limits, a brief examination of the hydraulic resources of Saint John's River seems to be in place.

Saint John's River may be considered to have its headwaters in Lake Washington in latitude 28° 6′ N. and longitude 80° 47′ west of Greenwich. Its general course as far as Lake George is about N. 33° W. Thence to a few miles below Jacksonville it follows on the whole a northerly direction, and finally turns to the east to debouch into the Atlantic.

Florida is geographically, perhaps, the most imperfectly known State east of the Mississippi River, and it is impossible to state with accuracy the extent of area drained by the river. The whole, or part, of the counties of Duval, Saint John's, Putnam, Volusia, Marion, Orange, and Brevard are tributary to it, and the area comprised in the watershed may be roughly estimated at 7,500 square miles.

One remarkable feature of Saint John's River consists in the numerous lakes through which it flows, or which are formed by it. From Lake Washington to Lake Monroe, a distance of about 90 miles by water, it passes through Lakes Winder, Poinset, and Barnes. The last-named, as well as Lake Monroe, covers an area of about 12 square miles. From Lake George, a distance of 50 miles, the widths of the river vary from 200 to 1,500 feet, and the depths from 8 to 31 feet. At its entrance into Lake George there is a bar with only $4\frac{1}{2}$ feet of water. Lake George is a fine sheet of water of an area of about 75 square miles.

From Lake George to Pilatka, a distance of 45 miles, the widths range from $\frac{1}{4}$ to $\frac{3}{4}$ of a mile. On this reach it receives its most important tributary, the Ocklawaha, which has a course of 70 or perhaps 100 miles, and is fed by innumerable ponds, lakes, and swamps, situated on the eastern slope of the central elevation of the State, known as the Florida Ridge.

From Pilatka to Jacksonville the river has various widths from $\frac{3}{4}$ of a mile to 3 miles and more, frequently resembling a lake rather than a river. About 22 miles below Tocoi it receives Black Creek, another important tributary. It is said that vessels drawing 12 feet might go about 13 miles up this creek but for a bar at its mouth, which reduces the depth to from $6\frac{1}{2}$ to 8 feet.

At Jacksonville the river is from 2,000 to 2,500 feet wide, with maximum depths of 70 feet or more.

There is little trustworthy information as to the annual rainfall in Florida. As the result of many years' observations we find it stated in the reports of the Chief Signal Officer that the average rainfall per annum is 49.8 inches in the South Atlantic States, and 53.65 inches in the Eastern Gulf States. At Jacksonville it amounts to about 58 inches, and at Fort Pierce, near the Atlantic Ocean and about 50 miles south of the headwaters of Saint John's River, it is stated by Lieut. M. L. Smith, United States topographical engineers, to be 73 inches. Taking the mean of the last two figures as the average rainfall over the whole region drained by the river, we get $65\frac{1}{2}$ inches, or $5\frac{1}{2}$ feet nearly, per annum, equal to 0.15 of a foot, or somewhat less than $\frac{1}{5}$ of an inch per day.

During an average ebb tide the drainage water collected during about $12\frac{1}{2}$ hours must be assumed to be discharged.

The volume of rainfall precipitated during *a day* on the entire river basin of 7,500 square miles surface would average 3,150,640,720 cubic feet $\left(\frac{5280^2 \times 7500 \times 5\frac{1}{2}}{365}\right)$; and during $12\frac{1}{2}$ hours 1,641,958,700 cubic feet.

The difference between the ebb and flood discharges through the Mayport section, amounting to 679,132,530 cubic feet, which should represent the amount of drainage water discharged through the section, is equal to about 41 per cent. of the estimated rainfall on the Saint John's watershed in $12\frac{1}{2}$ hours.

It is not probable that so large a proportion of the rainfall reaches the ocean.

The river above Jacksonville has generally sluggish currents, and from its considerable length it will take some time before all the available drainage water due to a certain period of rainfall can be discharged. During that time there will be a continual loss from evaporation and filtration, and it is probably nearer the truth to estimate that not more than 25 per cent. of the entire rainfall will find its way into the ocean.

To account by rainfall alone for the rather large difference of volumes deduced from the ebb and flood currents near Mayport, there must have been a precipitation of about 2,700,000,000 of cubic feet in $12\frac{1}{2}$ hours over the whole river basin, or of 5,215,000,000 in 24 hours. This would correspond to a fall of 0.3 of an inch per day, or about 9 inches per month, instead of the observed average of 0.18 of an inch per day. That such a rainfall took place is quite probable. It is well known that for a month preceding the gauging operations a series of heavy rain storms had prevailed over the largest portion of the watershed of the river. While it is true that the water level was but little affected from Pilatka downwards, for reasons already given, it is known that the water rose about 4 feet at the upper end of Lake George, 110 miles from Jacksonville, and about 8 feet in Lake Monroe, 165 miles from that city, and currents of 3 miles per hour were developed. There can be no doubt that when the river was gauged for flood, the supply of fresh water was in excess of the average amount, and diminished the volume of sea water entering the river.

