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REPORTS

OF

EXPLORATIONS AND SURVEYS

FOR

THE LOCATION OF A SHIP-CANAL

BETWEEN THE

ATLANTIC AND PACIFIC OCEANS,

THROUGH NICARAGUA.

1872-'73.

UNDER THE DIRECTION OF THE

HON. GEORGE M. ROBESON,

SECRETARY OF THE NAVY.

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
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NAVY DEPARTMENT, *Washington, June* 16, 1874.

SIR: I have the honor to acknowledge the receipt of an attested copy of a resolution adopted by the Senate on the 13th instant, directing the Secretary of the Navy "to furnish the Senate with the report and maps of the survey to ascertain a practicable route for an interoceanic ship-canal via the Lake of Nicaragua," and in compliance therewith to transmit herewith the report and maps called for.

Very respectfully, &c.,

GEO. M. ROBESON,
Secretary of the Navy.

Hon. M. H. CARPENTER,
President pro tempore United States Senate.

PREFACE.

The expedition for explorations and surveys to locate, if possible, a route for an inter-oceanic ship-canal through Nicaragua, was originally organized under an order of the Navy Department, dated February 14, 1872, by Commander Alexander F. Crosman, United States Navy, and sailed from New York by mail-steamer March 10. Arriving at Key West, the expedition was transferred to the United States steamer Kansas, Commander Chester Hatfield commanding, and arrived in that vessel off Greytown, Nicaragua, April 7. On the 12th of April Commander Crosman, in attempting to cross the bar in a ship's whale-boat, was unfortunately drowned. Commander Hatfield, upon whom the command of the expedition now devolved, immediately took charge in person, transferred his party to the west side of the lake, and pursued the work of carrying out the Department's instructions until the advent of the rainy season compelled him to cease operations. Leaving Midshipmen Keeler, Hughes, and Winslow, with a steam-launch and a few men, to do some hydrographic work in the lake for which the calmer weather of the rainy season was particularly favorable, the expedition sailed for the United States in the Kansas, leaving Greytown July 4, and arriving at Key West July 13, 1872.

In November, 1872, the expedition was re-organized under charge of Commander Lull; sailed from Hampton Roads, Virginia, December 3; arrived off Greytown December 20, when the work was resumed and carried on to completion.

PART I.

APPOINTMENT OF COMMANDER CROSMAN TO COMMAND THE EXPEDITION.

NAVY DEPARTMENT, *February* 14, 1872.

SIR: Having been selected to execute a survey of the Nicaraguan canal route, as in general indicated by the survey of Colonel Childs, you will make such inquiries, preparations of instruments, and arrangements as may seem necessary, in your judgment, for the party under your command, to accomplish this proposed work, and also a survey of the harbor of Limon, Costa Rica.

Requisitions of all kinds will be made on the Bureau of Navigation, and, when approved, will be supplied in the manner directed. Officers will be detailed to carry out the work, and as they report to you, as per order, will be regarded as on "other duty."

On reaching the Kansas or other vessel assigned to carry out the proposed work, you and the officers detailed will be placed on the books of that vessel on sea-pay until you return to the United States, when you will again be on "other duty" until relieved by the Department.

Respectfully,

GEO. M. ROBESON,
Secretary of the Navy.

Commander A. F. CROSMAN,
United States Navy, Philadelphia.

FLAG-SHIP WORCESTER, *Havana, February* 21, 1872.

SIR: Proceed with the Kansas to Key West and await the arrival there of Commander A. F. Crosman, who, I am instructed by the Navy Department under date of February 13, 1872, received to-day, has been ordered to take command of her, for the purpose of making a survey of the Nicaragua route, in pursuance of the act of Congress approved July 15, 1870. On your arrival at Key West seal and send the inclosed telegram to the Navy Department, (announcing your arrival there,) and at once take in your surveying equipments, now awaiting you there, and get on board all the supplies you can carry for the intended service.

Respectfully, yours,

S. P. LEE,
Rear Admiral, Commanding North Atlantic Fleet.

Commander CHESTER HATFIELD,
Commanding United States Steamer Kansas.

REPORT OF COMMANDER HATFIELD ON THE DROWNING OF COMMANDER CROSMAN AND OTHERS.

UNITED STATES STEAMER KANSAS, (3d rate,)
Off Greytown, April 13, 1872.

SIR: It is my painful duty to report to the Department the death by drowning of the following-named officers and men, viz:

Commander A. F. Crosman, commanding expedition.
Master Alfred Forée, attached to the Kansas.

William Walker, cockswain, attached to the Kansas.
Emil Birgfield, ordinary seaman, attached to the Kansas.
James Eley, ordinary seaman, attached to the Kansas.
William Arkwright, ordinary seaman, attached to the Kansas.

The circumstances attending are as follows: About 9.30 a. m. on the 12th instant Commander Crosman, with Passed Assistant Paymaster G. F. Bemis and Midshipman R. D. Stevens, left the ship in the whale-boat, with the intention of going to Greytown. About 9.45, in crossing the surf, the boat was capsized. The first cutter was immediately manned and sent to her assistance, with the intent that she should anchor outside the surf and float in a buoy attached to a line. Master Alfred Forée was placed in charge of the boat. In a few moments the boat returned, her anchor having been insufficient. She was then fitted out with additional anchors, a forty-gallon cask, and lines, Lieutenant Miller then going in the boat in addition to Mr. Forée. During this time two of the persons who had been in the boat could be discovered standing up upon the surf-covered bar, while the boat was a short distance from them with her crew clinging to her sides. The first cutter made several ineffectual attempts to get the line into the whale-boat, and, while still working, with that end in view, was capsized. The gig and dingey were immediately fitted out from the ship, the latter with anchor, cask, and lines, in charge of Midshipman A. Milliman, the former with archors, lines, and small India-rubber balsa, with the intention that it should be pulled through the surf, if possible, by Austin Denham, seaman, who professed himself capable and willing to make the attempt. Immediately after the whale-boat had capsized I fired a gun, hoisting the jack, with the view of getting the assistance of native boats from the shore, and soon after hoisted the ensign, union down, and continued firing guns at short intervals until the appearance of a shore-boat. The gig and dingey having dropped into the vicinity of the surf, attempts were made to get the balsa in to the assistance of the two persons standing on the bar, whom we believed to be Commander Crosman and Paymaster Bemis.

After considerable time and exertion the balsa, with a line attached, was pulled into the surf, when she immediately capsized; Denham, however, got on her again, and cutting the line to the gig, pulled in farther, but drifted down to leeward of the persons whom he was endeavoring to succor. The whale-boat and first cutter had meanwhile drifted far down to leeward, with their crews clinging to them, the boats continuing in the line of the breakers. There was a heavy swell setting in from seaward and a strong current setting out of the entrance, which caused the boats to remain in the surf, and made it impossible to get a line to them. About 11.30 a shore-boat, manned by natives, made its appearance, and immediately pulled into the surf and rescued those who were standing on the bar. Scarcely had this been done, when the gig, in charge of Ensign J. B. Briggs, was boarded by a sea which filled her, when she became unmanageable. The native boat immediately pulled to her aid, took out her crew, and towed her ashore. The whale-boat and cutter having meanwhile drifted about a mile to leeward in the surf, felt less the influence of the current which was setting out of the entrance. They therefore, under the greater power of the swell from seaward, commenced to fall in toward the shore, and before long brought up on the beach, where we could see their crews about them. About 2 p. m. signal was made from shore, "Commander Crosman, Mr. Forée, and four men lost." About 4 p. m. Lieutenant Miller reached the ship in a shore-boat, making the same report.

April 16.—The above report was written on the 13th, I not knowing what hour the steamer now here from Aspinwall might sail. On the afternoon of the 15th, the officers and men on shore, in charge of Ensign J. B. Briggs, came off. From Mr. Briggs and from the men I learn the following: After the whale-boat was capsized she drifted upon the bar immediately in front of the entrance, where the men obtained footing; Captain Crosman, until the last moment, retained his self-possession and command of the party; under his orders the boat was righted and kept head to sea; she was soon overturned again, in spite of their efforts to the contrary. Captain Crosman and Richard Pile, ordinary seaman, were washed away from the boat; after some little time they again reached the boat; she was again righted, but again overturned. On this occasion the boat was swept away from the bar to the northward and into deep water, Midshipman Stevens and four men clinging to her. Commander Crosman, Paymaster Bemis, and James Smith, seaman, were

left standing upon the bar. Commander Crosman endeavored to swim over to a small spit of land not far distant, which formed one side of the entrance. A five-knot current was running, which swept Commander Crosman away from both spit and bar, drifting him into the breakers to the south of the bar, where he was seen to sink in the surf. Paymaster Bemis and James Smith, seaman, were rescued from the bar by the shore-boat about 11.30. It is owing to the coolness of Smith that the paymaster was saved. Smith was cockswain of the whale-boat. Their capsizing was owing to the fact that their steerage-oar broke while going in, the boat then lurching to.

Richard Pile, ordinary seaman, and John Johnson, seaman, were the only two of the five on the boat who could swim; they staid by the boat until they got her ashore, for the sake of the others, and repeatedly saved the lives of the others when washed from the boat. I recommend them for medals of honor.

When the first cutter was capsized, Master Forée was almost immediately drowned, as were also William Walker, cockswain; Emil Birgfield, ordinary seaman; James Eley, ordinary seaman; and William Arkwright, ordinary seaman. Lieut. J. M. Miller, Midshipman Francis Winslow, and William Clark, landsman, came ashore together on a cask; the rest of the cutter's crew came in on their boat and oars. In the gig, Ensign J. B. Briggs and Midshipman A. B. Milliman, with their crew, came on shore in safety. Two of the men who could not swim were placed inside the boat, and the rest, outside of the boat, with their hands on the gunwales, worked her through the heaviest of the surf until the shore-boat came to their assistance.

As soon as possible Lieutenant Miller got a shore-boat and came off to report on board ship, arriving in a state of almost complete exhaustion. Ensign Briggs, therefore, was in charge of the five officers and twenty men who were on shore, all of whom he speaks well of. I would recommend John O'Neil, boatswain's mate, and George Hill, chief quartermaster, for medals of honor, they having particularly distinguished themselves for coolness, self-possession, and for the services which they rendered to others in the water.

On the afternoon of the 13th instant the body of James Eley, ordinary seaman, came on shore, which on the following morning, at an early hour, was interred with proper funeral ceremonies, by the direction of Mr. Briggs.

Until to-day a patrol has been kept upon the beach for the recovery of other bodies.

Edward Plunkett, ordinary seaman, received severe contusions, but is doing well.

I would respectfully recommend for a medal of honor Austin Denham, seaman, who went in on the balsa, at the risk of his own life, to give succor to those who were standing on the bar. I am indebted throughout this occurrence very much to Mr. J. E. Hollenbeck, of the Nicaragua Steam Navigation Company. As soon as our guns were heard, he dispatched his boat, which rescued the people from the bar. He also preserved our boats (except the gig, a total loss) by the hauling them up, and detailed certain of his men to patrol the beach. Inclosed I send sketch of bar and entrance.

Very respectfully,

CHESTER HATFIELD,
Commander.

Hon. GEORGE M. ROBESON,
Secretary of the Navy, Washington.

REPORT OF COMMANDER CHESTER HATFIELD, U. S. NAVY, COMMANDING UNITED STATES NICARAGUAN SURVEYING EXPEDITION, APRIL 12 TO JULY 13, 1872.

NAVY-YARD, *Washington, October* 21, 1872.

SIR: I have the honor to submit herewith reports of the proceedings of the Nicaraguan surveying expedition under my command.

In accordance with instructions from Rear Admiral S. P. Lee, I, on March 23, 1872, left Key West in command of the Kansas to take the surveying expedition under Commander Crosman to Greytown, Nicaragua. April 2 I arrived at Limon Bay, Costa Rica, where a party was landed to make tidal observations preparatory to a survey of the harbor.

The ship the same day proceeded on her way to Greytown, arriving off the harbor on the morning of April 3.

Commander Crosman landed on the following day, and made an arrangement for landing the expedition at the mouth of the Colorado River, the entrance there being better than at Greytown. April 6 I proceeded to the mouth of the Colorado, and on the 8th, the sea being smooth, got the launch out and landed a portion of the expedition. On the 11th I returned with the Kansas to Greytown to communicate with the mail-steamer.

On the morning of the 12th of April Commander Crosman, in endeavoring to land, was capsized in the surf and drowned. In endeavoring to render assistance Master Alfred Forée and four seamen were also drowned.

The death of Commander Crosman making it necessary that I should assume his duties, I placed Lieutenant-Commander White in command of the Kansas. On the 18th instant I proceeded to the mouth of the Colorado, and the same day effected a landing with the remainder of the expedition. The Kansas the same day proceeded on her way to Limon Bay to make a survey of that place, after which she was to make a survey of Greytown Harbor. On the 20th of April the expedition started up the Colorado River, arriving at Saint Carlos, on Lake Nicaragua, on the 26th instant, having experienced much difficulty in getting the steam-launch over the various rapids.

A bench-mark was here established upon a limb of a tree, west of the fort, 20 feet distant from the shore-line of high lake. The mark is the head of a nail driven into the top of the limb, which is sawn off. A gauge for recording the height of the lake was firmly established in 2 feet water at a point sixty yards distant from the bench-mark, the zero of the gauge being 10.9 feet below the bench-mark. On the 29th instant the expedition arrived at La Virgen, and the same day I made arrangements for procuring horses and mules from Rivas with which to transport the two parties of the expedition to the mouths of the Sapoa and Lajas Rivers, and the parties for tidal observation to the harbors of Brito and Salinas.

On April 30 a bench-mark was established on the root of a large tree in rear of the house of Mr. Ran Runnels, the mark being the head of a large screw, and a gauge for recording the height of the lake was secured to the wharf, the zero of which is 16.818 feet below the bench-mark.

The same day Midshipman J. D. Keeler, with a party of three men, started for Salinas Bay, and Midshipman S. M. Hughes, with the like number, for Brito, to make tidal observations. An unsuccessful attempt was made to land party No. 2 at the mouth of the Lajas River by means of the steam-launch.

On May 1 party No. 1, consisting of Lieut. J. E. Noell, Lieut. E. H. C. Leutze, Midshipman Frank Winslow, Civil Engineer J. F. Crowell, Assistant Surgeon J. W. Elston, and eight men, started for the mouth of the Sapoa River, there to commence their survey. On the same day party No. 2, consisting of Lieut. W. W. Rhoades, Master J. F. Moser, Civil Engineer A. G. Menocal, B. H. Whitfield, geologist, and seven men, commenced their survey at the mouth of the Lajas.

It being evident that the launch was too low in the water to be safe or useful, I made arrangements for raising her 18 inches; and leaving this work, with the duty of forwarding supplies to the different parties, to the supervision of Lieutenant Schetky, at La Virgen, I, on the 7th of May, set out for Managua to report my arrival in the country and the object of the expedition to President Quadra.

On the 10th instant I was presented to the President, and received many assurances of the good will of the Nicaraguan government toward the expedition, as well as offers of assistance.

Returning to La Virgen by the 15th with the intention of going immediately to the mouth of the Sopoa and joining party No. 1 in the survey of that route, I received a communication from Lieutenant Noell saying that, in consequence of the rains and of the illness of many of the party, he had been obliged to discontinue work after having accomplished the survey of half of that line. The results, however, already obtained were sufficient to demonstrate the impracticability of the route. As soon as possible I procured mules and horses to bring the party back to Virgin, and on the 22d arrived at their camp on the Sapoa.

On the 27th instant, having returned to La Virgen, party No. 1 started to survey a line up the Ochomogo River. Lieutenant Noell being sick, Lieutenant Leutze had charge of the party. Having seen the work commenced under favorable circumstances, I went to the mouth of the Lajas, and, following the picket, joined party No. 2. In accordance with the instructions issued, Lieutenant Rhoades, after surveying the line to Brito, had commenced the examination of a line diverging from the first, which promised favorable results. This line is designated on the maps and profiles as the Jesus Maria. I had before noticed a line through the valley of Buena Vista which appeared advantageous, and, after the examination of Jesus Maria, a reconnaissance of the Buena Vista was so satisfactory that I returned to examine it more thoroughly. The line of levels was, therefore, run to a point of the valley crossed by the Rivas and Granada road, and thence toward the Pacific at Brito through the valley of the Tola.

The summit-elevations by these last-named routes are greater than those by Colonel Childs's route through the valley of the Rio Grande; but, on the other hand, the length of the canal will be less and the character of the cuttings apparently more favorable.

On June 7 I returned to the party on the Ochomogo, and found that they had surveyed eight miles from the mouth.

On the 10th instant, owing to the heavy falls of rain, I deemed it advisable to discontinue work with both parties. We therefore returned to Virgin Bay, where I expected a bungo on the 17th to take the expedition to San Carlos. Owing to its non-arrival I was unable to leave with the last of the expedition until the 26th. A portion of the expedition crossed the lake in the launch on the 20th, but the second portion in the bungo were a week going from La Virgen to San Carlos, a distance of fifty-six miles.

On July 4 the expedition arrived on board ship at Greytown, and the same day sailed for Key West.

I was forced to leave the launch on the lake, as I did not feel justified in attempting to bring her down over the rapids after the experience I had had in getting her up, and on my arrival at Greytown I was the more convinced that my course in leaving her was the better. As much of the lake must be sounded, with a view to the construction of the canal, and as the rainy season is the most advantageous for performing such work, I left a party, consisting of Midshipmen J. D. Keeler, E. M. Hughes, and Francis Winslow, with four enlisted men, to perform this duty. Since my return to the United States Midshipman Keeler reports to me that he has run in nineteen miles of the western shore-line of the lake with compass and chain, besides obtaining soundings during the intervals when the lake is smooth.

In the execution of this work I cannot speak too highly of the *personnel* of the expedition. From the date of landing (April 18) to that of embarkation (July 4) there was no flagging in the zeal of any, it being recognized by all that the proximity of the rainy season rendered it necessary that every moment of daylight should be utilized for the survey. Much time was unavoidably lost in going and coming, by delays that were beyond my control, and the time in the field was thus reduced to about five weeks.

An examination of the maps and profiles will show a record of work that I think cannot fail to be satisfactory.

