seconds, that happening to be the length of time the floats were allowed to run. I supposed that the pulsations worked harmoniously from top to bottom, or *vice versa*, although not in a perfectly vertical plane, nor instantaneously. The horizontal curves of sheets A and C seem to show this to be the case, although of course many of the details of changes were lost owing to the time consumed in hauling in the floats, before running them out again at a different depth; for instance, the surface being measured at 11 o'clock, the 4 feet velocity would not be measured until 11.01 or 11.02. It will be noticed that during portions of the tide the mean velocities exceed the mid-depth, but it is generally when velocities are highest. Of course error in recording by log is considerable, friction in taking the line off the reel decreasing, and motion of boat and sea increasing velocities. More will be recorded at high than at low velocities, *i. e.*, if two true velocities were 20 and 10 respectively, there would be more than 10 difference recorded by the log line. This may have something to do with the gain of mean on mid-depth velocities when they are high. The mid-depth may be shifted ½ foot without material error for the bottom is uneven and soundings vary a foot between stem and stern of boat. In recording 40 feet velocities the float will be 100 feet away from the boat before being hauled in and possibly in a different depth of water, for with such velocity one must have 60 feet of slack to give the lower float time to sink to the depth for which it is gauged. For this reason in calculating the areas of the different sections, I have taken the mean of the areas of both cross-sections which were 100 feet apart.

The results of taking these two ebb discharges in the manner above referred to are as follows: Sheet A makes the mean velocity = 0.991 of the mid-depth, and Sheet C makes the mean = 0.974 of the mid-depth, a difference of 1½ per cent. only. Having no time to spare for further investigation, I considered I was justified in using this proportion, and in measuring the discharge at the different stations or sections took the half-depth velocity every five minutes. The contents of the horizontal curves formed on these velocities and multiplied by $\frac{0.991+0.974}{2}=0.982$, being considered to give a true mean velocity of the current. The results of the gaugings at the various stations during ebb currents are shown on sheet G. It would have been desirable in measuring the discharge to have occupied all 8 divisions of the cross-section the same day, but my facilities for work only allowed me to occupy 2 of them, thus taking 4 days to work across the river, and I regret to say that I found that I could not depend upon finding that the discharge at one station always bore the same or even close proportion to the one occupied the same day. At the same time I think that working two stations simultaneously is preferable to working entirely across a river with a few sta-

tions very far apart. It is evidently most desirable, as shown by these measurements, that in a tidal stream of great velocity they should be made as rapidly as possible in the same spot, and it seems highly probable that even in a sluggish tidal stream, floats, run with any great interval of time between them, would give erroneous results. At the commencement of this survey the Upper Saint John's, owing to an unusually rainy season, was very high and the range of tide at Mayport unusually small, being from 3½ to 4 feet. At the same time the current velocities were very great, reaching as high as 5 miles an hour on the surface, and but little less at the bottom. Notwithstanding this rapidity of current the ebb current did not commence to run down until 2 hours after high-water. With regard to the ebb discharges measured (plotted on sheet G) I am unable to make any proportions from the ranges of the tides, even when their high and low water levels are not far from the mean levels of an average tide. The discharge seems to depend more upon the duration of the current than the range of tide. The ebb current at the mouth of the Saint John's has these general characteristics.

The ebb current generally sets down 2 hours after high-water, by which time the tide has usually fallen on shore ⅓ its range, nor does a subsurface float gauged to the bottom show any trace of an outward current before that time, both surface and bottom practically turning together. The ebb current continues running out from 2½ to 3 hours after the tide has commenced rising on shore, it having risen from 1½ to 2½ feet before the current ceases, nor is there any trace of an under current running flood before that time. The average of the tide-gauge readings during an ebb current is less than ⅓ the range of tide, and in calculating the areas of sections a level of 1 foot above average low water has been used as a mean depth. The mean of 260 high and low water readings of the tide-gauge at Pilot Town gives a range of tide of 4′.3.

During the gauging of the ebb current of the river, three series of observations were made. Series I, from November 5 to November 8. Series II, from November 23 to November 26. Series III, from December 7 to December 12. During series I the tides were generally considerably above the mean levels of high and low water; for series III, nearly at or below those levels, whilst series II approached a mean between the others. Although there is considerable difference in the features of the three series, the general character of each series is more or less uniform. Of all the discharges measured, there was only one whose range of tide approached the mean range, and whose low-water level corresponded to mean low-water, this being on December 8. During the observations of the different series, the stations occupied simultaneously were as follows:

I. series: 1 and 2; 3 and 4; 5 and 6; 7 and 8.
II. series: 1 and 2; 3 and 4; 5 and 6; 7 and 8.
III. series: 6 and 1; 2 and 3; 4 and 5; 7 and 8.