LOCATION, LENGTH, AND HEIGHT OF THE JETTIES.

The north jetty has its shore end on Fort George Island. Its direction is about east 9 degrees south, its seaward end reaching the outer 16-foot curve. Its length is 9,400 feet from the high-water mark and 9,000 feet from low-water line.

The south jetty will start from the mainland, some distance below General's Mound. Its general direction is about east 38 degrees north, with its head at the outer 16-foot curve. Its length will be about 6,800 feet from the high-water line and 6,650 feet from low-water.

The jetties are designed to deepen the channel across the bar along or near the line occupied by it in the year 1853, and at different times subsequent thereto.

The width between the heads of the jetties will be from 1,600 to 1,800 feet. It is assumed at 1,600 in the following calculations.

Their heights are calculated for a mid-channel depth of 15 feet at mean low-water. From the shore ends out to a point on each jetty, about 2,000 feet distant from the sea ends, both jetties will be kept slightly submerged.

The stretch of 2,000 feet on the sea ends will be carried to the level of half tide.

The required mid-channel depth of 16 feet at low-water corresponds to a hydraulic radius of about 11 feet.

The average ebb-tide discharge at the Mayport profile was estimated to be 1,860,331,320 cubic feet during a period of 6 hours and 45 minutes.

The average discharge per second through that profile is therefore 76,557 cubic feet $\left(\frac{1{,}860{,}331{,}320 \text{ cubic feet}}{24{,}300 \text{ seconds}}\right)$.

The ebb current begins about 2 hours after high-water stand, and the tide falls one-third of its total range before the outward current begins; and since the outward current continues for $2\frac{1}{2}$ or 3 hours after the tide has commenced to rise, the average level of the water surface above mean low-water during the period of ebb-tide currents is only 1 foot.

The mean area of the profile near Mayport was found to be 34,935 square feet, with a hydraulic radius of nearly 20 feet.

The average velocity with which the water flows through the Mayport profile is 2.1914 feet per second $\left(\frac{76,557}{34,935}\right)$.

No slopes have been observed during the recent survey.

It would require a great number of observations to obtain a fair average result in regard to the slopes of the water surface near the bar. But the mean discharge and velocity being known, at least approximately, the formula of D'Aubuisson Downing will be used to determine the slope. For

V = mean velocity in feet per second,
S = slope or ratio of vertical descent to horizontal length,
R = hydraulic radius in feet,

we have

$$V = 100 \times \sqrt{R \times S}$$

At the Mayport profile we have

$$V = 2.1914 \text{ feet}$$
$$R = 20. \text{ feet}$$

therefore

$$S = \frac{V^2}{10,000 \times R} = \frac{4.8022}{200,000} = 0.00002401$$
$$\sqrt{S} = 0.0049.$$

When a permanent profile has been established between the heads of jetties by scouring and otherwise the slope originally existing is assumed to be restored.

Near the bar the ebb-currents act as they do at the Mayport profile, that is, begin about 2 hours after high-water slack; with a range of tide of 4.3 feet near Mayport, the elevation of the surface of the average profile is 1 foot, from which it is concluded that with a range of 5.4 feet on the bar the surface of the average profile is about 1.25 feet above low-water.

While the hydraulic radius at the gap is to be 11 feet at low-water, it will average 12.25 feet during the whole time of ebb-currents.

The width between jetties is fixed at 1,600 feet. The wetted perimeter, according to General Abbot's rule, will be 1.015 times as much, or 1,624 feet.

The area of cross-section of the bar-channel profile would then be equal to 19,894 square feet (1,624 × 12.25).

By the proposed location of the jetties a tidal prism will be added to the volume of outflow at Mayport, the area of which is about 1.186 acres, and the cubical contents 278,931,600 cubic feet of water.

The total volume of water flowing out during an ebb-tide between the heads of jetties and over the crests of submerged jetties is, therefore, 2,139,262,920 cubic feet, 88,035 $\left(\frac{2,139,262,920}{24,300}\right)$ feet per second.

To find the volume of water flowing out, on an average per second

through the gap, the velocity in feet per second is first found by means of the formula

$$V = 100 \times \sqrt{R \times S}$$

or by substituting the values of R and S

$$V = 100 \times .0049 \times \sqrt{12.25} = 1.715 \text{ feet.}$$

A mean velocity through the whole profile of 1.715 feet per second corresponds approximately to a mean bottom velocity of 1.25 feet. It appears, therefore, that even if the jetties are so arranged as to cause no material change in existing surface slopes, the bottom currents will produce scour. During that period of the ebb-flow, when the currents run with their highest velocity, the bottom velocity will, of course, exceed 1.25 feet per second.