Much interest was shown in the object of the expedition by the Nicaraguan government, the officials having been instructed to afford me all assistance needed. I am much indebted to General Urtecho, governor of Greytown, who accompanied me to Rivas and afforded material assistance, as also to Don José Chomorro, who, as my agent in Rivas, procured mules, macheta-men, stores, &c., as they were needed. The expenses of macheta-men and animals for transportation the Nicaraguan government desired to defray, but, in the absence of instructions on this point, I deemed it best to decline the offer. I am also much indebted to Mr. Hollenbeck, of the Nicaraguan Steam-Navigation Company, for assistance, as also to Mr. Ran Runnels, who furnished us store-houses

and quarters without charge at Virgin Bay, and in various ways assisted the object of the expedition. At Granada, on my return from Managua, I was made the recipient of courtesies that indicated a strong interest in the expedition by the citizens.

Accompanying I have the honor to submit the following reports:

Report of Lieutenant Noell, in charge of party No. 1, survey of Sapoa route.

Report of J. F. Crowell, civil engineer, with party No. 1.

Report of Lieutenant Leutze, in charge of party No. 1, survey of Ochomogo route.

Report of J. F. Crowell, civil engineer, with party No. 1.

Report of Lieutenant Rhoades, in charge of party No. 2, survey of Brito, Jesus Maria, and Buena Vista routes.

Report of A. G. Menocal, with party No. 2.

Report of B. F. Whitfield, geologist, with party No. 2.

Paymaster's bills of expenses of the expedition, with copies of bills, receipts, &c.

Journal of party No. 1.

Journal of party No. 2.

The maps and profiles not being completed have been turned over to Commander E. P. Lull.

Very respectfully,

CHESTER HATFIELD,
Commander.

Hon. GEORGE M. ROBESON,
Secretary of the Navy.

REPORT OF LIEUTENANT J. E. NOELL, U. S. NAVY, ON SURVEY OF THE SAPOA ROUTE, 1872.

HEADQUARTERS UNITED STATES EXPEDITION,
Virgin Bay, Nicaragua, May 27, 1872.

SIR: I have the honor to submit to you the following report of the operations of surveying party No. 1, under my command, while running a line of levels from the mouth of the Sapoa River across the divide to Salinas Bay, on the Pacific side.

In obedience to your orders of the 30th April, 1872, (a copy of which you will find inclosed, marked 1,) I took charge of the party on the morning of May 1 and proceeded to the mouth of the Sapoa, at which place we arrived about 5 p. m., and established a temporary camp on the north bank of that river, about one mile from its mouth; as we had no conveniences for making a shelter, we had to cover ourselves as best we could with our rubber blankets from the rain that fell during the night. We kept our provisions dry with hides belonging to the muleteers.

We commenced our line on the morning of May 2, at the mouth of the Sapoa. The initial point was established on a bluff, some 30 feet above the water in the lake, and permanent bench-marks established near by. An assumed elevation was given to the lake surface, conforming to the elevation determined two days previous at Virgin Bay, from the assumed height of the bench-mark there, which was taken as 200 feet above datum.

For the first mile the line was run as close as practicable to the shore-line of the river, occasioning a great deal of cutting and loss of time in getting through the swamps and crossing the small lagoons that set back from the stream.

For the next two miles advantage was taken of the Camino, which runs nearly parallel to the general direction of the river, and rarely departs from it more than a few hundred yards. Pickets were cut at intervals in order to permit of test levels being taken at the water-line to check the accuracy of the work.

Up as far as Peña Blanca (three miles) no appreciable difference of elevation in the river could be detected, but here the first rapid was reached and the first difficulties in the way of canal construction noticed.

The river runs over a bed of rocks, with a narrow channel of some 150 feet width, while on either side the banks rise abruptly, showing numerous outcrops of rocks; the fall here is 5 feet in 300.

One mile above a large quebrada, or dry bed of what in the rainy season is a stream, enters

the river. Between the two points the levels were carried along the water-edge, keeping the instrument and rod on opposite sides to avoid the heavy cutting otherwise necessary, while the compass was run over the high ground of the river bank, and down the quebrada, to make a junction at the mouth of the latter.

An examination of the character of the topography beyond this place showed that the most expeditious way to proceed with any degree of dispatch would be to run both the compass line and levels directly up the bed of the river, which was composed for the most part of shallow rapids, with here and there pools of deep water.

The rapids had to be waded, and the chain-men had to be assisted by the Carib boys we had with us, who swam the deep water with the chain. After a half day of this work, the difficulties became much greater; the rapids became swifter, and it was found necessary for officers and men to wade in rushing water waist-deep for long distances.

The river-bed was found to rise rapidly, and the elevation at the mouth of the Vueltas, 28,300 feet from the origin, was noted at 39 feet above the lake.

The frequent sharp turns in the course of the river, and the rocky nature of its banks and bed, would necessitate great cost of construction; otherwise no great obstacles exist, so far, in the way of the canal.

The instructions received verbally involved following the Vueltas River to its headwaters, there to meet a party of natives sent out previously to cut a picket northward from Salinas Bay across the divide, where the lowest level was supposed to be. With this in view, the work was carried directly up the dry bed of the Vueltas, which, though narrow and tortuous, afforded a better line than the higher banks, covered with heavy timber, would have done.

The ground rose very rapidly, and a short distance above the mouth of the Cacao, which empties into the Vueltas ten and a half miles from the initial point by the line followed, the elevation attained was 191 feet above the lake, or, with the assumed elevation of the lake, (183 feet,) 374 feet above the Pacific. From this point the line was explored across to Salinas Bay, following the picket above mentioned. Barometric observations indicated an elevation of 1,000 feet on the crest, and this was afterward verified by sextant observation from the side station at Salinas Bay.

On the Pacific slope the ground fell very rapidly, the inclination being about 40°, until the headwaters of the Conventios were reached, after which the line followed the bed of that stream nearly to Salinas Bay, where it cut two ridges, and entered the latter about one mile above the mouth of the river.

The exploration was continued from Salinas along the ridge to the hacienda de Sapoa, near the head of the Sapoa River, in Costa Rica, and appearances seemed to indicate that a much more favorable route could be found by following the Sapoa Valley up to that point, and there cutting across the divide toward Salinas, entering the bay at its head.

Upon returning from the exploration, the Sapoa was followed down from the mouth of the San Sapote as far as the mouth of the Vueltas, the intention being to take up the work there and continue it along the valley.

This distance is about five miles, and the river falls 96 feet in a continuous succession of rapids and cascades. The heavy rains and exposures had so reduced the men that the party was ineffective for the laborious work necessary here, and being camped on the banks of the San Sapote, near its junction with the Sapoa, with half of my party sick and the rest much debilitated, and no protection for men and provisions from the heavy and incessant rain; and also from the observations of myself and the officers of my party, and the reports of the natives, finding that the rainy season in that section of the country (it being among the mountains and quebradas of the Cordilleras) was upon us, and that in a few days the roads would be impassable, I, with the concurrence of the officers of the party, moved camp to the hacienda de Sapoa, where I could find shelter, and from where I dispatched a messenger to you.

The heavy rains, increase of the river, and sickness, prevented the survey of some ten miles of the Sapoa; but from the hacienda de Sapoa, some five miles over the Costa Rica line, and where I found the weather much better and an improvement in the health of the party, work was resumed, and a line extended over the divide and connected with the tide-station previously established at Salinas Bay.

The elevation of the water in the Sapoa, at the point above mentioned, was 572 feet above the Pacific, (mean low water,) and the highest point reached was 767 feet above.

At Salinas a permanent bench-mark was established above ordinary high tide. This was accomplished at noon, May 21. Had the party not been so unfortunate as to accidentally break their barometer, much information of interest might have been acquired concerning the elevations of such prominent points of the ridges as Muyatepe, Obispo, &c., and also in regard to the valleys of the San Sapote, Nispero, Positos, &c., tributary streams of the Sapoa.

On the afternoon of May 22 you arrived and gave orders to start early next morning for Virgin Bay, in accordance with which we broke camp the next morning, May 23, and took the route for Virgin, passing by Salinas to pick up Midshipman Keeler and party, who were at the tide-station, and who you also had ordered to meet us on the north beach of Salinas Bay.

The journey back, about sixty-two miles, was made in about one day and a half, most of the party doing it on foot, it being impossible to provide animals for them. We arrived in Virgin Bay and reported at headquarters at noon on the 24th instant. As the road traveled was extremely bad, and we had some rain on the way, the party was completely exhausted upon its arrival.

In a journal which I kept, and which I respectfully forward with this report, you will find a record of the progress and condition of the party, and other minor details which I did not think necessary to inclose.

By your orders on April 30 I dispatched Midshipman Keeler, with three enlisted men of my party, to Salinas Bay, with instructions to establish a station there for the purpose of observing the tides of the Pacific.

The full report of his observations and their results, and his map and sketches of the bay, I have not yet received, but as soon as they are received I will forward them to you.

I also have not yet received the report and records of Civil Engineer J. F. Crowell, but will forward them, with a profile and map of the line we ran.

In regard to Midshipman Keeler, he arrived at Salinas Bay on the 2d May, and after making the necessary preparations, commenced observing the tides on the 4th. He had some difficulty in finding a suitable point to establish the station, on account of getting water for drinking and cooking purposes. On May 7, change-day, he found the lunitidal interval to be $3^h\ 15^m\ 6^s$, which he took as the vulgar establishment of the port. He did not remain long enough to rectify it, either by observation on the day of full moon, nor had he sufficient data to find the corrected establishment.

The facilities for obtaining fresh water are very limited in Salinas. The water used by him was obtained by digging wells in the beds of the quebradas, which, during the rainy season, are running streams. And the water obtained by this method, going even as far as three-fourths of a mile, is bad and brackish. The natives say that fresh water is to be found in abundance on the island in the bay; but Mr. Keeler having no boat, (although he tried very hard to procure one,) could not verify their report.

From appearances the bay would afford a good shelter for all classes of vessels, and valuable wood is found in great abundance on this side of the divide. In fact the wood on this side of the divide is of much more commercial value than it is on the lake side, the wood there being generally of a soft, pithy character, though often growing to a great size.

Midshipman Keeler reports that he was kindly treated by the natives, though I cannot say so much for those we encountered on our route, they evidently regarding us with much distrust, and in some cases fear. It was with difficulty that I could get the few macheteros we had, and, from what I could learn, they were afraid to come to work with us, although we gave them no reason, and we felt the want of them very much. They are very ignorant generally, and I found the information that they gave in regard to directions and distances to be very incorrect.

Inclosed, marked 2, you will please find the report of Acting Assistant Surgeon J. W. Elston, who accompanied my party as medical officer.

Very respectfully,

J. E. NOELL,
Lieut., U. S. N., Commanding Party No. 1.

Commander CHESTER HATFIELD, U. S. N.,
Commanding United States Nicaraguan Surveying Expedition.

REPORT OF LIEUTENANT E. H. C. LEUTZE—SURVEYING OPERATIONS ON THE OCHOMOGO ROUTE, 1872.

HEADQUARTERS, VIRGIN BAY, NICARAGUA, *June* 11, 1872.

SIR: In obedience to your order, I took charge of party No. 1 on May 27, and, on board of the steam-launch, proceeded to the mouth of the Ochomogo River, arriving there about 2 p. m. on the next day. During the night we camped on the northern extremity of Zapatero Island, to which place we had to go in order to hire a canoe, which was thought necessary for landing the party.

On May 28 we established our camp at the hacienda of Ochomogo, and the party was there joined by Mr. Maxillian de Sonnenstern, the Nicaraguan government engineer.

On the morning of May 29 we commenced the survey at the mouth of the river, following it a little more than a mile, to the first rapids, the general course of it being to the northward and eastward. At this point we left the river and took up a line indicated by Mr. de Sonnenstern, which ran nearly west, through the woods and over a plain covered with jicaral trees. It has a length of about seven and a half miles, and strikes the river about 3,000 feet to the northward of Ramada. It crosses the road to Concepcion about five miles, and the Camino Real to Granada about seven miles, from the mouth of the river.

On this line a great deal of cutting had to be done. No rock was found excepting at the first rapids. The jicaral plain is covered by deep black mud; but some outcrops of soft sandstone tend to show that large beds of the same are underneath the upper layers of mud.

The greatest elevation found was 112 feet, and the water-surface at the point the line was discontinued 79 feet, above the lake.

From this point we ran back along the river-bed, leveling down to the surface every 2,000 feet. The general direction of the river to Paso Real was found to be to the southward and eastward, and from that point to the ford on the road to Concepcion to the eastward. At the last-named place we again left the river, and cut a line running to the northward and eastward, with the object of intersecting the first line. This was accomplished after measuring 2,000 feet, the point of intersection being 11,700 feet from the origin. From this point a third line was cut down to the river, which was reached in 1,700 feet.

The soil is composed of rich earth, and as no sign of any rock can be seen, excepting in the river-bed, which is 50 feet below the banks, it is to be inferred that no rock will be found to at least that distance below the surface.

At San Rafael the river was gauged as accurately as possible, the mean of the observation being 100,000,000 gallons daily.

As the divide has not been reached, no opinion can as yet be given on the practicability of the route. So far, however, everything looks favorable, there being enough water in the river to allow lockage on both sides of the divide, by which means a great deal of cutting will be avoided.

The work had to be abandoned, as the rainy season has set in. During the last week we often found difficulty in carrying on the survey, on account of the heavy rains that fell every night and during the latter part of the afternoon.

The party returned to Virgin Bay on horseback, arriving at headquarters at 2 p. m., June 10.

Inclosed you will please find the report of Civil Engineer J. F. Crowell, marked A; also the record-level and compass-book, the log of the party, and a chart of the route.

Very respectfully, your obedient servant,

E. H. C. LEUTZE,
Lieutenant.

Commander CHESTER HATFIELD, U. S. N.,
Commanding Nicaraguan Surveying Expedition.

REPORT OF LIEUT. W. W. RHOADES—SURVEY OF THE RIO LAJAS ROUTE, &c., 1872.

HEADQUARTERS U. S. NAVAL NICARAGUAN SURVEYING EXPEDITION,
Virgin Bay, June 14, 1872.

SIR: In obedience to your orders of May 28 instant to proceed in charge of party No. 2 to the mouth of the river Lajas, and level, as nearly as possible, the route taken by Colonel Childs when surveying from that point to the Pacific at Brito, with the object of finding a practicable route for a ship-canal of 26 feet depth, I have the honor to give the following condensed report of our work.

Wednesday, May 1, with a party composed of the following officers, viz: A. G. Menocal, civil engineer, J. F. Moser, master, United States Navy, and Prof. B. F. Whitfield, mineralogist, I started from Virgin Bay, commencing the survey at the bench-mark established at that place, connecting it with our bench-mark at the mouth of the Lajas described in the level-book as follows, viz: bench-mark on ceiba-tree on the right bank of the river; tree blazed with a cross on side facing the river; bench on top of spike driven in on the east side of the tree, about 2 feet above ground; spike at bench driven in about 8 inches, leaving 2 inches above the surface; distance of the bench-mark from the lake, 699 feet. The datum-line was assumed at 200 feet below this bench. High-water mark of the lake was obtained through information given by the natives and marks on the banks along the lake shore, and was found to be 199.449 feet above the datum-line, or .551 of a foot below the established bench. This high-water mark was taken in order to show in the profile an approximate height above the highest water in the lake. The water in the lake at present (May 2, 1872) was found to be 5.746 feet below the assumed high-water mark. The water in the river was found to be at the same time .146 of a foot above the lake water. The survey was continued from the mouth of the Lajas at its intersection with the lake, (where we found a bar composed of sand and gravel, washed up to a height of 5 feet above the present water-level in the lake,) and continued along the left bank of the river through a level country, well wooded, with a heavy undergrowth, for a distance of one mile and thirty-six hundredths, to a bend of the river near the hacienda of San Pablo, where the line leaves the river, takes a more westerly direction, and at a distance of two and fifteen-hundredths of a mile meets the Guscanol, a small stream descending from the summit-level and running into the Lajas about four miles south of our line. The level of the water in the river Lajas at the point where the line leaves that stream was found to be 4.992 feet below the assumed high lake, and the elevation of the bank of the river at the same point was 2.11 feet. In his description of this line Colonel Childs states the latter elevation to be 5 feet above his assumed high lake; and as we have been unable to find any of his bench-marks or any other point of reference for the location of the line, we have made use of his data to compare our elevations with his, and from which we found his high lake to be 2.889 feet below ours. In following Colonel Childs' line from the banks of the Lajas to the Guscanol frequent reconnaissances were made for some distance on both sides, and we observed that by running another line to the right, and from 500 to 1,000 feet from the line, through the head of a small ravine and the gap of small hills, an easy curve could be located joining these two points, by which a much lower elevation was obtained, and consequently a considerable saving in the cutting, as will be shown in the profile of both lines when completed. From the point where our line intersects the Guscanol the survey was continued along the general direction of this stream, intersecting it in several places, along a broad and gradually-ascending plane to the head of the stream at the summit-level, which was found to be 43.007 feet above our assumed high lake, and five miles and twenty-five-hundredths of a mile from our first station at the mouth of the Lajas. At this point the line occupies the head of a ravine on the westerly side of the Costa Rica road, and, descending at the rate of 15.37 feet to the mile, it follows the ravine for a distance of one mile and thirty-seven-hundredths; and at the further distance of one and sixty-one-hundredths of a mile crosses the Limon ravine, (called by Colonel Childs the Espinol,) a stream of large dimensions during the rainy season; then by an easy curve to the left the line meets the Rio Grande in seven miles and thirty-five-hundredths from the shore of the lake, at an elevation of 7.8 feet below our assumed high lake. From this point the line follows the bed of the river along its serpentine course, in a very narrow and irregular valley from 100 to 150 feet wide, running through the projecting

spurs of high hills of the dividing reach on both sides for a distance of two miles, at which point the line, by an easy curve to the right, and at an elevation of 21.7 feet below assumed high lake, is traced across a lateral valley for a distance of one-half mile, when it again intersects with and occupies the bed of the river, at an elevation of 30.6 feet below high lake, for a distance of 2,000 feet, through an opening in another dividing reach, after passing which the line leaves the stream to the left, and, taking a northerly direction, was traced along the eastern bank of the ravine over undulating lands to its extreme northerly point. The river then takes a westerly course and runs along the southern boundary of the valley of the Tola, and the line, located in the same direction, meets the river Tola at a distance of thirteen and sixty-five hundredths of a mile from the lake, at an elevation of 43.3 feet below high lake. Following the same general direction along the valley, the line passes through a narrow gap about 100 feet wide, formed by high hills to the right and a projecting spur on the left; following from this point a favorable location through a narrow valley, between small isolated hills on the left and the high hills of the Cordillera on the right, at a distance of 1,250 feet, it again occupies the bed of the Rio Grande. The banks of the river at this point are formed by high, steep hills on the north and low valley to the southward, when, after occupying the bed of the river at an elevation of 92 feet below high lake for a distance of 400 feet, the line leaving the stream was extended westerly through broad plane lands, and then, by a curve to the left, along the slope of the Cordilleras, to meet the Rio Grande at a distance of eighteen and seventy-eight hundredths of a mile from the lake. From this point the line occupies the channel of the river, and the survey was continued along the right bank to the mouth at Brito, where an outline survey of the harbor was made and the elevation of the highest tide taken, giving a difference of level with our assumed high lake of 104.469 feet, and the present level of the lake, 98.97 feet. The total length of the line as located, from the shore of the lake to that of the Pacific, was nineteen and forty-six hundredths of a mile.