The simultaneous measurements give proportions between the following stations as observed during the same tide: 1 and 2; 2 and 3; 3 and 4; 4 and 5; 5 and 6; 6 and 1; 7 and 8. Unable to find any data that could be applied to calculating the discharge of the river, from the range of tides or duration of currents, I have attempted to do so from the proportion of station to station, and calling the station having the greatest velocity 1,000 to find the ratio of others. That being found, there is the nearly average tide range of December 8, whose discharge can be used in finding that of the entire cross-section. As stated above, the general feature of each series seem to be more or less applicable to every station occupied whilst the taking of that series was in progress, and, in default of better data, I consider the proportions derived therefrom to be of value. The following table is compiled from sheet G, includes all ebb discharges observed, and gives the proportion of the average of each station to unity, which is applied to the highest velocity.

TABLE X.

Station.	Date.	Total 10 second velocities divided by number of observations.		Average velocity in feet per second during tide.		Number of seconds current ran down.		Discharge per square foot of area of section during tide.	Total.	Average.	Ratio to unity.
I	Nov. 8	$\frac{2052}{95}$	=	2.160	×	28,200	=	60,912	170,456	56,819	0.687
	Nov. 26	$\frac{1966}{88}$	=	2.234	×	26,100	=	58,307			
	Dec. 11	$\frac{1727}{90}$	=	1.919	×	26,700	=	51,237			
II	Nov. 8	$\frac{2550}{99}$	=	2.575	×	29,400	=	75,705	210,827	70,276	0.849
	Nov. 26	$\frac{2548}{90}$	=	2.831	×	26,700	=	75,587			
	Dec. 7	$\frac{2007}{91}$	=	2.205	×	27,000	=	59,535			
III	Nov. 7	$\frac{3024}{101}$	=	2.994	×	30,000	=	89,820	248,206	82,735	1.000
	Nov. 25	$\frac{2979}{93}$	=	3.203	×	27,600	=	88,402			
	Dec. 7	$\frac{2359}{91}$	=	2.592	×	27,000	=	69,984			
IV	Nov. 7	$\frac{2680}{101}$	=	2.653	×	30,000	=	79,590	220,737	73,579	0.889
	Nov. 25	$\frac{2716}{93}$	=	2.920	×	27,600	=	80,592			
	Dec. 8	$\frac{2044}{82}$	=	2.492	×	24,300	=	60,555			
V	Nov. 6	$\frac{2518}{94}$	=	2.679	×	27,900	=	74,716	210,106	70,035	0.846
	Nov. 24	$\frac{2393}{90}$	=	2.659	×	26,700	=	70,995			
	Dec. 8	$\frac{2173}{82}$	=	2.650	×	24,300	=	64,395			
VI	Nov. 6	$\frac{2073}{91}$	=	2.277	×	27,000	=	61,479	172,507	57,502	0.695
	Nov. 24	$\frac{2073}{84}$	=	2.467	×	24,900	=	61,428			
	Dec. 11	$\frac{1674}{84}$	=	1.992	×	24,900	=	49,600			
VII	Nov. 5	$\frac{1764}{89}$	=	1.982	×	26,400	=	52,324	162,395	54,132	0.653
	Nov. 23	$\frac{2389}{93}$	=	2.568	×	27,600	=	70,876			
	Dec. 12	$\frac{1323}{82}$	=	1.613	×	24,300	=	39,195			
VIII	Nov. 5	$\frac{747}{83}$	=	0.900	×	24,600	=	22,140	114,700	38,233	0.462
	Nov. 23	$\frac{2150}{93}$	=	2.311	×	27,600	=	63,783			
	Dec. 12	$\frac{972}{76}$	=	1.279	×	22,500	=	28,777			

Station 8 was located on the edge of an eddy, which sometimes struck out beyond it well towards Station 7. November 23 was one of the few days upon which I ever saw the current passing by Station 8, or on the north side of the river, with a steady stream.