The quantity of water discharged through the new bar-channel profile would average 34,091 cubic feet (19,894 × 1.715) per second.

The balance of the water, or 53,944 cubic feet per second (88,035—34,091), should pass out across the crests of the submerged portions of the jetties.

After deducting from the entire length of each jetty 2,000 feet of outer length, as being too high to permit the passage of any important amount of water, and also the length from high-water to low-water on shore, the aggregate length of the submerged portions of both jetties would be 11,650 feet.

These submerged crests are assumed to form straight lines, and to be held at a uniform level.

By determining the hydraulic radius of this jetty profile of 11,650 feet length, the theoretical depth of the crest below mean low-water will be fixed.

If *A* represents the average area of waterway across the jetties, then

$$R = A \div 11,650$$
$$V = 100 \times .0049 \times \frac{\sqrt{A}}{\sqrt{11,650}}.$$

The average discharge across the jetties is estimated at 53,944 cubic feet per second; therefore,

$$53,944 = A \times V = A \times \sqrt{a} \times \frac{.49}{\sqrt{11,650}},$$

and

$$A = \sqrt[3]{\left\{\frac{53,944 \times \sqrt{11,650}}{.49}\right\}^2} = 52,072 \text{ square feet.}$$

The mean hydraulic radius of the average profile of waterway across the whole length of the submerged jetties would therefore be 4.47 feet $= \left(\frac{62,807}{11,650}\right)$.

This would place the crests of the submerged portions of the jetties a little more than 3 feet below the level of mean low-water, if built to a uniform height. In practice they would have to be carried considerably higher in order to overcome the more or less constant flow of drift material and the tendency of the waves to flatten the profile of the bar channel.

Correction having been made for abnormal ranges of tide, in computing the discharge there would seem to be no reason to doubt the general accuracy of the result within reasonable limits for error. The volume differs only 7 per cent. from that obtained by calculations based on the area of the tidal basin.

Capt. James B. Eads, estimating from this data, in a report upon the practicability of deepening the channel through the Saint John's Bar, submitted to the mayor of Jacksonville, Fla., on the 29th of March, 1878, placed the average discharge on each tide at 2,000,000,000 cubic feet.

The channel depth between the jetties will, of course, be something less than the computed depth, and less than the same volume of discharge would maintain elsewhere on a stretch of the river, for the reason that the agencies which create the bar—the drift sand, currents, and waves—continue to operate, and the depth actually kept up in the new channel is the resultant of these forces and the increased scouring power established against them.

The channel depth will doubtless fluctuate within a range of a few feet, the shoalest period being immediately subsequent to a prolonged northeast storm, while the deepest will result from a conjunction of freshets and strong off-shore winds.

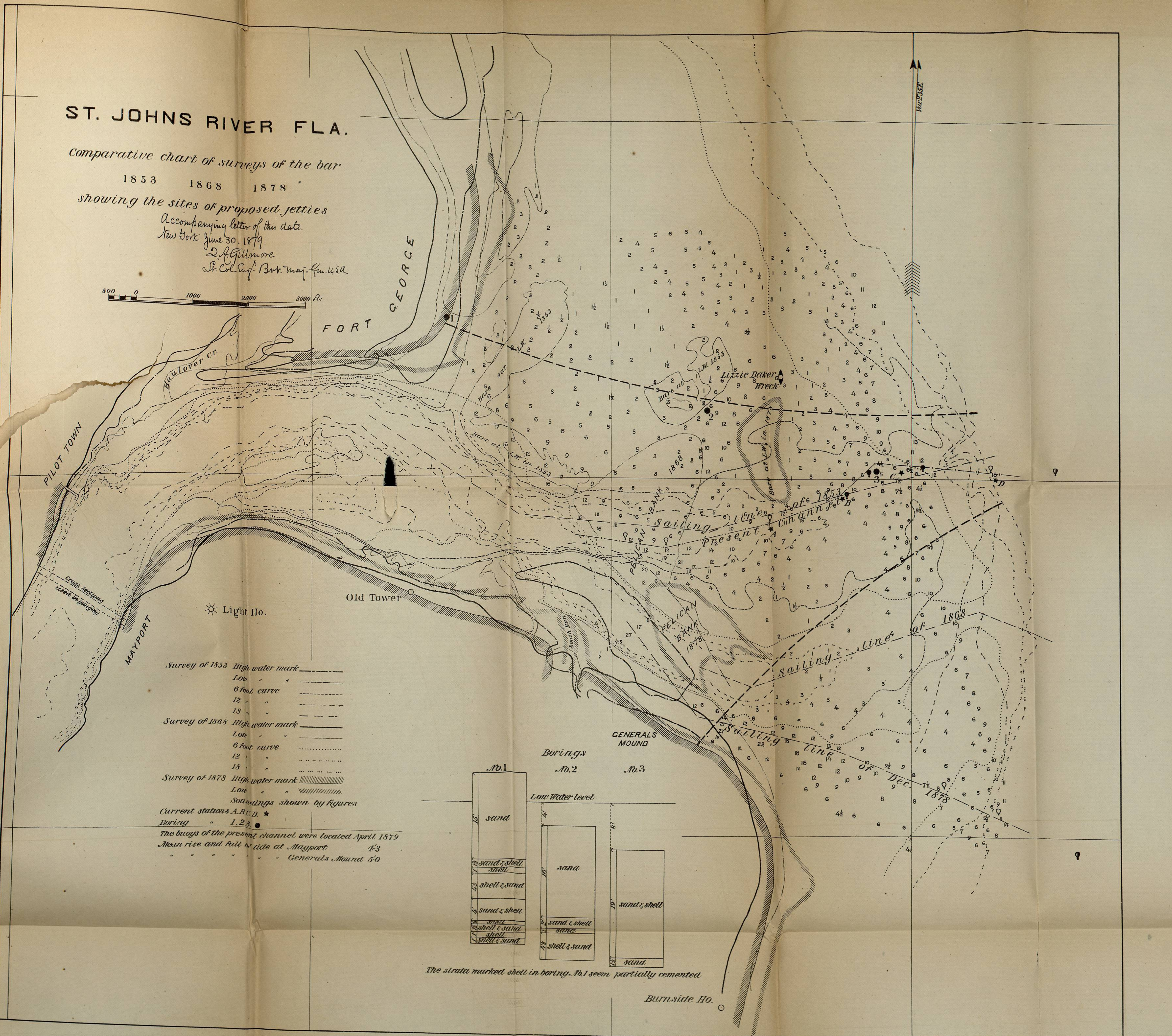
CONSTRUCTION AND ESTIMATES.