The Rio Grande, connected as it is with this line and the projected canal, I located the entire distance from where the line meets the stream to its mouth at the port of Brito. An elevation was taken at every 100 feet and at every transit-station, with the spirit-level, from the mouth of the Lajas to the port of Brito.

The river Lajas rises on the eastern slope of the dividing ridge, and after running six or eight miles in a northerly direction, through a comparatively level country, it enters the lake about ten miles to the northward and westward of its source. During the dry season a gravel bar is formed at the mouth of the river by the action of the waves and the prevailing northeast winds blowing across the lake. At the time we commenced the survey this bar extended back 512 feet from the shore of the lake, from which point the water of the river percolates through the sand and gravel to the lake. The width of the river, from the mouth to the point where the line diverges from it at San Pablo, varies from 90 to 100 feet. Between these two points the elevation of the banks averages about 3 feet above the level of the water, and from soundings taken at every 200 feet the average depth of water was found to be about 10 feet. The bed of the river is trap-rock, covered in some places with a deposit of mud and sand.

The Rio Grande rises on the easterly slope of the same range of hills and about three miles north and west of the Lajas, and, after running in a northerly direction about four miles, receives the Limon or Espinal, (a large permanent brook,) bends to the westward, and, by a narrow, tortuous, and irregular valley, passes through the dividing ridge, and thence through a more capacious and regular valley, after receiving the river Tola and several smaller streams, to the Pacific at Brito. The channel of that part of the river occupied by the line as located is from 60 to 90 feet in width, and 20 to 30 in depth, cut by the action of the current through a bed of hard trap-rock, which rises to from 5 to 10 feet of the surface.

In surveying the line just described we made frequent reconnaissances of the surrounding country on both sides, with the object of finding another line by means of which the route might be shortened and the inconvenience of occupying the bed of the Rio Grande avoided. Such an indication being found at a place called Los Horcones, (a large indigo hacienda,) near Las Serdas, and having finished the survey of the first route, we returned back to the last-named place, and, starting from an established station and bench-mark, we ran a transit and level line with the object of locating the streams La Chocolata and Los Horcones, and determining the elevation of their

beds and that of the divide near the estate of Jesus Maria. The elevation at the intersection of the Chocolata with the Rio Grande is 31 feet below our high lake. From this point the bed of the brook gradually rises to its junction with the Los Horcones, where it reached an elevation of 35 feet above the lake. We then followed the last-named stream to its source at the summit-level, a distance of one mile and eighty-seven hundredths from the Rio Grande, at an elevation of 123 feet above high lake. Seven hundred feet east of this point we reached the highest elevation, equal to 129 feet above high lake. From thence the line rapidly descends along the bed of a small brook to the hacienda of Jesus Maria, at a distance of two miles and nine-tenths from the banks of the Rio Grande, where it meets the Rio del Medio at an elevation of 83 feet, and thence to the lake—an approximate distance of seven miles from the starting point. A line could be located through this route with an approximate total length of sixteen and five-tenths miles from the lake to the Pacific, and satisfy the desired conditions of being independent of the Rio Grande. For want of time a further survey could not be made of this line, but permanent bench-marks and established stations were left to complete the survey at a future time. Starting from an established station and bench-mark at Jesus Maria, we ran the transit and level along the road connecting this point with Buena Vista, with the object of making a preliminary survey to determine the practicability of a route through the latter place, as recommended by you. We reached the summit level, finding an elevation of about 190 feet above the lake, and had worked down toward the Tola through a most beautiful valley, a distance of about two miles, when we stopped work on account of the heavy rains, leaving permanent bench-marks and stations, to continue the work at some future time.

I stopped work on the 11th of June at Calcuta, and started for Virgin Bay on the 12th at daylight, arriving there that evening with my party and the results of our survey, which I herewith respectfully submit.

Very respectfully, your obedient servant,

W. W. RHOADES,
Lieutenant United States Navy, Commanding Party No. 2,
U. S. Naval Nicaraguan Surveying Expedition.

Commander CHESTER HATFIELD, U. S. N.,
Commanding Nicaraguan Surveying Expedition.

REPORT OF J. FOSTER CROWELL, CIVIL ENGINEER—SURVEY OF THE SAPOA RIVER, NICARAGUA, 1872.

WASHINGTON, *October* 18, 1872.

SIR: I have the honor to present the following report in regard to the survey of the valley of the Sapoa River, in Nicaragua, with reference to its fitness for the route of the proposed inter-oceanic ship-canal:

GEOGRAPHICAL POSITION.

The river Sapoa empties into Lake Nicaragua at a point about fourteen miles southeast from Virgin Bay, and forty-six miles in a straight course from San Carlos, at the foot of the lake. It has its source in the elevated table-lands which extend, near to the Pacific coast, from the Bay of Salinas toward the east. Its head is about three miles due east from the bay, in a narrow cañon which is about 200 feet in depth and extremely crooked in direction; the bottom of the cañon is elevated some 580 feet above the sea. The general course of the river is northeast and north; it is very tortuous, and sharp bends frequently occur; its total length is twenty-two miles.

NATURAL ADVANTAGES.

The great advantage of a magnificent harbor at one extremity and the shortest line of lake navigation from the other, indicates at once strong reasons for the location of the canal by way of the Sapoa. Unfortunately, however, topographical obstacles occur so formidable as to almost, if not entirely, neutralize these great advantages, as will be shown by the facts subjoined further on.

CHARACTER AND METHOD OF THE SURVEY.

The survey was commenced at the mouth of the river on the morning of May 2, 1872. The brief time allotted to the work, necessitated by the near approach of the rainy season, did not allow of its development in detail, but the general results obtained, and especially the leveling operations, can be relied on as entirely accurate.

The method pursued was to follow the banks of the stream as closely as possible with the compass-line, chaining the distances, and to take surface-elevations at maximum intervals of 500 feet, with intermediate heights, where deemed necessary. Wherever attainable, the elevation of the water in the river was noted. In the low bottom-lands near the mouth it was not considered advisable to adhere to the banks invariably, as the vegetation was very dense, requiring great labor in cutting, and the numerous swamps and lagoons, though of small size, would have made such a course very difficult; but, instead, to follow the trail or picket used as a public road, which ran nearly parallel to the river, at a short distance from it. Numerous connections were made with the shore-line to locate it, and careful reconnaissances made in canoes of such portions of the stream as could not be directly reached.

After passing the first rapids, which were encountered at the small plantation called Peña Blanca, about three miles from the mouth, it was found necessary to carry the lines and levels directly up the bed of the stream, on account of the steepness and loftiness of the banks.

TOPOGRAPHICAL FEATURES.

For a distance of two miles above the mouth the banks of the stream are low and flat, and the river-valley is about a mile in width, excepting near the lake, where it is shut in on the west by a bluff between 20 and 30 feet high.

The river is shallow; numerous bars of alluvial deposit are met, and light canoes are the only craft for which it is navigable. Across the mouth are sunken reefs on which has formed a sand-bar. The width at the mouth is 400 feet, a short distance above the mouth it is 200 feet, and at Peña Blanca only 120 feet. One mile below this last-named point the river-banks grow suddenly bold, and increase in height until here they are elevated nearly 40 feet. At this point, as before mentioned, the first rapids occur; the river at the foot of the rapids is but 0.3 foot higher than at the lake; at the head of the rapids the water-surface is 5+ feet higher, which difference of elevation occurs in 260 feet of distance. Half a mile farther up the stream, the dry bed of a large creek, which in the rainy season brings down an immense volume of water, enters through a deep gorge or "quebrada" from the west. At the junction the main valley makes a sharp bend to the east, and above it the river is a series of rapids and cascades; the banks become higher, bolder, and more contracted.

At station 251, nearly five miles from the lake, is another sudden change in the direction of the valley, which then trends due south. In the sharp angle thus formed is the mouth of a small stream from the east; the elevation of the water in the river here is 15.9 feet above the lake, or 112.3 feet above Pacific high tide.

At station 260, (900 feet beyond,) there is a further difference of 14 feet, making the entire rise 29.9 feet above the lake. A remarkable precipice, towering some 150 feet perpendicularly from the stream, here causes it to make two right-angle turns. Thence to the mouth of the river Vueltas, at station 281, the course is straighter, with a more gradual rise. The Vueltas is an important stream, entering on the left bank; at the time of the survey, however, it was almost dry. Its mouth is about five and three-quarter miles from the lake, at an elevation of 135 feet above the Pacific.

LAS VUELTAS.

In accordance with the instructions received when commencing the survey, the line here debouched from the main valley and followed up the bed of Las Vueltas, which is, as its name indicates, a very crooked stream, and, in fact, more like a mountain gully than a river.

It has few tributaries, and all insignificant with the single exception of the Cocoa River, which enters from the east, some four and a half miles above the confluence with the Sapoa.

On the morning of May 10, eight days after commencing the work, station 551 was reached,

ten and a half miles from the lake, with an elevation of 191.651 feet, or 288.033 feet above the Pacific, and, from the positive indications of the existence of much greater altitudes beyond, it was deemed advisable to make a reconnaissance in advance before continuing the line.

At the same time that the surveying party had left the general headquarters at Virgin Bay, a small force of native macheteros, or woodsmen, had started for Salinas Bay, to cut a trail from the shore of the bay across the divide to the headwaters of the Vueltas, and at this time had penetrated to within two miles of the point where the survey was suspended. Provided with a barometer and pocket-compass, and attended by two native guides, Lieutenant Leutze and myself set out for Salinas Bay by way of this trail on the morning of May 11. As we proceeded toward the source of the Vueltas we found no change in the prevailing character of the country, except that the ground became steeper and more broken. At a distance of four and a half miles we mounted a high hill, over which the trail led, which appeared to be a rounded spur jutting out from the main chain of the mountains, but subsequent examination showed it to be the root of a long ridge stretching far to the northeast, forming at its extremity the hill of Moyatepec, whose foot is washed by the Sapoa; it divides the waters of the Vueltas from those of the San Sopote, another tributary of the Sapoa, which will be again alluded to. By barometer the elevation of the summit was found to be 620 feet above the sea. Passing down the side of this hill we crossed a valley near its head, and then climbed the main ridge, crossing it in a notch not more than 40 yards in width, and at least 200 feet lower than the adjacent mountains. An accident had rendered the barometer useless just before we reached this point, but by comparing its summit with the one just crossed it was judged to be 1,000 feet above the sea.

Subsequently observations were taken with a sextant at the tide-station at Salinas Bay, from which the notch was distinctly visible, and the elevation thus found to be 1,031 feet above the sea.

PACIFIC SLOPE.

On the Pacific side the descent is very rapid; about 500 feet vertically occurs in the first 500 yards of distance, and the remaining 531 feet in about five miles.

Following the dry bed of the Conventios for some distance, and then striking across the transverse foot-hills which border the north side of the bay, we reached the shore, with all hope of finding a favorable line via the Vueltas entirely dissipated.

Owing to the entire absence of water in the highlands, and the difficulty of access to the summit, it would have been impossible to continue the lines and levels over the ridge at this point without much suffering and risk, and accordingly, after remaining a day at the tide-station to repair the barometer and to recover from their fatigue, the exploring party resolved to abandon the project and to seek a more promising route to the eastward.

Ascending the high table-lands before described, the head of the Sapoa was reached and its valley followed down some ten miles. The result of this observation was a conviction that the most favorable conditions of any for canal location were presented by the main valley of the Sapoa, from the mouth as far as the entrance of the valley of the Posetos, a small but unfailing stream that flows at the western foot of the table-lands and joins the Sapoa about fourteen miles from the lake, and thence by the Posetos to the divide. Accordingly the exploring party returned to the main body, which shortly after set out to take up the work at the confluence of the Sapoa and Vueltas and extend it as above.

Heavy rains, and the sickness that resulted from the constant drenchings, made it impossible to follow out this plan, and we were obliged to be content with visual observation only, from the mouth of the Vueltas to the Posetos.

A few days after, when those on the sick-list had sufficiently recovered, it became possible to start a line of levels from the Sapoa, where the Costa-Rican road crosses it, and extend them across the table-land down to the tide-station of Salinas, where they were connected with the tide-gauge. This was done in order to determine the elevation of the source of the Sapoa, and the line followed was selected for convenience of working, and not as a projected line for the canal. The examination of the Posetos Valley had to be omitted altogether. The following facts were developed by the explorations between the mouth of the Vueltas and the source of the Sapoa:

For the first six miles the Sapoa is composed of an almost uninterrupted series of rapids and

cascades, with two "falls;" at this distance the mouth of the San Sapote is met, which is 100 feet higher than that of the Vueltas.

The San Sapote is a stream of about the same size as the Vueltas, and, like the latter, is dry during a large part of the year.

Three miles farther on two small streams, the Nispero and Posetos, unite and empty together into the Sapoa. They flow on either side of the high hill of Obispo, which closely resembles Moyatepec.

Beyond the Posetos rise abruptly the table-lands, and the Sapoa Valley becomes more and more contracted until it terminates in the cañon mentioned heretofore.

High hills, with occasional precipitous cliffs, rise from either bank of the Sapoa between the Vueltas and the Posetos, and it was with the greatest difficulty that the exploration was accomplished. With the party as constituted the complete survey would have been impossible.

Above the Posetos a few small streams enter from the east, but none from the west. The valley is inclined steeply, and there are innumerable rapids. The total rise from the lake to the source is 488 feet, the latter being 584.4 feet above Pacific high tide.

From the foregoing description, and an examination of the accompanying map and profiles, it will be seen that the construction of a canal by this route would be attended with immense cost. Apart from the deep cuttings, which would in all probability totally condemn this route, enters the great labor of widening and straightening this valley at numerous points, and providing adequate water-way for the immense drainage of the Sapoa water-sheds during the times of heavy rains. The question of the position of the summit-level of the canal, whether it should be at the lake-level or elevated much higher and supplied by the water of the Sapoa, which has excited discussion among former examiners of this route, is omitted in this report, together with any plan or proposition, because of the almost insuperable difficulties in the way in the lower section of the Sapoa Valley. Moreover, besides these natural obstacles, the physical and mechanical difficulties of construction would be unusually great, because of the immense haul required to remove the excavated material and of the nature of the geological formation, which throughout most of the region is composed of primeval and volcanic rock, generally exposed, and so twisted and contorted by upheavals of the strata as to render its being worked economically an impossibility. In view of these considerations, I have no hesitation in altogether condemning this route, considering that, beyond the desirable features possessed by its termini, it contains not a single element of success.

Herewith are a map of the survey of the Sapoa and accompanying profiles.

Respectfully submitted.

J. FOSTER CROWELL, C. E.,
Assistant Civil Engineer, Nicaraguan Surveying Expedition.

Commander CHESTER HATFIELD, U. S. N.,
Commanding Nicaraguan Surveying Expedition.

REPORT OF J. F. CROWELL, CIVIL ENGINEER, ON SURVEYING OPERATIONS RIO OCHOMOGO, 1872.

HEADQUARTERS NICARAGUAN SURVEYING EXPEDITION, U. S. NAVY,
La Virgen, Nicaragua, June 15, 1872.

SIR: I have the honor to present the following report concerning the preliminary survey of the Ochomogo River as far as completed, with reference to its availability as a route for the proposed ship-canal between Lake Nicaragua and the Pacific.

The survey was commenced at the mouth of the Ochomogo, and extended eight and three-quarter miles up the river, to a point 3,000 feet above the rancho of Remada. Two lines were followed, one keeping close to the banks of the stream, the other diverging to the westward about two miles from the mouth, and cutting directly across the country to the above-mentioned point, where it was again connected with the main line. Levels were taken over both lines, and also at the surface of the water in the river.

An unsuccessful attempt was made to explore the route farther on toward the summit-level, which, from information received, is about two miles beyond the point reached by the survey; but this had to be abandoned. On this account, therefore, no definite opinion can be here expressed in regard to the fitness of the route for the purposes of a ship-canal, and this report must b , necessarily, confined to the discussion of the few important facts developed within the limits of the survey.

In the last mile of its course the river has a fall of but two-tenths foot, with low banks, mostly of alluvial character, offering no obstacles of any kind in the way of cheap construction of a canal. The mouth of the stream is obstructed by bars, which, however, could be easily removed by dredging at inconsiderable cost. Above the first mile the river has a rapid fall from the point reached by the survey, the elevation of the water there being 79 feet above the lake, which would give a rate of fall, if uniform, of about 10 feet per mile. The levels taken at the water-surface show but a trifling variation in the rate of fall. The bed of the stream is composed of layers of trap-rock of moderate hardness, lying nearly horizontal, with a slight dip to the westward, and susceptible of easy working. Excepting at a few points the rock does not appear above the low-water line. The banks are steep, rising generally from 10 to 15 feet above the stream. The width of the waterway varies from 100 to 150 feet, and there are few sharp turns in direction, both facts worthy of consideration.