The above table shows the proportion of station to station by taking the discharge of all tides collectively. For the purpose of comparison, they will now be taken individually.

$$\text{Dec. 11.}-\frac{\text{Station 6}}{\text{Station 1}}=\frac{49600}{51238}\text{ then Station 6}=0.9680\text{ of Station 1.}$$

$$\text{Nov. 8.}-\frac{\text{Station 1}}{\text{Station 2}}=\frac{60912}{75705}\text{ then Station 1}=0.8046\text{ of Station 2.}$$

$$\text{Dec. 7.}-\frac{\text{Station 2}}{\text{Station 3}}=\frac{59535}{69984}\text{ then Station 2}=0.8507\text{ of Station 3.}$$

$$\left.\begin{array}{l}\text{Nov. 7.}-\frac{\text{Station 4}}{\text{Station 3}}=\frac{79590}{89820}\text{ then Station 4}=0.8861\text{ of Station 3.}\\ \text{Nov. 25.}-\frac{\text{Station 4}}{\text{Station 3}}=\frac{80592}{88402}\text{ then Station 4}=0.9116\text{ of Station 3.}\end{array}\right\}0.8988$$

$$\text{Dec. 8.}-\frac{\text{Station 5}}{\text{Station 4}}=\frac{64395}{60556}\text{ then Station 5}=1.0640\text{ of Station 4.}$$

$$\left.\begin{array}{l}\text{Nov. 6.}-\frac{\text{Station 6}}{\text{Station 5}}=\frac{61479}{74716}\text{ then Station 6}=0.8286\text{ of Station 5.}\\ \text{Nov. 24.}-\frac{\text{Station 6}}{\text{Station 5}}=\frac{61428}{70995}\text{ then Station 6}=0.8653\text{ of Station 5.}\end{array}\right\}0.8469$$

The above give proportions between all stations from 1 to 6. To obtain those of stations 7 and 8, as we have no simultaneous observations between either of them and one of the above 6, a fair comparison can be derived from the discharges of December 11 and 12, which had about the same tidal range, duration, and relative levels.

$$\frac{\text{Dec. 12.—Station 7}}{\text{Dec. 11.—Station 6}}=\frac{39195}{49600}\text{ then Station 7}=0.790\text{ of Station 6.}$$

The proportion of Station 8 to Station 7 is taken from that of November 23, that being the only day upon which the current flowed evenly through that station.

$$\text{Nov. 23.}-\frac{\text{Station 8}}{\text{Station 7}}=\frac{63783}{70876}\text{ then Station 8}=0.90\text{ of Station 7.}$$

From these proportions another table of ratios to unity can be obtained.

TABLE Z.

Station 1	=0.684	Station 5	=0.956
Station 2	=0.850	Station 6	=0.810
Station 3	=1.000	Station 7	=0.639
Station 4	=0.899	Station 8	=0.575

The ratios of Stations 1, 2, 3, and 4 coincide practically with those in the last column of Table X. With Stations 5 and 6 there is a discrepancy. By referring to the above proportions of stations to one another, it will be seen that the ratio of Station 6 can be taken from either Station 1, December 11, or Station 5, November 6, from the latter of which the ratios in Table Z were taken. Should the value of Station 6 be taken from Station 1, December 11, its value would be to unity 0.662, and that of Station 5 taken from Station 6, with a value of 0.662, would be 0.784, derived as follows:

$$\left.\begin{array}{l}\text{November 6.}-\frac{\text{Station 5}}{\text{Station 6}}=\frac{74716}{61479}\text{ then Station 5}=1.215\text{ of Station 6.}\\ \text{November 24.}-\frac{\text{Station 5}}{\text{Station 6}}=\frac{70995}{61428}\text{ then Station 5}=1.156\text{ of Station 6.}\end{array}\right\}1.185$$

$$\text{then }0.662\times\frac{1.185}{1.000}=0.784\text{ ratio of Station 5 to unity.}$$

From these values derived from the proportion of Station 6 to Station 1, December 11, another table of ratios can be obtained, marked Y, and to show the comparisons clearly, the Tables X and Z are placed alongside together with one derived from taking the mean of Tables Y and Z.