The jetties are to consist of a superstructure of riprap stone resting on a mattress of logs and brush. The thickness of the mattress will vary from 18 inches in shoal water to 36 to 38 inches in deep water. Logs and brush will also be introduced as a hearting should it be found expedient and advantageous to do so.

The side slopes on the outer faces of the jetties and upon the inner faces for a distance of ½ mile from the sea ends will be about 1 upon 4 or 5. Elsewhere the inner slopes will vary from 1 upon 2 to 1 upon 1½.

Owing to the more or less continued prevalence of heavy swells, and also of breakers upon the shoals where the jetties will be located, it may be found advantageous, if not necessary, to carry on the construction from a platform and tramway directly over the line of the work resting on piles driven as the work progresses. The piles will materially assist in keeping the work in place. Unless palmetto be used the piles should be treated for protection against the teredo.

North jetty, 9,400 feet long.		
1,526,000 cubic feet mattress, at 6 cents per foot	$91,560	
97,400 cubic yards stone, at $4.25 per yard	413,950	
		$505,510
South jetty, 6,800 feet long.		
1,452,250 cubic feet mattress, at 6 cents per foot	87,135	
100,000 cubic yards stone, at $4.25 per yard	425,000	
		512,135
Total cost for both jetties, all riprap above foundation		1,017,645
Add for piling and tramway for both jetties	125,000	
For raking and dredging between jetties	45,000	
		170,000
		1,187,645
For superintendence and contingencies, 10 per cent. on $1,187,645		118,764
Total for both jetties		1,306,409


ST. JOHNS RIVER FLA.
Comparative chart of surveys of the bar
1853 1868 1878
showing the sites of proposed jetties
Accompanying letter of this date.
New York June 30. 1879.
Q. A. Gillmore
Lt. Col. Eng. Bvt. Maj. Gen. U.S.A.
500 0 1000 2000 3000 ft.
FORT GEORGE
Haulover Cr.
PILOT TOWN
MAYPORT
Light Ho.
Old Tower
Lizzie Baker Wreck
PELICAN BANK
PELICAN BANK 1878
Sailing line of 1853
Present Channel
Sailing line of 1868
Sailing line of Dec. 1878
Cross Sections used in gauging
GENERALS MOUND
Burnside Ho.
Survey of 1853 High water mark
Low " "
6 foot curve
12 "
18 "
Survey of 1868 High water mark
Low " "
6 foot curve
12 "
18 "
Survey of 1878 High water mark
Low " "
Soundings shown by figures
Current stations A.B.C.D.
Boring " 1.2.3.
The buoys of the present channel were located April 1879
Mean rise and fall of tide at Mayport 4.3
" " " " " " Generals Mound 5.0
Borings
No.1 No.2 No.3
Low Water level
sand
sand & shell
shell
shell & sand
sand & shell
shell & sand
shell
shell & sand
sand
sand & shell
sand
shell & sand
sand & shell
sand
The strata marked shell in boring No.1 seem partially cemented