The average depth of cutting by the river line would be 39.2 feet above the water-level, for a length of seven and three-quarter miles. The highest elevation reached on the other line is 110 feet above the lake. Following this second line a saving in distance of one and three-quarter miles could be made, with an increased amount of cutting, averaging for six miles 71 feet above the water-level. As far as quantities merely are concerned, this comparison is obviously in favor of the river line in the ratio of 3 to 4; but it would be found, probably, on further examination, that the difference in cost of construction would render the other the cheaper, as it runs through the soft black mud of the jicoral country, which is very easily worked.

No plantations or improvements of any kind are to be met with anywhere on either line, a point not to be disregarded.

In addition to the other work of the survey, the river was gauged at San Rafael, about five miles from the mouth, by which the discharge was found to be 100,000,000 gallons per day of twenty-four hours. In the absence of certain information it is only presumable that the daily discharge *never* falls short of this quantity; but the indications in the bed of the stream, the testimony of other persons, and the fact that the measurement was made just before the rainy season set in, seem to warrant the presumption, which, if correct, might admit of the introduction of one or more locks, thus dispensing with the lake as a feeder, raising the summit-level of the canal, and correspondingly reducing the cutting. The practicability of this suggestion can only be determined after the survey shall be completed, at some future time, across the divide and to the Pacific, as it depends on the situation of the source of the river and the available length of space for the development of the increased lockage on the Pacific slope.

It is considered highly probable that a line more favorable than either of the two which have been gone over can be found by keeping to the eastward of the river a short distance. And it is by no means certain whether the route should follow the general direction of the river to the divide, or whether it should leave the valley at Paso Real, about six and one-half miles up the mouth, and strike directly across to the Escalanta River.

Perhaps the strongest point in favor of the location of the canal on this route is the magnificent roadstead at the lake entrance, an advantage not possessed by any other part of the lake.

The entire length of lines surveyed is 71,500 feet, or about thirteen and one-half miles, accomplished in eight days of actual work, in addition to which three miles more were partially explored.

Accompanying this will be found a map and profiles of the work.

Respectfully submitted.

J. FOSTER CROWELL,
Civil Engineer, Nicaraguan Surveying Expedition, U. S. N.

Lieutenant E. H. C. LEUTZE, U. S. N.,
Commanding Party No. 1.

REPORT OF B. F. WHITFIELD, M. D., GEOLOGIST OF THE NICARAGUAN SURVEYING EXPEDITION.

SIR: In obedience to your order I have the honor to make the following report on the geology of that portion of the state of Nicaragua surveyed under your supervision:

Nicaragua, though eminently a volcanic district, presents a remarkable diversity in its geological aspects as well as in its climate, soil, and other physical characters. First. Along the course of the San Juan we find low, swampy marshes, at its mouth and origin, with an intervening portion of more elevated districts, undulated by the demolished cones of extinct volcanoes. Second. While on the western side of the lake we found the results of the most terrific volcanic action in the beds of lava which cover everything, with the exception of a few limestones which remain as witnesses of the long periods of repose prior to the disgorgement of the igneous rocks. Third. In the vicinity of Leon the country spreads out into extensive plains; and it is not until we reach Choulates that we find evidences of primary strata. Of these four natural divisions of Nicaragua, it has been my province to visit only two, and it is to these that the following remarks will be restricted: first, the elevated districts of the department of rivers; second, the valley of the San Juan.

DEPARTMENT OF RIVAS.

In studying the geology of this portion of Nicaragua, we notice the following facts:

1. The absence of metamorphic, or the granitic rocks and slates.
2. The predominance of volcanic rocks.
3. The occasional outcropping of fossiliferous rocks.
4. The extensive occurrence of alluvial deposits.

No rocks older than the fossiliferous make their appearance. If any have ever been exposed during the upheavals in this district, they have since been covered by lavas. Farther north they make their appearance in the region of Chontales.

Volcanic rocks.—From the lake to the Pacific these rocks form an almost uninterrupted bed, covering in all rocks deposited prior to the time of their origin. By a casual observer passing through the country this might not be fully appreciated, as the rock is generally decomposed on the surface, and is covered by a rich soil, so that except where it has been artificially cleared it is covered by forests. Except along the water-courses it is seldom that the rock is left uncovered, and in some places a close observer might travel for a number of miles over tracts where the rock is but a few feet below the surface, without observing it. Along the lake below the mouth of the Lajas, these rocks form terraces which rise from 10 to 20 feet above the water-level. They frequently dip from the lake, and then present a handsome relief. They are much worn by the waves, and it is from this cause that the layers have their peculiar direction, they having once formed the interior slope of a mountain, the side facing the lake having since been carried away. Trap-rocks make their appearance along the course of the Lajas and Guscoyol. The banks of the former are generally muddy, but excavations show the mud to exist to no great depth. The Guscoyol has cut its way almost entirely through rock. In the valleys of the Rio Grande and Rio Chacalapa these rocks are covered to a considerable depth by alluvial deposits. Near Calcuta the rocks rise at places into perpendicular escarpments to a height of a hundred feet, producing, by their bleak summits, a striking contrast with the fertile valley that spreads into a level plain at their foot.

Of course these rocks have no regular thickness. They seem to have their greatest thickness near the divide, as that seems to have been the seat of the greatest volcanic activity. From this they probably have a tendency to thin out toward the lake and ocean, but this is uncertain. At a well at the Espinal the rock is about 50 feet thick. At Soledad, where it overlies limestone, it is 12 feet. At Tempate, where it also overlies this stone, it is 10 feet thick. As a general rule, however, the rock has a very much greater thickness, sections of several hundred feet failing to penetrate it.

The depth at which the trap-rocks occur below the surface varies greatly with the nature of the surroundings. They approach nearest the surface on the hills, where they are covered only by soil and the clay formed by their own decomposition, which is not more than 2 or 3 feet, except where the rock is largely feldspathic, in which case it may be more. That in the valleys the depth

is greater, is only approximately true, though it is generally the case. At San Pablo, on the Lajas, the rock is at the surface, but for some distance above no rock can be found at a depth of 10 feet. At Calcuta a section of the alluvial deposits of the Chacalapa exposed trap-rocks 25 feet below the surface, while a section of 50 feet was obtained on this river, at another place, without reaching volcanic rocks. As no instruments were provided for taking the depths at which trap-rocks occur along the proposed canal routes, no accurate estimate could be made, the only observations being from natural excavations along the water-courses. From these it would appear that between the mouth of the Lajas and Buen Retiro the average depth will not much exceed 4 feet; from this point, however, to the Pacific, the rocks underlie an alluvial deposit, and have a much greater depth.

The volcanoes that have furnished the great beds of rock which overspread this portion of Nicaragua are now extinct; their craters have been destroyed, their cones demolished, and their places are now unknown. The craters of Ometepe and Madera are still discernable, but they are probably more recent. In many instances no elevation remains, and all that is seen is their lava. Some probably never had cones, but we have reason to believe that the majority were peaks, which have since been leveled by the action of water. Where a section has been made in a bed of this rock by a running stream, or on a shore by the action of the waves, we notice that generally the rock is composed of layers which sometimes are variously colored; and these layers are highly inclined, having sometimes a dip of 30° or even 35°, but almost always sufficient to prove that they had flown from a very considerable elevation. These rocks at the surface are no more elevated than those in the immediate vicinity, and consequently we are forced to believe that they once formed mountains, but have since been reduced to a level with the surrounding country.

Many of the volcanoes have left eminences varying from mere mounds of 10 feet to mountains hundreds of feet in height. These have generally rounded tops, and give no evidence of volcanic action unless their interiors are examined. When they rise to a considerable height their sides are steep and often precipitous. These ancient denuded peaks constitute the principal features of the divide, where they form a continuation of the Cordillera.

Where the rocks are exposed they present the following characteristics: They usually have the appearance of having been deposited in successive layers, which vary from half an inch in thickness to many yards. These layers, though generally of the same material, are frequently interstratified with various volcanic products. Their structure may be columnar, or the layers may simply consist of concretionary balls cemented together. This concretionary structure is peculiarly characteristic, and is carried to such an extent as to render much of the stone unfit for building purposes. When it has been exposed some time, that portion acting as a cement first decomposes and the rock falls to pieces, these pieces consisting of concretions which are more or less oval, and varying from half an inch to several feet in diameter. When they are struck with the hammer they break into concentric coats, which scale off something like the shell of a nut. If the mass be sufficiently decomposed, the exfoliation continues to the center; but if not, the interior is hard and does not yield readily to the hammer. The clay formed from these masses possesses the same property, and may be peeled off with the nail. This form of the rock is exceedingly common, and passes gradually into the columnar structure.

When the layers or beds are very thin it resembles shale, for which it has been mistaken.* A good example of this is found in the bed of the Rio Grande, not far below Las Serdas. Another, on a larger scale, occurs on the coast, near the mouth of the river. Here the waves have worn away the shore side of one of these old volcanoes, so that a perpendicular section, several hundred feet high, of the mountain has been formed. It occurs in many other places.

As has been remarked, these rocks sometimes have an inclination of 30° or 35°, but this is not common, the average dip being not more than 12° or 15°. The rock is generally basalt and trap. Besides these, trachytes, a massive feldspar, scoriæ, tufa, and other volcanic rocks occur.

Fossiliferous rocks.—An idea of the relation which the fossiliferous strata and the volcanic rocks bear to each other in this country, may be formed by supposing that, at the close of the era of the limestones of this district, which I have for convenience termed the Soledad limestone, a succession of violent upheavals began, attended with intense volcanic activity, which resulted not only in the elevation of these strata from their submerged condition, flexing and faulting them at

* See Childs' Report.

the time, but also in again submerging them in a deluge of molten volcanic products. During the occurrence of the later phenomena, the submergence in lava was almost as complete as it had previously been in water, for only here and there are found projecting ledges of the rocks, which seem only to have escaped being covered by their superior elevation. It must be remembered, however, that while in geological time these igneous rocks belong to the same "epoch," time was required for the accomplishment of the work, and it was only by successive outbursts and isolated lava-currents that the country has been covered. Limestones, with few exceptions, are the only fossiliferous rocks that have been noticed in this portion of Nicaragua. No marls, shale, nor sandstone have been found that I know of. The limestones are generally covered directly by igneous rocks. From this we would infer that not a great while elapsed after the deposition and upheaval of the limestone before the trap-rocks were ejected. At Las Juntas there is a considerable stratum of clay lying between the limestone and the trap, which was deposited, however, before the upheaval took place, a fact that we know from finding in it the remains of corals.

Soledad limestone.—This limestone, so named, a conclusion formed from the great similarity both in composition and degree of decomposition of the rock in different parts of the country from the locality of its principal outcrop, probably underlies the greater part of the volcanic deposits on the eastern side of the divide. Another limestone occurs on the western side, but whether it represents a portion of the same formation or not, it is difficult to determine, from the extreme paucity of fossils in the former. Should we resort to a comparison of the stone to find its place, we meet with another difficulty. At Las Juntas (on the western side of the divide) we find a limestone resembling that at Soledad, and containing fossils. At Tempate (about one and a half miles from Las Juntas) we find another, which differs both in appearance and composition from that of either of the former places, but by its fossils is proved to be identical with that at Las Juntas. Were the nature of the limestones more constant, we would have reason for considering them as parts of one formation. On the contrary, as we have less grounds for separating them, I shall for the present embrace all under the head of Soledad limestone. The outcrop at Soledad, about a league from La Virgen, is one of the largest and most important that these strata make. It occurs near the summit of a small hill, but does not project above the level of the surrounding rocks. It seems to have at first shown but a small surface, but it has since been laid bare to a larger extent for obtaining the stone for making lime. The outcrop make its appearance from beneath the decomposing trap-rocks, by which it is overlaid. The strata are highly inclined, faulted, and partially crystallized. Dip 45°, strike east and west. The stone in some places has the appearance of being volitic, which, as will be seen, is the case with that at several localities. The volitic grains are generally about the size of a pea, and, when examined with the microscope, appear to be made up of a great number of smaller ones.* They are composed of carbonate of lime, but seldom as highly colored as the mass of the rock. When the rock is highly colored, as the red limestone at the mouth of the Guscoyol, they impart to it from this cause a peculiar speckled appearance. The colors are never bright enough, however, to make the stone valuable. Specimens of Soledad limestone contain serpentine and gypsum. A large bed of the latter occurs near this place, which has probably been derived from the Soledad beds by the action of sulphuric acid springs, which are well known to abound in volcanic districts. The serpentine would indicate the presence of magnesia. The limestone at the mouth of the Guscoyol has no other peculiarity than that mentioned, but for which it would hardly deserve a notice. It is small, contains few fossils, and the stone is too impure to be used.

At Las Juntas, (on the western side of the divide,) about a hundred yards from the river, may be found indications of limestone strata approaching the surface. At this place, upon the top of a hill which rises suddenly to a height of about 100 feet, are evidences of limestone having been reached in the sinking of a shaft, many years ago, in search of ores. It seems that after penetrating the igneous rocks, and a clay bed overlying the limestone, the project was abandoned. Many of the materials taken from the excavation, which is now nearly filled, are found on the top and sides of the hill. Among these are fossils and fragments of limestone, showing marks of the tools used in excavating; compact masses of limestone, several feet in diameter, have also been

* Seldom show concentric layers.

brought up; these show few signs of crystallization. The occurrence of fossils in a good state of preservation at this locality renders it of special interest.

A bold outcrop occurs about a mile and a half from Las Juntas, near the top of a hill known as Tempate. The strata are highly inclined, and make their appearance from beneath trap-rocks. The stone has been quarried here as well as at another place near La Flor. Besides these is another limestone at Recreo, which, however, does not reach the surface, and only the stone brought up from an old shaft could be examined. The stone is impure, but contains fossils.

Alluvial.—Besides the alluvials restricted to the water-courses, there are others which are so different in their origin and position as to require a separate notice; I have reference to the plains, prairies, jicaral country or cienegas, as they are called by the natives. These are alluvial deposits which generally occupy more elevated districts than the others, and have been formed from tufa, scoriaceous lava, and other volcanic *débris* brought down the sides of the mountains, and in some cases apparently from the leveling of the mountains themselves, and forming extensive flats of stiff clay. They are generally destitute of any vegetation, except guira or jicoral trees and grass. The latter dies down during the dry season, but furnishes good pasturage for stock after the periodical rains set in. During the dry season the clay cracks to the depth of 4 or 5 feet, and is so hard that it would break the strongest implement of agriculture. These prairies sometimes have a furrowed or rippled appearance, which is not easily accounted for. These furrows are several feet broad and run north and south, and present great uniformity. The clay is generally of some dark color, such as blue or black, though sometimes passing into lighter shades. It absorbs water rapidly and becomes pasty, and is used by the natives in the construction of their houses. During the rainy season these plains are converted into bogs, and it is for this reason that they have received the name "cienega," or swamps.

These deposits are most frequent along the divide, but they are not restricted to this locality, as they occur occasionally near the Pacific coast, and down almost to the lake-shore. They never occur, however, to any considerable distance from the mountains, from which they have received the materials of which they are composed. They generally extend to the depression of some stream, where their limit is sharply marked by the vegetation of the bottom-lands. The latter, which comprise the second class, may generally be recognized by their rich soil and rank vegetation. They differ materially from those of the eastern slope, the latter having been derived from rocks of a more feldspathic nature, and consisting mostly of red clays. The deposits, which are generally composed of a sandy loam, sometimes have this material interstratified with clay, gravel, sand, and tufa.

The following section, taken from the banks of the Rio Chacalapa, at Calcuta, will give a general idea of their composition:

No.	Str.	Name.		Thickness.
8		Sand and loam.	26	10 ft.
7		Clay with some sand.	16	4 ft.
6		Fine and coarse sand.	12	3 ft.
5		Hard clay.	9	1 ft.
4		Fine and coarse sand.	8	3 ft.
3		Hard clay.	5	1 ft.
2		Coarse sand.	4	4 ft.
1		Trap rock.		?

These deposits all present the same general characteristics.

For indigo, one of the principal products of the country, these lands are not well suited, this plant requiring a dry soil, and thriving better on the soil of hill-sides, where there is rapid drainage. Coffee, another product, requires high elevations, and can only be raised in elevated districts. But maize, cotton, sugar-cane, and cacao all do well. For cotton and cane, these lands could hardly be surpassed.

VALLEY OF THE SAN JUAN.

The San Juan River flows through a series of alluvial deposits which it has formed for itself. Nothing, however, attracts our attention as being of special interest until we reach its delta. Here changes have taken place within a few years past that are truly wonderful, and cannot be without interest to every geologist.

Changes of portions of the bar or spit, which materially affect the utility of the harbor, have been frequently noticed, but these have been in such a way that there are few now who can realize the extent to which they have been carried.*

To illustrate the extent of these deposits, I have reduced and combined the maps of Mr. Orville W. Childs (a survey of the harbor made in 1851) and that of Lieut. J. W. Miller, U. S. N., of the present survey. By glancing at the map the following facts will at once be apparent:

1. A change in the position of the river near its mouth, which is now nearly three-fourths of a mile from its former channel.
2. A complete remodeling of the form of the harbor.
3. A complete obliteration of the eastern basin of the old harbor.
4. The formation of a new spit in advance of the position of the old one.
5. A closure of the northern outlet,† with a simultaneous opening of one at harbor head.

These changes have been due to alterations at the junction of this river with the Colorado in such a way as to change the direction of the volume of water, producing a greater or less degree of navigation of the waters in the former.

BUILDING MATERIALS.

Stone.—Although the country has been literally covered with igneous rocks, good building-stone is not as abundant as might at first be supposed. The rock generally is either open or loose in texture, contains pyrites in considerable quantities, or decomposes rapidly, from some unaccountable cause, when exposed to the action of the atmosphere. The rock is, as a general rule, basalt or trap, and is so much split up in concretionary masses in many places as to render it entirely useless as a building material. But it is difficult always to form a very definite idea as to the properties of the stone, as it is almost invariably decomposed on the surface, and no quarries have been opened for obtaining it. I had hoped to have had an opportunity of seeing a practical test of the stone at various localities in the old artificial structures, such as fortifications, indigo-vats, &c., but was disappointed for reasons that will presently appear.