	Table Y.	Table Z.	Table X.	Table from mean of Y and Z.
Station I	0.684	0.684	0.687	0.684
Station II	0.850	0.850	0.849	0.850
Station III	1.000	1.000	1.000	1.000
Station IV	0.899	0.899	0.889	0.899
Station V	0.784	0.956	0.846	0.869
Station VI	0.662	0.810	0.695	0.731
Station VII	0.523	0.639	0.653	0.577
Station VIII	0.472	0.575	0.462	0.519

The discrepancies seem to originate with the proportion of Station 5 to Station 4 on December 8, when the discharge at the former was greater than at the latter. This was the only occasion upon which they were occupied simultaneously. Now on two previous occasions when these stations were gauged (though on separate days), when the range of tides and their relative levels agreed moderately well, Station 4 on both occasions had the greater discharge. Taking the mean of these two discharges, Station 5 had a proportion of 0.905 to Station 4, giving a ratio to unity of 0.813. The three measurements at Stations 4 and 5 taken together give Station 5 a proportion to Station 4 of 0.951, giving a ratio to unity of 0.854, which corresponds closely to that on Table X. From these tables I have selected Table X as giving about the best ratios, and have plotted a horizontal curve (sheet K), showing the ratios of the different sections, from which, whatever single discharge may be selected, the discharge of the entire cross-section may be calculated. On the same sheet, for the sake of comparison, I have also plotted the ratios from Tables X, Y, Z, and the mean between Y and Z, and constructed the figure of each by joining the points with straight lines. Then taking the total sums of the ordinates of each figure, respectively, I find they bear the following proportions:

Assuming the figure derived from Table X	=1.000
Then the figure derived from Table Y	=0.958
The figure derived from Table Z	=1.053
And the figure derived from Tablemean of Y and Z	=1.000

From this the greatest difference between the figure obtained from Table X and any other is about 5 per cent., and the greatest difference in any two of the figures, viz, Z and Y, about 9 per cent.

When more than one boat is employed in gauging with log-line and reel, the way in which such lines and the floats are handled by the individuals in charge will easily cause discrepancies of 2 if not 3 per cent. in the measurements.

Having the ratios of each section as given by the curve on sheet K constructed from Table X, it is necessary to take one of discharges at some one station with which to calculate the discharge of the entire cross-section. I have selected the discharge of December 8 at Station 4 for the reason that the tidal range is nearest the mean, and that I was present when the measurement was made. The rise and fall of tide was 4′.5 with its low-water at mean level. I correct the discharge for a range of tide of 4′.3 in the following way: $\frac{60556}{45}=1345\frac{1}{3}\times 43=57{,}856$ cubic feet of water discharged per square foot of area in a period of $6\frac{3}{4}$ hours, which is about the duration of a normal ebb current. The proportion of Station 4 to Station 3 or unity being 0.89, the corresponding discharge at Station 3 is 65,005 cubic feet. I have therefore taken 65,000 cubic feet as the discharge per square foot of area during a normal tide at Station 3 or unity. The proportions from the curve, derived from Table X (sheet K), give, therefore, the following amounts of discharge per square foot of area for each section:

Section I, inshore division	28,600
Section I, offshore division	46,800
Section II	55,250
Section III	63,700
Section IV	57,850
Section V	55,250
Section VI	44,850
Section VII	42,250
Section VIII, offshore division	34,450
Section VIII, inshore division	16,250

From this we derive the total discharge of each section.

	Discharge per square foot of area of section during tide.		Area of section in square feet.		Total discharge of section during tide.
Inshore division, Section I	28,600	×	1,040	=	29,744,000
Offshore division, Section I	46,800	×	1,715	=	80,262,000
Section II	55,250	×	4,920	=	271,830,000
Section III	63,700	×	4,570	=	291,109,000
Section IV	57,850	×	4,360	=	252,226,000
Section V	55,250	×	4,580	=	253,045,000
Section VI	44,850	×	5,180	=	232,323,000
Section VII	42,250	×	6,280	=	265,330,000
Offshore division, Section VIII	34,450	×	1,705	=	58,737,250
Inshore division, Section VIII	16,250	×	585	=	9,506,250
Total discharge of river in cubic feet during a normal current of $6\frac{3}{4}$ hours					1,744,112,500

In addition to the ebb discharge the flood current was also measured, each station being occupied once. The horizontal curves derived from the flood velocities are plotted on sheet H. Not having time to calculate their discharge, they are forwarded for inspection. One feature of the currents is this, that neither during flood nor ebb are the greatest velocities found in the deepest water. The cross-section of the river shows the water-way to be deepest near the banks, with a middle ground in the center. These channels are covered by sections 2 and 7. During the ebb current the greatest velocity is in sections 3 and 4, and during the flood in sections 4, 5, and 6. The water seems to move with greater eddying motion in sections 2 and 7 than in any of those lying between them, and this motion may account for the greater depth being found in those two sections. The observations taken during series I of the ebbs and throughout the floods were doubtless influenced by the high state of the up river.