The presence of iron pyrites is not so constant in the rocks west of the lake as it is in those along the San Juan, where they occur in the feldspathic rocks in large proportions. The stone at San Carlos partakes more of the nature of that on the Pacific slope. The rock of San Carlos to which reference is here had is a trap occurring on the eastern side of the hill, where it forms an abutment about 20 feet high, at the foot of which there is a level tract extending to the river. It is compact, fine-grained, hard, and stands exposure well. Above this and on the other side of the hill are a number of volcanic rocks, all of which, however, have a loose, open texture, and are useless as building materials. It is of the loose fragments of the latter that the old fort on the top of the hill was built. It is now in ruins.

The rock at Castillo and Machuca is of poor quality. That at Machuca is quite pretty when freshly broken, from the large proportion of pyrites which it contains, but those soon tarnish. The rock at Castillo also contains pyrites. The castle built of this stone in 1760 is now in a dilapidated condition. The walls are coated with rust, much defaced, and many of them fallen. On the west-

* Compare O. W. Childs' Report, p. 44, with E. G. Squier's Nicaragua.

† This has since re-opened.

ern side of the lake a basalt of good quality may be found at Las Serdas. It is compact, hard, stands exposure well, and will make a good building-stone. It occurs in abundance, extending in a line of hills along the river for several miles. In the rock near the summit of the hill at Las Serdas the crystals of chrysolite are of considerable size, and give greater beauty to the stone, but do not stand exposure as well as that at the base, where this mineral is disseminated through the rock in smaller grains. The trap along the lake shore near La Virgen possesses some good properties, but it is too much jointed to be used where large blocks are required.

A good building-stone may be found in the vicinity of Recreo, on the Guscanol, and near Calcuta. A very old indigo-vat was found at Recreo, but as it was built of loose stone it afforded no valuable information.

From what has been said it will appear that durable building-stone is not very abundant in this section of Nicaragua. This indeed does seem to be the case, but it must be remembered that only an approximate idea can be formed from observations restricted to the surface.

There is but little doubt that in the construction of a canal stone could be frequently found of good quality and in sufficient quantities. An excavation of such extent, much of which would be almost entirely through rock, could hardly be made without the discovery of materials adapted for the construction of locks and other purposes for which they would be needed. But, while this will doubtless be the case in many places, there will probably be more where some other material will have to supply the place of stone.

Limestone.—Limestone, as has been remarked, occurs in abundance at several localities. That at Soledad is a compact stone, well suited for building purposes. This stone so far has only been used for the manufacture of lime, for which it is well adapted. The stone at Tempate exists in large quantities, and from its convenient locality will probably prove of great value. The outcrop is situated about 200 yards from the Brito line, and but a short distance from the river.

As no analyses have been made of these limestones, a more thorough description of their properties cannot be given, observations taken from structures of masonry in the country having furnished all information obtained as to their value.

Clay.—Good clay for brick, tile, and pottery occurs in abundance throughout the country.

Respectfully submitting this report for your approval,

I have the honor to remain, very respectfully, your obedient servant,

B. H. WHITFIELD, M. D.

Commander CHESTER HATFIELD, U. S. N.,
Commanding Nicaraguan Surveying Expedition, U. S. Steamer Kansas, Key West, Fla.

REPORT OF SURVEY OF HARBOR OF GREYTOWN, NICARAGUA, BY LIEUTENANT JAMES M. MILLER, U. S. N., 1872.

UNITED STATES STEAMER KANSAS, (3d rate,)
San Juan de Nicaragua, July 4, 1872.

SIR: I have the honor to submit the following report of the survey of the harbor of San Juan de Nicaragua.

On Friday, April 13, I landed in San Juan with a surveying party from this ship, consisting of Ensign J. B. Briggs, Midshipman H. C. Nye, and ten men, taking the ship's dinghy with me.

I established headquarters in a house very kindly given us by the Central American Navigation Company.

On Monday, April 22, I commenced operations; established a tide-gauge, established base-line, and sent out a party with surveyor's compass and chain to commence running in the shore-line. Continued work whenever the state of the weather would permit. We were interrupted frequently, as the rain commenced shortly after we landed and continued up to the very day of our departure.

Having run and plotted the shore-line, we sounded the harbor, river, and offshoots, and then probed the substrata to find out the character, going to the depth of 17 feet below the bottom

proper. In probing I made use of iron tubes 1½ inches in diameter and 15 feet in length; screwed one into the other as the depth increased.

The Central American Navigation Company loaned me a large launch, of which I made use.

I found the bed of the harbor to the depth of from 6 to 10 feet black mud, mixed with alluvial deposit and decayed vegetable matter. Below this depth, sand, dark gray, with red specks.

I went no farther than 17 feet, as I came to the same character of bottom as that found by Mr. P. C. F. West in 1865 at the depth of 40 feet.

TIDE.

The highest spring-tide rises and falls 20 inches. During the rainy season the river rises 2 feet above high tide.

RAINY SEASON.

This year the rainy season began a month earlier than usual, it beginning the 1st of May, when the ordinary time is the 1st of June.

CHARACTER OF HARBOR.

The natural phase of the lower (western) part of the harbor is continually changing, caused by the wash of the current of the river inside and the sea outside.

ENTRANCE TO HARBOR.

The dry-season entrance is at harbor-head, across the bar formed just in front.

In the rainy season the current of the river becomes so swift that it forces an opening at the point marked in chart with red lines. I submit the chart and the specimens of the substrata.

I wish to tender my thanks to Mr. J. E. Hollenbeck, general agent of the Central American Navigation Company, and the gentlemen in that employ, as well as the citizens of San Juan, for the assistance given and the uniform kindness extended us.

And I would like to mention the zeal and willingness with which the officers and men with me performed their duty.

Very respectfully, your obedient servant,

JAS. M. MILLER,
Lieutenant, U. S. N., in Charge Surveying Party.

Commander CHESTER HATFIELD, U. S. N.,
Commanding Nicaraguan Surveying Expedition.

PART II.

REPORT OF COMMANDER EDWARD P. LULL, UNITED STATES NAVY, COMMANDING EXPEDITION FROM OCTOBER 22, 1872, TO JULY 20, 1873.

NAVY DEPARTMENT, BUREAU OF NAVIGATION AND OFFICE OF DETAIL,
Washington, October 17, 1872.

SIR: You are hereby detached from special duty in the Bureau of Yards and Docks, and on the 22d instant you will relieve Commander Chester Hatfield in the command of the Nicaraguan surveying expedition, who has been directed to turn over to you all orders, books, maps, instruments, and information of every kind pertaining thereto in his possession. He will furnish you with memoranda relating to everything connected with the expedition and its equipment.

The results of the expedition, as far as obtained before the setting in of the rainy season, are now being brought up at the Washington navy-yard.

You will complete this with all convenient dispatch, and make such preparations in the organization and obtaining necessary outfits of all kinds as will enable you to leave Hampton Roads by the 1st of December next, either on board of the Kansas or some other national vessel that will be detailed for the purpose.

By direction of the Secretary.

Respectfully,

DANIEL AMMEN,
Chief of Bureau.

Commander EDWARD P. LULL, U. S. N.,
Washington, D. C.

[Indorsement.]

Relieved Commander Hatfield and assumed command October 22, 1872.

EDWARD P. LULL,
Commander.

REPORT UPON THE SURVEY FOR AN INTEROCEANIC SHIP-CANAL THROUGH NICARAGUA, BY EDWARD P. LULL, A. M., COMMANDER, UNITED STATES NAVY.

WASHINGTON, D. C., *December* 1, 1873.

SIR: I have the honor to submit the following report of the work performed, and the results obtained, by the United States surveying expedition lately operating in Nicaragua:

The following naval and civil officers were attached to the expedition, viz:

Naval officers.—Commander Edward P. Lull, commanding expedition; Lieutenant-Commander G. C. Schulze; Lieutenant William W. Rhoades; Lieutenant Eugene H. C. Leutze; Lieutenant Jacob W. Miller; Lieutenant Jefferson F. Moser; Master John M. Hawley; Master J. B. Briggs, (of the United States steamer Kansas, joined the expedition April 9;) Master K. Niles; Ensign James H. Bull; First Assistant Engineer George M. Greene; Assistant Surgeon John M. Bransford; commander's clerk, Augustin L. McCrea, jr.

Civil officers.—Chief civil engineer, A. G. Menocal; civil engineer, J. Foste Crowell; mineralogist, J. E. Cropsey; draughtsman, A. Pohlers; aid, W. V. W. Reilly.

In addition to these there were attached to the expedition several young men, with petty-officers' ratings, detailed for duty as rod-men, chain-men, and pole-men.

The following instruments and other articles of outfit were either on hand or provided, viz:

Instruments, &c.—Two engineer's transits; three spirit-levels; two gradienters; two surveyor's compasses; two delicate pocket aneroid barometers; four mercurial mountain barometers; one boring-apparatus, for testing excavations; one current-meter; surveyors' chains, pins, watches, pocket-compasses, sounding-leads, and lines; drawing instruments and materials, field-glasses, &c.; transit and level books, sounding-books, necessary stationery, &c.

General outfit.—Axes, hatchets, machetas, shovels and picks, camp-kettles, and frying-pans; and for each officer and man one shelter-tent, one India-rubber blanket, one knapsack, one haversack, one canteen, one pair of leggings, one hammock, and one mosquito-net.

Five months' provisions for sixty men were prepared, put up in packages of from 35 to 60 pounds each, and so securely as not to be liable to injury from exposure to heat or moisture, and consisted of the following, viz: bacon, soup and bouilli, tomato-soup, hard bread, rice, beans, sugar, and coffee.

The expedition was originally organized under instructions of the Department issued in February, 1872, to Commander A. F. Crosman, and, after the death of that officer, carried out in part by Commander Chester Hatfield. These instructions required an exploration within the limits of the state of Nicaragua, to discover, if possible, a practicable route for an interoceanic ship-canal.

GEOGRAPHICAL DESCRIPTION.

Nicaragua, in shape a quadrilateral of very unequal sides, lies between latitude 10° 40′ north and 15° 20′ north, and between longitude 83° west and 87° 40′ west. Lake Nicaragua lies in the southwest part of the state, is about ninety miles long, and from thirty-five to forty-five miles wide. To the northward and westward of Lake Nicaragua, with a surface-level from 22 to 28 feet higher, lies the smaller Lake Managua, connected with the former by the Rio Tipitapa, through which, however, there is no visible flow of water at the present time, though Lake Managua has no other visible outlet. Lake Nicaragua discharges its waters through the river San Juan, which, leaving the lake at its southeast extremity, flows in a generally east-southeast course to the Caribbean.

The Cordillera is divided in the northern part of the state; one branch, extending to the eastward, sends its multitudinous spurs to the coast and to the banks of the San Juan, while the other, passing to the westward of the lakes, sinks in some places into a mere range of hills. This is particularly the case near Leon, and again near Rivas.

THE PROBLEM AND ITS SOLUTION.

A glance at the map will show that any project for a canal through Nicaragua must involve the lake of the same name, not only because its water is needed at the summit-level, but because it occupies the narrowest part of the country. The problem, then, to be solved is the finding of the most accessible line of communication from the lake to the Pacific on one side, and to the Caribbean on the other. The coast-line on either side, and the shore-line of the lake, were long ago laid down, the former with great, and the latter with a passable, degree of accuracy.

The river San Juan, forming the only outlet of the lake, leaves it at the southeast extremity, at which point the lake-shore approaches most nearly to the Caribbean. It is quite clear that there is between the lake and the Caribbean a line of communication, and that it is not only the shortest, but the lowest line, for if any other were lower, or as low, then would there be another outlet. How good a line, both in an engineering and a commercial point of view, this will prove to be, is the only question to be solved on that side of the lake. This information, however, would be of no practical value unless it was also found that a practicable line could be located between the lake and the Pacific. The first efforts of any explorer would therefore naturally be turned to that side of the lake.

A narrow strip of land divides the lake from the Pacific, and our examination of the map shows that from Virgin Bay, on the lake, to San Juan del Sur the distance is but twelve miles. Were our knowledge of the country confined to the coast and shore lines above mentioned, the route between these two points would naturally be the first examined, and the results obtained would be thereafter used as a standard of comparison until some other line was found, the sum of whose conditions gave a better general result.

The conditions to be sought are:

1. The shortest distance.
2. The lowest profile.
3. The most favorable profile.

To explain what is meant by this last, as a descent must be made from the lake to the sea by means of locks, that profile is the most favorable, other things being equal, whose summit is nearest the lake, as it enables us to locate our locks to the greatest advantage, which advantage is often twofold: first, we are saved the necessity of crowding the locks together, which sometimes is, and sometimes is not, disadvantageous; and, second and principally, we are enabled so to locate the locks with reference to the surface as to diminish very much the amount of excavation required. Reference to the following diagrams will make this explanation more clear:

In each figure the line A, B, L, C represents the profile. We will suppose the horizontal distance from A to C to be fourteen miles, the summit-level in each case to be 200 feet above the point A, the summit to be in Fig. 1 at a horizontal distance of two and a half miles from the point A, and in Fig. 2 to be ten miles from the corresponding point. The line of the canal starting from the point A in each case, is continued till it intersects the surface on the opposite slope. It is plain that the amount of excavation in the second case is very much greater than in the first. Regarding the figures A, B, L in each case as a triangle, we have the altitude the same, while the base in the second is thirteen miles, to seven and a half miles in the first; but the ratio of increase is much greater even than this, for, supposing the excavation to be in earth, the cross-section widens at least three feet for every one foot of increased depth of cutting.

It is probably needless to explain that the location of the divide would be of no consequence in the case of a through cut between two points whose level was the same.

In addition to these the steepness of the sea-slope has to be taken into consideration. On the line leading to San Juan del Sur the descent is so rapid that, even if the summit-altitude were not so great, it would be impossible to locate the requisite number of locks without placing two or

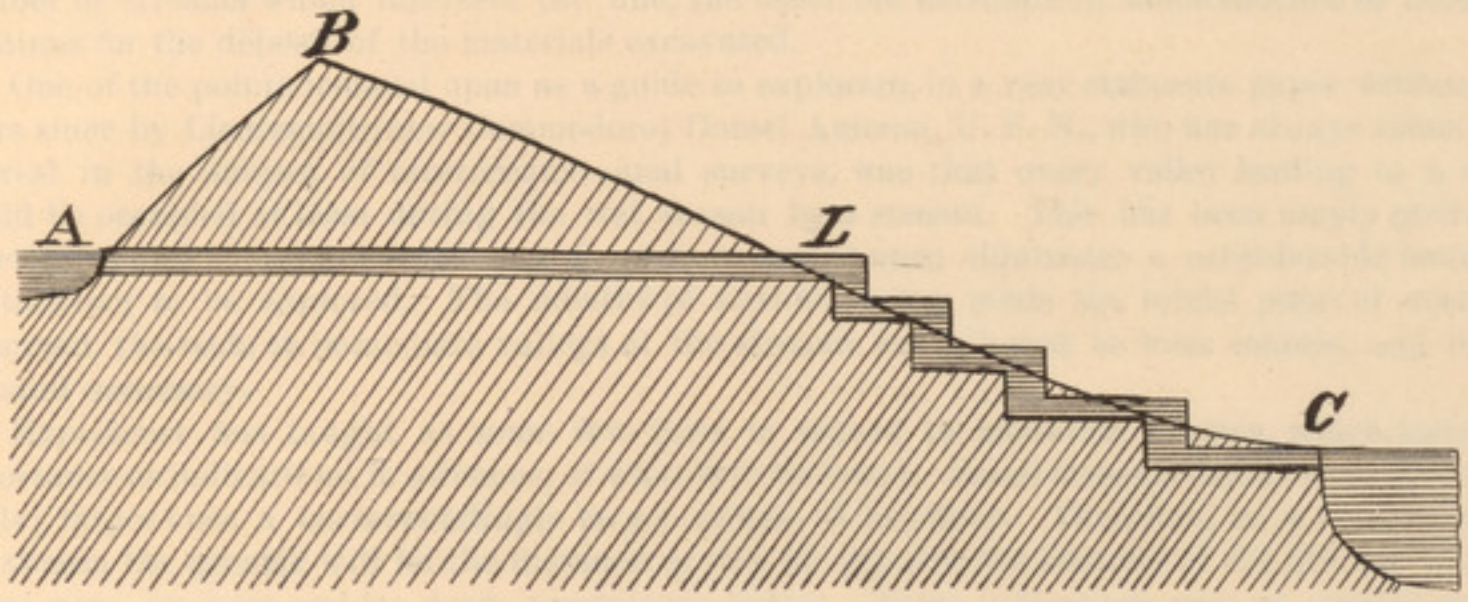


Fig. 1.

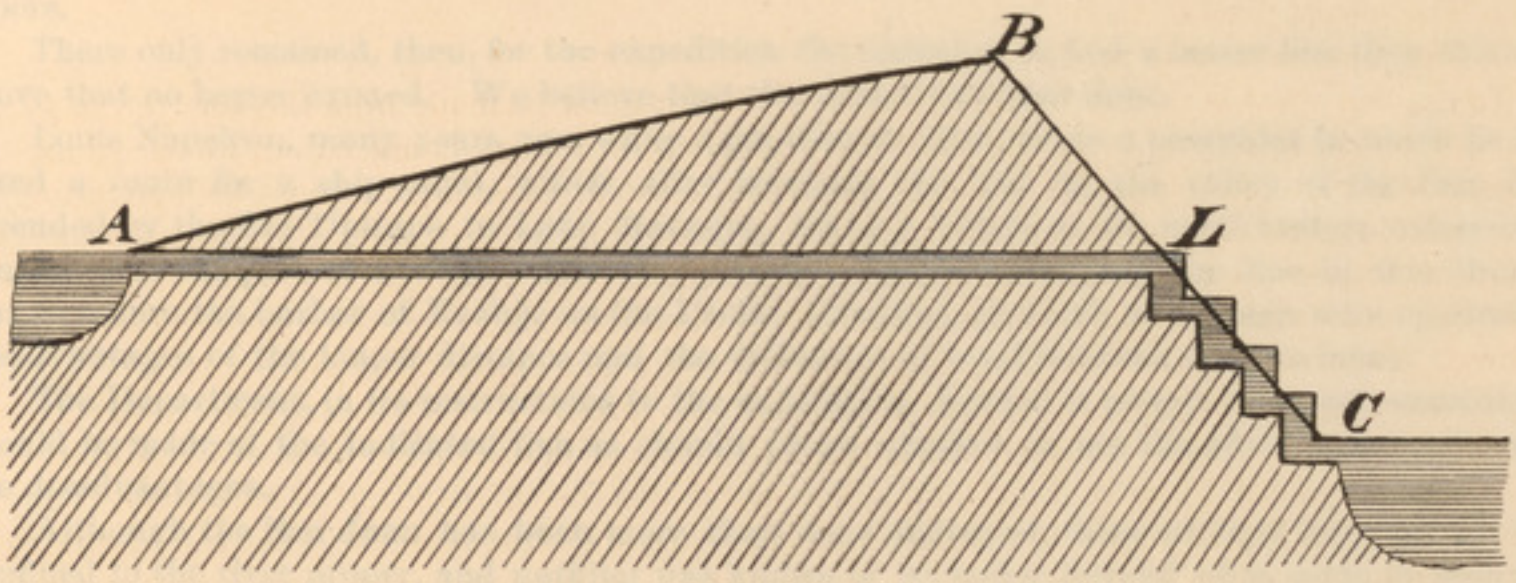
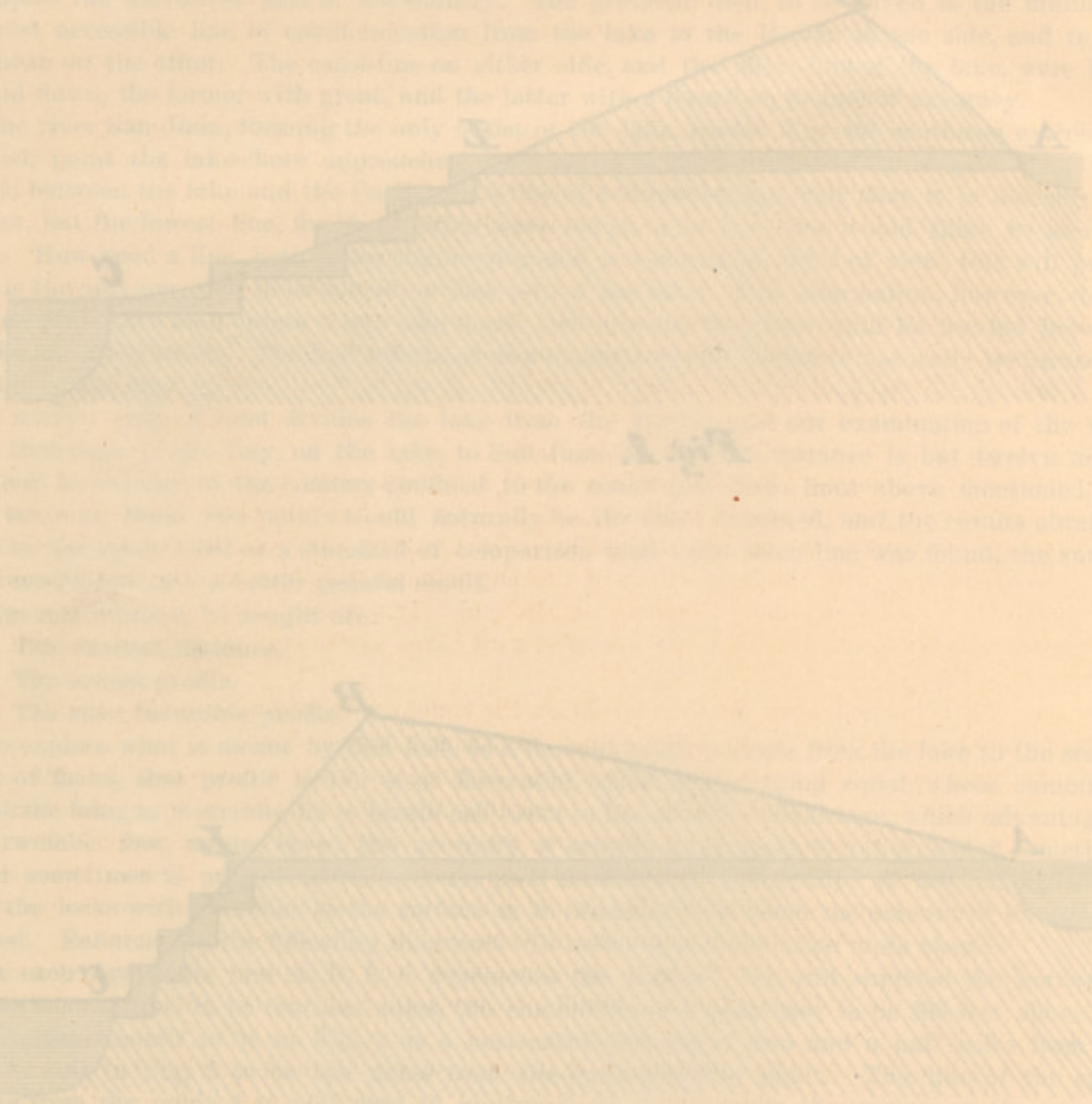


Fig. 2



more side by side, a system which has too many disadvantages to be resorted to, except it be impossible to avoid it.

A fourth consideration is that the line shall debouch at a point where a sufficient harbor either exists or can be made to protect the mouth of the canal from the sea.

Of course, in comparing different routes, these points have to be considered together, as it often happens that the route superior in one respect is inferior in another.

There are two other very important considerations to be kept sight of, one of which is the number of streams which intersect the line, the other the existence or non-existence of accessible locations for the deposit of the materials excavated.

One of the points insisted upon as a guide to explorers, in a very elaborate paper written some years since by Lieutenant (now Commodore) Daniel Ammen, U. S. N., who has always taken great interest in the subject of interoceanic-canal surveys, was that every valley leading to a divide would be occupied at least during the wet season by a stream. This has been amply proved by experience, and is now regarded as a fixed fact, and at once eliminates a considerable amount of the territory to be explored. The mouths of streams being made the initial point of every line examined, the beds or immediate valleys of the streams are followed to their sources, and beyond if found necessary.

Experience has taught us some few facts in regard to mountain-streams, which have their importance as indications, in advance, of what is to be found. Small streams drain but limited watersheds; larger ones a correspondingly larger extent of territory. Therefore, as a rule, the larger the stream the greater will be the distance, or else the greater the altitude of the divide. Streams whose rises are very sudden drain precipitous slopes. These indications were of greater moment on the eastern than on the western side of the lake.

Fortunately a great deal was known in advance in regard to the western division of the work, The country had been more or less explored, and at least one line had been reported as extremely favorable, *i. e.*, that from the mouth of the Rio Lajas to Brito, surveyed by Col. O. W. Childs in 1851. In accordance with the instructions of the Department, this line was the first examined by the expedition of last year, under Commander Hatfield. The report of Colonel Childs was found to be correct in the main, and his route was afterward taken as the standard of comparison for all others.

There only remained, then, for the expedition the endeavor to find a better line than this or to prove that no better existed. We believe that the former has been done.

Louis Napoleon, many years ago, while a prisoner at Ham, wrote a pamphlet in which he indicated a route for a ship-canal, which, after reaching the lake by the valley of the San Juan. ascended by the Rio Tipitapa to Lake Managua, leaving which at its northwestern extremity it continued to the port of Realejo. The only possible object of carrying the line in this direction was to secure the harbor of Realejo as the Pacific terminus, to which advantage were opposed the disadvantages of the longer distance and the difference of level between the two lakes.

The Department, in its instructions to the expedition, deemed it proper that such examination should be made of the indicated line as should prove whether or not the advantages outweighed the disadvantages.

Although the San Juan has been more than once surveyed, these surveys have always been confined to the river proper, and nothing was known of its valley beyond what could be seen from its banks; and when it is considered that there is seldom a spot where the eye can penetrate two rods' distance, it will be seen how extremely limited the information was. Even in positions where, by looking up or down a reach, one was able to see above the tops of trees, but little could be told in regard to the ground, whether undulating or flat, the tendency of the trade-winds blowing so constantly in the same direction being to smooth out upon the tops of the trees the inequalities that exist at their roots; in other words, the trees in the valleys, being protected from the wind, grow to greater height than those exposed to its influence upon higher ground.

The Department's instructions required that the river should be examined with a view to such improvement as should fit it for ship-navigation, wherever such improvement should be deemed possible, and that a location should be sought in its valley for an independent canal, to supplement such portions of the river as should be found not to be susceptible of such improvement.

It was neither the design of the Department, nor was it within the limits of possibility, to make, with the means and time available, particularly with the very small appropriation, an exhaustive, final survey. I feel safe in asserting, however, that the country has been so far examined that a close approximation to the best line has been found. The line as laid down upon the maps and the computations herewith presented are the result of actual survey. Nothing has been taken for granted, while, on account of the great promise of the lines at the outset, the surveys have been made much more in detail than would have been the case if they had been considered mere preliminary reconnaissances. So that, while it is altogether probable that the line may be improved upon in many places, it can never be found to be any less favorable than it is here represented.

In addition to the resurvey of Childs' route, Commander Hatfield examined and found impracticable the line starting from the mouth of the Rio Sapoa, ascending to the divide by the valley of that river and terminating in Salinas Bay, on the Pacific. This line is generally regarded as the boundary between Nicaragua and Costa Rica.

He also partially examined a line indicated by Colonel Maximiliano de Sonnenstern, the state engineer of Nicaragua, following the valley of the Ochomogo, and having for its objective point on the Pacific the mouth of the Rio Escalante. The Ochomogo empties into the lake some thirty miles north of the mouth of the Rio Lajas.

The advent of the rainy season prevented Commander Hatfield's completing the work here, and also prevented the examination of another line to which his attention had been directed, in the vicinity of Childs' route, and which it was hoped would prove superior to the latter.

SAILING OF THE EXPEDITION.

The expedition of the present year sailed in the United States steamer Kansas, Commander A. V. Reed, from Hampton Roads, Virginia, on the 3d of December, 1872, and arrived off Greytown, (or San Juan del Norte,) Nicaragua, December 20. We succeeded on the day following our arrival in getting everything on shore without accident or delay. An unoccupied building in Greytown was procured as a store-house, and a large portion of the provisions were placed therein for safe-keeping until needed.

Commander Reed, with the Kansas under his command, was directed to make a chronometric expedition between Greytown and Aspinwall, of which latter place the longitude and latitude have been very accurately fixed by the astronomers of the different Darien expeditions.

It was determined to proceed to the west side of the lake and complete the work in that section before commencing in the valley of the San Juan. A short delay occurred on account of the lake steamer's not being on the east side of the lake to carry us over, but on the 30th of December we embarked on the steamer Castillo, with such instruments, stores, and provisions as we wished to carry with us.

Our party consisted of seventeen officers, seven petty officers, and seven blue-jackets from the Kansas. Mr. Bull was left at Greytown in charge of the stores.

Even thus early, at the very beginning of the dry season, the water in the Lower San Juan was so low that the river steamer, not drawing over 18 inches of water, grounded several times before we reached the forks, and on each occasion several of the deck-hands jumped overboard and waded about until the channel was found—a very rapid and practical way of sounding, but certainly an entirely novel one to us.

The silting up of this branch of the San Juan River we looked upon as very discouraging at the time, but, as will appear further on, we subsequently came to regard it as a very fortunate circumstance, and one which will largely contribute toward the improvement of the harbor at Greytown, if a canal is ever built, as, according to our plan, it will be necessary to close this mouth altogether, and admit to the bay only the water brought by the canal, and which, coming from the San Juan above the mouth of the San Carlos, will be entirely free from silt.

Tying up at night and traveling only by daylight, we had a good opportunity of making a general examination of the character of the river and of planning our work in its valley, when we should reach that portion of our operations.

A distance of eighteen miles by the river brought us to the forks of the Colorado; thence to the mouth of the San Carlos the main river is also very shallow, being silted up by material which comes from the San Carlos and the Serepiqui. Between the mouth of the San Carlos and the foot of the Machuca Rapids, a distance of twenty miles, and known as the Agua Muerte, the river is deep, with very little current. The Machuca are the lowest of the system of rapids, and are named for Don Diego Machuca, one of the earliest explorers of Nicaragua, and one of the very few who have been thus commemorated; in fact there is but one other as far as I recollect, Don Gil Gonzales, for whom a river is named in the department of Rivas. The other rapids are known, respectively, as the Balas, the Mico, the Castillo, and the Toro.

Great difficulty is experienced by the steamers in running these rapids during the low stage of the water, those at Castillo becoming entirely impassable; here there is a tramway originally built by the Nicaragua Transit Company, connecting the landing at the foot with that at the head of the rapids, and over which the cargoes of the steamers are shifted.

At Castillo is located the first custom-house, Greytown being almost a free port. Don Saturnino Reyes, the administrator of customs, with his officers, Messrs. Báez and Vigil, had received orders from the government to pass through all articles belonging to the expedition, and to facilitate us as much as possible. We were afterward much indebted to these gentlemen for kindness and hospitality, as well as to Col. Eustacio Sandoval, the commandant of the fortress, which frowns from the hill-top overlooking the bend in which the rapids are, and which, built just two hundred years ago, to prevent the incursions of the dreaded buccaniers, was made famous in 1769 by the successful defense conducted against an attack by the English, by Doña Rafaela de Herrera, whose father, the commandant, was very ill, and who, according to the Spanish account, "stepping outside the limits of her sex, made extraordinary efforts for the defense, her first success in the newly acquired art of managing artillery being the repulse of the enemy, and the killing of the officer who directed the attack."

Eleven years later, *i. e.* in 1780, occurred the celebrated English expedition under Nelson, by which this fort was captured, though abandoned in less than a year afterward, on account of the ravages of disease among the English force.

A village of bamboo huts, and also bearing the name of Castillo, or more properly Castillo Viejo, skirts the base of the hill, along the shore of the river, and the tramway, above spoken of, occupies the center of the only street.

While we were waiting for the steamer, some of the men amused themselves by catching sharks; three good-sized ones were landed in the course of a few minutes; the river San Juan and Lake Nicaragua both abounding in them, and being the only fresh-water bodies in the world, as I believe, where they are found.

Embarking in the steamer Panaloya, at Castillo, we were soon carried above the Toro rapids, commencing about seven miles from the former place, and were transferred to the lake steamer Commodore H. A. Adams, a vessel which had recently been brought out from New York.

By daylight, on the morning of the 3d of January, we found ourselves upon that beautiful sheet of water, Lake Nicaragua; Ometepe towering up nearly a mile high ahead of us, forming nearly a perfect cone, and Madera, its sister peak on the same island, scarcely less high; the high Chontales coast visible on the right; Mombacho and Zapatero looming up in the distance; the Costa Rica hills on the left, with here and there an island dotted in the lake; while the glorious trade-wind sky, painting the whole with gorgeous tints, made a scene of enchantment.

The lake was exceptionally calm, and early in the afternoon we reached the dilapidated wharf at Virgin Bay; this, also, is a relic of the Transit Company, and has not been repaired since the company ceased to exist. We were met at the landing by Midshipmen Keeler, Hughes, and Winslow, who had been left by Commander Hatfield with a steam-launch and a few men to do such hydrographic work in the lake as was needed, and for which the calm weather of the wet season was particularly favorable. These very able young officers were under orders to proceed home to be examined for promotion, and the expedition was deprived of their services, which would have been very valuable.

Notwithstanding the unsafe condition of the wharf, we soon succeeded in landing the instruments, stores, and provisions, and commenced immediate preparations for putting the parties into the field.

COMMENCEMENT OF OPERATIONS.

Two parties had been organized before reaching Virgin Bay, and were ready to go into the field at once. They consisted of the following, viz:

Party No. 1.—Lieut. E. H. C. Leutze, in charge; Civil Engineer J. F. Crowell, in charge of the transit instrument; Lieut. J. W. Miller, in charge of spirit-level; four petty officers and one seaman, as rod-men, pole-men, and chain-men; and, also, two Caribs.

Party No. 2.—Lieut. William W. Rhoades, in charge; First Assistant Engineer George M. Greene, with transit instrument; Lieut. J. F. Moser, with the spirit-level; Mr. J. E. Cropsey, mineralogist; four petty officers and three seamen, as rod-men, pole-men, and chain-men.

In addition to these there were required for each party twelve natives, to be employed as macheteros or choppers, muleteers, and cooks. These, with pack and saddle mules, were obtained without trouble, through the kind offices of Messrs. Pedro and José Chamorro, leading merchants of Rivas, one an ex-senator, and the other an ex-minister of finance of the state. Through the kindness of these gentlemen we were saved much trouble and delay in obtaining help and in supplying our other needs, and I shall ever hold them in grateful remembrance.

Don José Chamorro was, shortly after our arrival, specially commissioned by his government to aid us, but it was impossible for him to do more than he had been doing voluntarily.

Sixteen dollars a month for men, and $12 for horses and mules, with subsistence for each, were charged, being the ordinary rates in that part of the country.

The following constituted the equipments of parties in the field, viz:

Instruments.—One engineer's transit; one spirit-level; two level-rods; two transit-poles; one 100-foot chain; one binocular marine-glass; one tape-line; one prismatic compass; field note-books, stationery, &c.

Equipments.—Two axes; three hatchets; eight machetas; one lantern; three mess-kettles; two frying-pans, buckets, &c., to which the officers added a few dishes, knives and forks. And to each officer and man, one shelter-tent, water-proofed; one ship's-hammock; one mosquito-net; one India-rubber blanket; one blanket; one knapsack; one haversack, and a stout pair of leggings; stout duck or linen trousers; woolen shirts, worn inside the pants; under flannels, carefully worn; a tin-pot, pan and spoon, and a canteen, completed the outfit of each person.

The shelter-tents being made large enough for one person only, were combined into larger tents by sewing four, six, and eight together, according to the number of persons to occupy them. After a short time both officers and men had accustomed themselves to making very comfortable houses, and very rapidly, by setting up forked stakes or taking advantage of convenient trees for the support of a ridge-pole and two side poles, over which the tents were spread; the hammocks were then laced or nailed to bamboo poles at the sides, and a cross-piece at the head and foot lashed to these, so as to spread the hammock out flat, which, with four forked stakes, one at each corner, as supports, made very comfortable beds.

The daily ration consisted of the following for each person, viz: ¾ pound of bacon; 14 ounces of bread; 3 ounces of coffee; 4 ounces of sugar; 1 pound of soup and bouilli, or one pound of tomato soup, alternating; ½ pound of rice, or ½ pint of beans, alternating. All of these articles, as has been said, were put up in portable packages, and in such shape as to be little liable to injury by exposure to rains or the other vicissitudes of transportation. The soup and bouilli, and tomato soup, were purchased; the other articles were put up at the Inspection of Provisions and Clothing, under Pay-Director Eldridge, at the New York navy-yard, and were of superior quality.

To Lieutenant Rhoades's party was assigned the work of the examination of the route already referred to, which it was hoped would prove to be superior to that of Childs'. This line began at the mouth of the Rio del Medio, followed up its valley, crossed the divide, and descended to Brito by the valley of the Rio Grande; a small portion of it coinciding with Childs' line.

Lieutenant Leutze's party was directed to complete the examination of the Ochomogo line. Master K. Niles, with three men, was sent to Brito to establish a tide-gauge.

Previous to setting out on this duty, Mr. Niles, with Midshipmen Hughes and Winslow, ran a traverse with compass and chain, from Virgin Bay to San Juan del Sur, over the transit road, to connect those two points.

An American gentleman, Mr. Ran Runnels, formerly United States consul at San Juan del Sur, but now residing at Virgin Bay, kindly placed at our disposition a cottage which he owned, to be used as a store-room, draughting-room, and quarters for officers; while the cuartel, or barracks, was given to us by the agent of the government as a hospital, &c. We fortunately had but little use for it in that capacity, however. To Mr. Runnels and his estimable family we were, and had been since the landing of the first expedition, constantly indebted for hospitality and assistance of every kind in their power. The commanding officer accepted an invitation to become their guest, and received every kindness and attention which their thoughtfulness could devise. They will long continue to occupy a warm place in the heart of every officer in the expedition.

Lieutenant-Commander Schulze, the executive officer, was placed in charge of the commissariat, as the keeping up of supplies required one of the most experienced officers. The commanding officer and the chief civil engineer were left free to move from party to party as occasion demanded.

The parties began work January 7; party No. 2 establishing their bench-mark at the lake-level, party No. 1 taking up the line on the Ochomogo, at the point where it was abandoned the previous year. Observations were taken daily at a lake-gauge at Virgin Bay, to show the amount of fall in the level of the water.

As the Medio line gave great promise at the outset, party No. 2 were directed to make their survey with great care and with considerable detail. The traverse was run with an engineer's transit and chain, and cross-sections were taken at every 500 feet, extending 500 feet either way. The levels were taken at every 200 feet or less. Frequent reconnaissances in all directions were made to secure the best direction for the line proper. As the country in the vicinity was more or less cultivated, at least on the eastern slope of the divide, the party was able generally to encamp in haciendas, often having the use of buildings for shelter; the line running through several plantations of coffee, cacao, indigo, bananas, plantains, &c., and alternating between these and the dense forest-growth of the region.

In the party operating upon the Ochomogo a surveyor's compass was substituted for the transit; in other respects the instruments were the same. The line being less promising, and, in fact, scarcely promising at all, a close reconnaissance, rather than a detailed survey, was required. A few days served to show that this line was altogether impracticable. The level had reached 87 feet above the lake, although the end of the traverse was still a distance of some miles from the divide. Reconnaissances were made in several directions by Messrs. Leutze, Menocal, Miller, and Crowell to find a lower pass than that they were now approaching, elevations being carefully measured by the aneroid barometer. It was found that the lowest pass was 225 feet above the lake-level, with a long slope on either side, making a very bad profile. There was, of course, no need of further examination. The line was accordingly abandoned, and the party removed to the banks of the Rio Gil Gonzales, some eighteen miles south of the Ochomogo, and whose valley was the only other locality where there was a possibility of finding a practicable route.

I might here add of the Ochomogo line, that it had merely been indicated by Colonel Sonnenstern as one of the localities which should be examined.

In the mean time party No. 2 were making excellent progress, the line developing well, and, except that it was longer than had been expected, (the lake-shore lines not having been correctly laid down on the maps,) it was proving quite as good as had been hoped.

On the 15th of January Colonel Sonnenstern, by order of his government, joined the expedition. This gentleman is thoroughly acquainted with the territory and the people, is very popular everywhere, and not only rendered us very valuable assistance in our work, but by his genial companionship lightened many a tedious hour in saddle, canoe, and camp.

As the parties were now well under way with their work, the commanding officer, with Mr. Menocal, Colonel Sonnenstern, and Mr. Hawley, set out to make a reconnaissance covering the route heretofore described and known as Napoleon's route.

On our arrival at Granada we were met by Mr. Hollenbeck, an American merchant doing business in Greytown, and president of the Nicaragua Steam Navigation Company, who for his own purposes desired to go over the ground which we proposed to examine.

The expedition had already been indebted to Mr. Hollenbeck for numerous favors, and he now

added to these by offering us the joint use of a small metallic life-boat belonging to one of his vessels, which offer was gladly accepted; and we made preparations to set out as soon as the weather, which was then quite boisterous, should moderate sufficiently.

Señor Quadra, the president of the republic, being in the city, we called during the day to pay our respects to him, and were very cordially received. Señor Quadra was kind enough to say that his government was anxious to do all in its power for the assistance of the expedition, and that we had only to express our wishes to have them complied with.

In the evening, by invitation, we attended the wedding of the daughter of the Italian consul-general, Señor Costigliolo, with a young physician of Granada. It was a grand affair, guests being present from all parts of the State, the President giving away the bride.

A handsome ball followed the marriage ceremony. The national band, brought from Managua for the purpose, furnished most excellent music. We were very favorably impressed not only with the appearance and manners of the ladies and gentlemen present, but particularly with the elegant taste displayed in the toilets of the former. We were told, and could readily believe, that many of them had been brought from Paris for the occasion.

On the following morning, *i. e.*, the 26th, Colonel Sonnenstern set out by land with the saddle and pack animals for the head of Lake Managua, where he was to erect a signal, in the vicinity of Leon Viejo, to indicate to us the proper landing-place. Mr. Hawley was taken with a sharp attack of fever and was unable to proceed. Mr. Menocal, Mr. Hollenbeck, and myself embarked in our little boat for the estuary of Panaloya, a distance of fifteen miles.

Taking soundings as we went, we reached the mouth of the estuary early in the afternoon, having, fortunately for our comfort, had but little wind, as a short, chopping sea gets up in the lake with very little provocation, making its navigation by small boats uncomfortably wet.

Passing a mud-bank at the entrance with about 5 feet of water, we continued our soundings through the estuary, through Lake Tisma, (so called,) and into the Rio Tipitapa. The banks of the estuary and lakelet are low and swampy, changing as the river is ascended to high, firm ground, with a good deal of rock.

Nightfall overtook us some two miles from the foot of the rapids and abreast the hacienda of San Juan, where we landed for the night, the hospitable proprietor permitting us to hang our hammocks under a shed, in company with pigs, dogs, and innumerable fleas.

Bright and early the following morning we proceeded on our way, carrying the soundings to the foot of the rapids, so called, for there was no water passing over them. From deep water outside the estuary to this point the distance is sixteen miles, with an average depth of 10 feet, muddy bottom, through which it would be necessary to dredge a channel 16 feet deeper in the event of the canal's taking this route.

The river had now ceased to be navigable even for the smallest canoe, its bed being full of rocks and bowlders, perfectly dry on the surface, though showing the water through the breaks and fissures here and there. This continues for one mile. Next there is an intervening section of deep water, now without current. Then the river again assumes its rocky character for another mile; near the village of Tipitapa, at its origin, there is a fall of 12 feet. Lake Managua has not been high enough for several years to discharge any water through the Tipitapa, except such as may percolate through the rock.

From a plantation near the foot of the lower rapids we fortunately obtained an ox-cart, and, hauling out our boat, we placed her upon it and sent her to the upper lake. Two of the party then started to make a paced traverse in the same direction, taking with them one of the aneroid barometers; the third remaining at the starting-point with the other barometer, and taking observations at ten-minute intervals till those in advance had had time to reach the upper lake and get settled readings of their instrument at its water-level, in order that we might measure the difference of the level of the two lakes by comparison of the barometer readings. Up to this time we had found no current whatever either in the estuary or the Rio Tipitapa; the water at the foot of the rapids was, of course, therefore at the same height as that in Lake Nicaragua.

We found the difference of level to be about 22 feet, (as a barometer can never be read with sufficient accuracy to say exactly.) Lieut. John Bailey, an English officer, many years since, had found the difference of level to be 28 feet; and Colonel Sonnenstern, some years later, had found

nearly the same. We therefore felt somewhat doubtful of the accuracy of our results, though Colonel Sonnenstern afterward explained that Lake Managua was several feet lower than at the time he ran his levels, while Lake Nicaragua was still 2 feet above low-lake, which he had used as his reference plane.

As it was desirable to know the exact difference of level, however, a small party, as will appear further on, was afterward sent to measure it with the spirit-level. They found the difference to be 22.3 feet. This difference is, of course, liable to considerable fluctuations, consequent upon the relative amounts of rain which may fall in the sections of country that the two lakes respectively drain. So that in all calculations it will be necessary to regard it as differing from 22 to, say, 27 feet, as an unusually rainy season in the northern part of the State might raise Lake Managua to its former height. This, however, seems to be rather among the possible than probable events, in view of the length of time which has elapsed since it has occurred.

The ox-cart made very slow progress with our boat, and, while waiting for it at the little village of Tipitapa, (since destroyed by fire,) we made a thorough examination of the bed of the river and the adjacent banks, which are very high and rocky. A short distance below the fall which has been mentioned there are three sulphur springs, whose water is at boiling-heat. Near them are the remains of a masonry bridge, probably a century and a half old, and one of the few bridges of any kind in the country.

About sunset our boat was launched, and we concluded to start for Managua City, a distance of fourteen miles, running the risk of not finding it in the darkness rather than remain in so uninviting a spot as was Tipitapa.

Our soundings showed shallow water for about two miles from the outlet of the lake, with muddy bottom, which could probably be deepened by the dredge to any desirable depth.

We were fortunate enough to reach Managua at about 11 o'clock, and to find lodgings at a hotel kept by an Englishman, Mr. Hazlam.

Early the following day we got under way again for the western end of the lake. After rounding the promontory formed by the extinct volcano of Chiltipeque, our course became about west-northwest to Leon Viejo, a spot marked by a few ruins, but showing no sign upon the lake-shore, and, like numerous other places in the country, existing as a town only in name. Leon Viejo has the advantage of many of the others, though, in that a town once existed on its site, the city of Leon, founded in 1523 and continuing till 1610, when it was removed to its present location.

Sailing along parallel to the coast, we had an excellent opportunity to examine the formation of the country near the shore. The distance from Managua City to the end of the lake is about forty miles. The breeze being rather light, we found ourselves at nightfall near a spot called on the maps Moabite; but this, again, is one of the towns yet to be built. Hanging our hammocks in the low-spreading branches of a tree we had a refreshing night's rest, after being so long under a hot sun and in a cramped position, owing to the small size of our craft.

Shortly after daylight we set out again, and, keeping close to the shore, we soon had the pleasure of seeing Colonel Sonnenstern's signal. By the time we got abreast of the place where the colonel was waiting for us quite a brisk breeze had sprung up, and we narrowly escaped being swamped in landing.

Colonel Sonnenstern, or Don Max, as he is called by everybody, had our horses ready for us on the beach. Comparing our barometers, one of the party remained at the water-side taking and recording barometer-readings at ten-minute intervals, while the rest mounted and proceeded to Pueblo Nueve, a distance of seven miles, following a route indicated by Don Max, observing their barometers at various points on the road, particularly the highest, and again at Pueblo Nueve. After giving sufficient time for these last, the observer at the lake-shore also mounted and joined the party at the Pueblo.

On the following day, *i. e.*, the 30th, Mr. Menocal and myself made a careful paced reconnaissance from Moabite to Pueblo Nueve, again taking observations for heights, Mr. Hollenbeck going to the lake-beach with the other barometer.

On the 31st several other lines leading from the lake to and across the divide were examined, Colonel Sonnenstern acting as guide and indicating the depressions. The lowest depression found was 80 feet higher than the lake, with a long, gradual slope on either side, making a bad profile.

From the observations above recorded we arrived at the following conclusions, viz:

To carry the canal through Lake Managua and on to Realejo or to the Gulf of Fonseca: first, there would have to be dredged a channel at least sixteen miles in length, from deep water in Lake Nicaragua to the foot of the rocky portion of the Rio Tipitapa, the depth of water being now, on the average, 10, and in the deepest places but 12, feet; thence an independent canal of four miles, with three locks to lift from the level of Lake Nicaragua to that of Managua; next a channel two miles in length, to deep water in Lake Managua, to be dredged, the water now gradually deepening in that distance from 4 feet to 5 fathoms.

From Managua City to the western end of the lake the Cordillera extends in an unbroken wall, gradually lessening in height from about 1,200 feet till it loses itself in a high plain.

Several lines were run from the lake-shore to a distance of from three to five miles, leading, as has been said, through the passes indicated by Colonel Sonnenstern. We found long, gradual slopes, with heights varying from 80 to 200 feet above Lake Managua, which of course gave, taking the mean difference of level between the two lakes, from 105 to 225 feet above Lake Nicaragua, nor were we quite sure when the lowest of these levels was found that the summit had been reached.

The least distance from the lake to Realejo is some thirty miles; so that, even if the profile were much better than it is, the line bears no comparison with Childs' route on account of the distance alone, without considering the six additional locks, three ascending and three descending, required. We found one other objection, which would of itself be fatal to the line: the geological formation of that part of the country is entirely volcanic; a line of volcanoes, nine in number, and all more or less active, extends from the lake toward Realejo, nearly parallel to, and in close proximity with, the proposed line of canal. While writing these pages news comes of the outburst of one of them, Monotombo, (whose base is washed by the waters of the lake,) accompanied by a shock of earthquake which was felt slightly as far as Virgin Bay, a distance of eighty miles. The soil and the underlying rock are so extremely porous that even in the wet season no streams deserving the name flow into the lake from that side, all the rain that falls being drunk up by the earth. We examined all the wells that we met, and found them from 100 to over 300 feet deep. If a canal were built through this region, it would be impossible to keep it full unless it were made artificially water-tight from one end to the other, which would involve a cost equal to that of the excavation. For all of these reasons we regard the route as utterly impracticable.

In the survey made by Lieutenant Bailey many years since, and to which reference has already been made, that gentleman professes to have found a pass with but 56 feet above the lake-level. Many of his statements are found to be entirely unreliable, and this is no doubt like the rest. For example, he finds Lake Nicaragua to be 121 feet above mean tide in the Pacific, while the true difference is but 107 feet. Many of his other statements have been proved to be equally incorrect.

One valuable discovery resulted from our reconnaissance, which was the existence of a lime-stone quarry near Tipitapa, from which a seemingly high order of natural hydraulic lime is produced.

Having finished our reconnaissance, and Mr. Hollenbeck having succeeded but little better than we in the object of his search, viz, a feasible route for a railroad from the lake to Leon, we started by land on the 1st of February for Managua, passing through Nagarote and Mateares on the way, and stopping at the former long enough to admire the magnificent Jenisero tree, which has been so often described by travelers, and whose spreading branches shade at least an acre and a half of ground. We were very glad at sunset to find ourselves again under the hospitable roof of mine host Hazlam, at Managua, (although we were obliged to accommodate ourselves, four persons, in a room 10 feet by 12,) the more so as we were here joined by Mr. Hawley, who brought us the first mail we had received since leaving the United States. We were honored by numerous visits from ministers, senators, members of congress, and other prominent gentlemen, all of whom manifested the greatest interest in our labors, and the hope that the work of building a canal might soon become an accomplished fact.

The following day being Sunday, we remained quietly at Managua, and in the evening were

honored with a serenade by the national band, by direction of the president of congress, Don Joaquim Pedro Chamorro, a cousin, by the way, of our excellent friends of the same name at Rivas. Senator Chamorro came himself with the band, accompanied by Don Anselmo Rivas, the minister of foreign relations.

On Monday we waited long enough to make an official visit to the president, who again expressed his great interest in the enterprise in which we were engaged, and again offered on the part of his government all the assistance in its power. This offer we found the authorities everywhere not only instructed but personally anxious to make good, while the people, particularly the more intelligent classes, were equally well-disposed toward the expedition.

While waiting for the proper hour to make our visit, we availed ourselves of the opportunity to visit Lake Tiscapa, one of several beautiful little sheets of water occupying what are evidently the craters of extinct volcanoes; the surfaces of the water from 80 feet, as in the case of Tiscapa, to over 400 feet below the general level of the surrounding country, and all without visible outlets.

We set out on our way to Granada at midday, and at sunset reached Valle-Gottel, a small settlement clustered around the only well to be found between Managua and Masaya. The proprietor of the village is an American citizen, though of German birth, who is displaying a great deal of enterprise, and will ultimately have a magnificent place. He publishes a paper, has established a church, a school, and various shops, and will no doubt soon attract a considerable population. We were very hospitably entertained at his house for the night, and resumed our journey on the following day, passing through Masaya, where we visited another of the curious lakes above mentioned. The surface, as shown by our barometers, is 320 feet below the general level of the land, and the lake furnishes all the water used in the city. This but a few years since was transported up the precipitous pathway leading to the lake, and for nearly a mile, to the heart of the city, by Indian women and girls, who carried several gallons at a time in earthen vessels suspended in nets resting on their backs and shoulders and supported by a band passing over the forehead. American enterprise has erected, recently, a steam pumping apparatus, by which the water is raised and conducted to a reservoir in the middle of the city, where it is sold for a small amount—enough to bathe and water a horse or mule costing but 5 cents. The water-carriers have not been quite driven from the field, however, as we met numbers of them on our way down to the lake. The reservoir above referred to, built of stone above ground, has been made perfectly tight by the use of lime made from the stone-quarries near Tipitapa. Our attention being thus called to it, we examined other works constructed with the same lime, which we found to be a superior order of hydraulic lime. It is said to be found in great abundance, and to be quite accessible.

Between Valle-Gottel and Masaya are the lava-fields, one of the most terrible spectacles of desolation I have ever seen, extending from the volcano of Masaya toward the lake for a distance of nine miles, and over three miles wide—a black, ragged mass, with only here and there a bush or small tree struggling for existence, although it is over a hundred years since the eruption by which it was caused.

Giving our animals a much-needed rest of a day and a half at Granada, we again pushed on to the Rio Gil Gonzales, where we joined Lieutenant Leutze's party on the 7th of February.

The line which this party had been examining commenced in a miry swamp at the lake side, into which the Gil Gonzales finally loses itself after dividing into numerous branches. This swamp was in many places utterly impassable, and gave a great deal of trouble in the establishment of an initial-point at the lake. Lieutenants Leutze and Miller, in making a reconnaissance for this purpose without a guide, and accidentally following one of the branches instead of the main river, lost their bearings, and only reached the camp after a walk of thirty miles. After great labor on the part of both officers and men the line was at last located from the lake shore to hard ground, and started toward the divide. A distance of some seven miles, following the valley of the river, carried the elevation to 261 feet above the lake, with a gradual rise. A reconnaissance to the divide showed that, by that pass, the elevation was at least 300 feet higher. The line was therefore abandoned, and several other depressions examined, instrumentally and by reconnaissance.

On the day of our arrival the last attempt was made by Lieutenant Leutze and Mr. Crowell,

who returned to camp unsuccessful. The examination having been very thorough in every direction which afforded the slightest promise, Lieutenant Leutze was directed to abandon the line and return with his party to Virgin Bay, which he did on the following day, while we proceeded to visit Lieutenant Rhoades.

At the time of my last previous visit to Lieutenant Rhoades he was still east of the divide, his line passing within less than a mile of the city of Rivas, and the party were encamped on the hacienda of San Vicente, where they were treated with great hospitality by its proprietor, General Don Vicente Zamoro. Since that time the line had crossed the divide, and, entering the valley of the Chocolata, had descended with that small stream to its junction with the Rio Grande, whose valley it was now following.

In honor of the late commander of the expedition the name of Hatfield Pass was given to the depression through which the line crossed the divide. The hopes previously indulged with regard to the advantages of this route had been realized, as will be more fully shown further on. Excellent progress had been made, considering the character of the country and the thoroughness of the work. The head of the line was now within four miles of Brito.

The party had encamped at the estate of Jesus Maria, the property of Don José Orcullo and brother; at Los Horcones, belonging to Señor Chamberlain; at Las Serdas and Las Juntas, which last, as well as La Flor, where they now were, was the property of our good friends the Messrs. Chamorro, of Rivas. At all of these places they had been very hospitably and kindly treated by the proprietors and their people.

The officers and men, like those of party No. 1, were all well, though nearly everybody in each party was suffering with innumerable itching sores, upon all parts of the person, produced partly by dietetic and possibly by climatic causes, but mainly by the bites and stings of insects and the poisonings of different vines and plants; principally among the former were the *garapatas*, a vicious species of wood-tick, which swarm almost every leaf and plant growing near the ground, and are of every size from that of a pin-point to that of a large split pea; transferring themselves by thousands to one's clothing and thence to the person, they bury their heads under the skin and are extremely hard to get rid of. Frequently beating the clothing with a switch will rid one of a great many of the little pests, but it was seldom that any one passed a whole day without finding a greater or less number upon his person. A dear-bought experience on the part of one or two of the officers had taught us also to examine very carefully our clothing, especially our boots and shoes, before putting them on, for scorpions, one species of which is very poisonous. These, with snakes, tarantulas, myriads of insects of various sorts, and innumerable lizards of all sizes and colors, are things to keep a nervous person in a constant state of agitation. The lizards, to be sure, are perfectly harmless, but it takes some little time to get so used to them as not to mind their extreme familiarity. Mosquitoes, except in the swamps, are rarely met with on the west side of the lake.

Although the region in which the parties were operating contained several estates more or less cultivated, yet by far the greater part of each line was through an unbroken virgin forest, the rank tropical vegetation in many places forming a perfect jungle. Occasionally were met large areas filled with the terrible pica-pica, as it is called by the natives. It is a tall bush loaded with a kind of bean, whose pods are covered with a down consisting of minute barbed needles. These are detached from the bush at the least shake given to it, and alighting upon the person produce perfect torture, seeming to penetrate through the clothing as easily as into the unprotected parts of the skin. The sensation produced is exactly like that of fire. It was sometimes found impossible to cut through the pica-pica at all, and slight deflections of the line were caused by it several times. It is only at certain seasons that the pica-pica is so troublesome, and our parties unfortunately experienced it at its worst.

The weather was delightfully fine; the refreshing trade-winds, blowing very regularly, tempered the heat of the sun during the day, and there was seldom a night when one could sleep comfortably without a blanket or other light covering.

On the 15th of February Lieutenant Rhoades' party reached Brito, and Mr. Greene and Lieutenant Moser connected their traverse and levels, respectively, with Mr. Niles' tide-gauge.

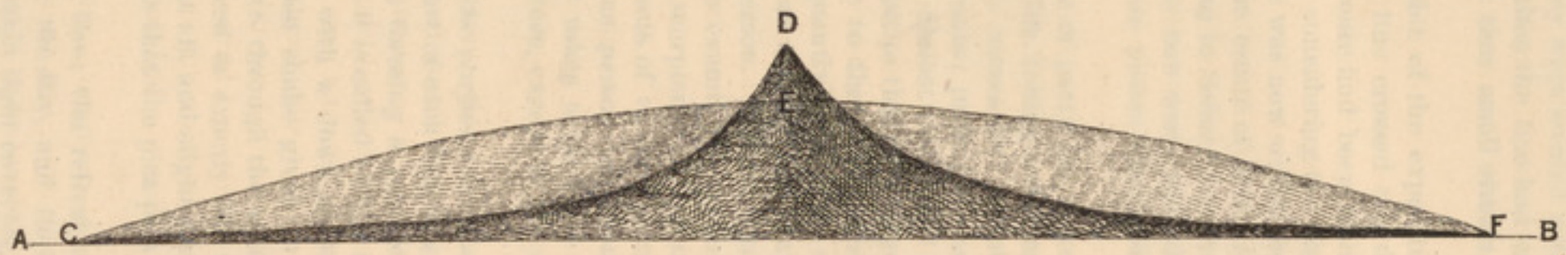


Fig. 3.

N. PETERS, PHOTO-LITHOGRAPHER, WASHINGTON, D. C.

A few days were then spent in making detailed surveys of some particular localities. The traverse as already examined having been plotted, and the proposed line of the canal laid down on the map, it was found that it would be necessary, if possible, to turn in four places the channel of the Rio Grande, and also that particular information was needed at two or three other points, for which purpose the special surveys were directed. At the same time Mr. Hawley, with a few men, was sent with the boring apparatus to test the character of the excavations likely to be met.

A party consisting of Lieutenants Leutze and Miller, Mr. Crowell, Mr. McCrea, and three men, was also sent to run the levels between Lakes Nicaragua and Managua, in order to ascertain the exact difference of level.

On the 14th of February, accompanied by Dr. Bransford, I made a visit to Brito, with a view of making such examinations as were necessary for planning the formation of a harbor. I found that such a thing as a boat or canoe for making soundings was not to be had anywhere in the vicinity; and, in fact, the surf was so heavy as to make it dangerous for a boat not specially built for surf-landing, even if we had been supplied with one.

Mr. Niles and his little party were living in a small hut, which they had built, near the tide-gauge, and in which we were entertained with the best they had in the shape of a breakfast. On our return we visited Lieutenant Rhoades and his party at La Flor, where they were still encamped. Fortunately the doctor's services were not required in either place. We reached Rivas some time after nightfall, pretty thoroughly tired out, having been eleven hours in the saddle. The Nicaraguans have little cause to boast of their roads. Except in the immediate vicinity of the larger cities they are simply execrable. The trees seem to have a most persistent habit of falling across them, and when they do so no one ever thinks of removing them; a detour is made in the most convenient direction, which soon becomes a more or less beaten pathway, the branches and undergrowth being cut away just enough to make it possible to pass. The result of this system, continued for many years, is to make the roads so tortuous that one has often to travel, in going from place to place, at least twice the actual distance of the one from the other. This condition of things will probably not be improved till the country is more divided up into small farms, when the greater need of roads, and the increased number of persons to keep them in order, will both contribute to that very necessary element of development, an easy means of communication.

On our return to Virgin Bay Mr. Runnels communicated to us information, which he had received from a gentleman in San Juan del Sur, in regard to a route which his informant regarded as entirely feasible for a canal, leading from that port to the valley of the Limon River, which empties into the lake a few miles below Virgin Bay. This information Mr. Runnels gave us, though having no very great faith in it himself. As our rule was to examine everything which gave the slightest promise, it was resolved to make a reconnaissance of this line, though neither Mr. Menocal nor myself entertained any hope of its proving of value.

It is quite remarkable how few intelligent persons there are on the American isthmus, or in Central America, who have not some theory, each differing from his neighbor, as to the best route for a canal. These theories are generally based on information received from hunters, India-rubber men, and others, whose calling makes them acquainted with the mountain-passes. And odd as the assertion may seem, the fact that these *practicos* regard a pass as low and favorable for a canal, is almost a certain indication that it is the worst possible location to seek for a feasible line; their judgment being based entirely upon the fact that the rise is so gradual as to be inappreciable to them, which condition, of course, makes the profile, as I have said, the worst possible for a canal. A reference to the accompanying diagram will illustrate this idea. Two profiles, C E F and C D F, are combined for the sake of comparison. A B is the bed-line of the canal. A glance will show that, although the profile C D F actually has a greater, and, to a person traveling over it, would seem to have a very much greater summit-level than the profile C E F, yet the amount of excavation would be greatly less, or, as it is generally expressed, there would be much less deep cutting in the former than in the latter case. This explanation is given in case these pages should ever be read by a non-professional, to illustrate what is meant by a good profile or a bad one.

February 18th Mr. Menocal, Mr. Runnels, Dr. Bransford, and myself, started for San Juan del Sur, making some examinations on our way. On the following day Mr. Menocal started with guides

to examine the indicated pass, Dr. Bransford establishing a temporary barometer station at the water's side, where he continued to observe at ten-minute intervals, until Mr. Menocal had had time to reach Virgin Bay, and to get observations at that place. These last, by the way, on being compared with those taken at the same time by Dr. Bransford, (each observer using a magnifying-glass,) gave the difference of level between sea and lake at 106 feet, or agreeing within two feet of the difference shown by the spirit-levels at that stage of the water in the lake. The lowest pass found by Mr. Menocal in the Cordillera was 605 feet above mean tide at San Juan del Sur, while the summit-level was so close to the Pacific shore as to leave no room for locks, even if the height had not been so great. Mr. Christophle, who had pointed out the route, was the only one disappointed in this, as he was the only one who had expected any better result.

The pass was called Camino Viejo, or Barranca, and is the line formerly followed by the Costa Rica road, hence the first of its two names. The very rapid growth of vegetation had entirely obliterated the road, which was abandoned but a few years ago for the much better one built by the Accessory Transit Company, from San Juan del Sur to Virgin Bay, and a picket had to be cut nearly the whole distance, until the transit road was reached, at about three miles from the latter place. The reconnaissance cost Mr. Menocal about the severest day's labor which he had during the expedition, having to make the distance on foot.

On the same day procuring, through the kindness of Mr. Murray, of San Juan del Sur, a small boat, and four boys as a crew, I pulled to Brito, a distance of nine miles, to make the necessary soundings off that place. Fortunately I had made previous arrangements with Mr. Niles to erect, and Mr. Greene to fix by the transit, such signals as were needed for locating the lines of soundings, as the surf was too heavy for landing, although a strong breeze was blowing off shore, causing a little toppling surface-sea, directly opposed to the swell, and drenching us thoroughly before we reached San Juan on our return, and where our arrival, late in the afternoon, caused considerable relief to our friend Runnels, who confidently expected that we would be blown off to sea.

From Virgin Bay, Lieutenant-Commander Schulze had chosen the same day to run some lines of soundings off the mouth of the Rio del Medio, in order to carry the profile of the line of canal to deep water in the lake, and had made even worse weather of it than we had done. Having to pull some six miles in a small wooden dinghy in the trough of the short-chopping sea, caused by the strong trade-winds, his boat was fairly swamped once or twice, but fortunately in shoal water.

On the 20th of February, Lieutenant Leutze and party arrived at Virgin Bay on their return from Tipitapa; Mr. Niles and party arrived from Brito on the same day; and on the 22d, Lieutenant Rhoades, with party No. 2, and Mr. Hawley, with his boring party, also arrived at headquarters, having completed the work assigned to them. Preparations were at once made to transfer the expedition to the valley of the San Juan. For reasons which will be given under the appropriate head, the route just surveyed, and known as the Rio del Medio line, was regarded as showing a better combination of favorable conditions than any other line, and to be entirely practicable, not only in an engineering but also in a commercial sense.

On applying to the Messrs. Chamorro for the amount of the indebtedness of the expedition for the hire of men, animals, &c., I was informed by them that they had been directed by the government of Nicaragua to pay on its account all expenses for such objects incurred by the expedition; this very handsome offer I did not feel at liberty either to accept or decline, without communicating it to your Department. In answer to my communication I was directed to decline the offer, with the Department's thanks, not only for that, but for all the assistance which had been given us by the government and authorities of Nicaragua. This order I communicated to the Messrs. Chamorro, and also to the minister of foreign relations, Don Anselmo Rivas, who caused it to be published in the official gazette.

Our friend, Mr. Hollenbeck, having been notified that we were ready, sent the lake steamer to Virgin Bay for us; we embarked in her and proceeded to the mouth of the Zavalo, a tributary of the San Juan, which it joins just above Toro Rapids. Arriving March 4, 1873, we named our encampment "Camp Grant."

GENERAL DESCRIPTION OF THE SAN JUAN RIVER.

Descending the San Juan, we find it a broad, open river, with an average depth of 19 feet for twenty-eight miles, when we reach the first, called the Toro Rapids. These are some two

miles long. Next we have a stretch of clear river for seven miles; then the second, or Castillo Rapids, less than a quarter of a mile in extent, and taking their name from the fort upon an adjacent hill. Seven miles farther we reach the Mico and Balas, coming so close together as to form really continuous rapids; their extent is not quite one mile. Four miles farther down we come to the Machuca Rapids, the last which we find; their length is about two miles.

For twenty miles from the foot of Machuca Rapids the river has a depth varying from 20 to 60 feet, with but little current; this section is called "Agua Muerte," or dead water. At the foot of the Agua Muerte the San Carlos is received into the river, and is the first considerable tributary met. Above this, although every valley has its little stream often deep enough to give a good wetting to our parties in crossing, yet the most of these are insignificant.

The Zavalo and Poco Sol are the largest of the upper tributaries, but have but little effect upon the main river. Opposite and below the mouth of the San Carlos, which comes from a long distance up in the Costa Rica hills, the San Juan changes its character altogether, and is filled with shoals and sand-bars. Twenty-four and a half miles below the San Carlos is the confluence of the Serepiqui, a river of similar character and size, and also coming from the Costa Rica side.

Thirteen miles farther we come to the forks of the Colorado; here the main river divides into two branches, the principal of which, the Colorado, flows to the eastward, and empties into the sea; the less, called the Lower San Juan, passes more to the northward, and is divided into several mouths, one of which, the Tauro, discharges its waters into the sea; the others empty into the lagoon which was once the harbor of Greytown.

About four miles above the forks of the Colorado, a small caño leaves the main river to the left, and flows in a direction generally parallel to the Lower San Juan, which it finally joins near Greytown.

The valley of the San Juan is entirely uninhabited, with the exception of the town of Greytown at its mouth, the villages of San Carlos and Castillo Viejo clustered around the forts of the same name, and a few isolated plantations, so called, the most of which are below the mouth of the Serepiqui. Fort San Carlos is situated just at the outlet of the lake, and is one of the numerous specimens, now gone to decay, of the stupendous work done by the Spanish in their Central American colonies.

Most persons who are acquainted with tropical streams agree in the opinion that, as a rule, their adaptation to slack-water navigation is almost, if not quite, impossible, on account of their being subject to sudden and violent freshets. The San Juan, having its origin in a body of water so large as Lake Nicaragua, and being fed, as said above, by insignificant tributaries in its upper portions, is not there subject to these freshets. Below the confluence of the San Carlos, which drains a large extent of mountainous country, the San Juan partakes of the character of other rivers in the same region; further on it will be seen that we propose to use the river only above the mouth of the San Carlos, and an independent canal from there to the sea. At the present time the freshets of the San Carlos, by backing up the water of the San Juan, affect the rises in the latter even as high as the foot of Machuca Rapids. This backing-up will be entirely overcome by the dam which it is proposed to place at the mouth of the San Carlos.

A rapid examination of the river, made while on our way to Virgin Bay, had convinced us that the navigation from its head to the Castillo Rapids could be so improved as to fulfill the conditions required; it was therefore determined to begin at the latter place the survey for an independent canal route.

The organization of parties Nos. 1 and 2 remained pretty much the same as before, except that Mr. Hawley took charge of the level in Lieutenant Leutze's party, relieving Lieutenant Miller, who was placed in charge of a separate party to make a survey of the river proper. Master Niles, Ensign Bull, and Mr. Hamilton Browne,* a young English gentleman, who accepted the vacant position of first-class apothecary, were assigned to Mr. Miller's party as assistants.

Colonel Sonnenstern was the bearer of instructions from his government to Colonel Sandoval, the commandant at Castillo, to let us have as many of his soldiers as could be spared, to act as

* Mr. Browne, with his brother, had recently come to the country with the view of purchasing a coffee estate, which they have since done, and it was while waiting for the completion of their negotiations that he accepted the position above referred to. In his travels he had learned to treat the simple fevers of the country.

macheteros. Colonel Sandoval was able to let us have but eight men, just half as many as we needed, and after trying in vain for nearly a month to get more, either on the river or at Greytown, Colonel Sonnenstern went to Granada, where he procured a full supply. In the mean time the parties had to work very short-handed, adding no little to the severity of the labor.

The section of country adjacent to the river, between the Castillo and the Machuca Rapids, is exceedingly broken, many of the mountain-spurs extending to the very water's edge. This section of the work bid fair to present more difficulties in locating a canal, and consequently required a more careful examination than any other. I concluded to keep the two parties together, until past Machuca, giving to Mr. Rhoades' party the main line, and to Mr. Leutze's the special surveys of the several rapids, and the probable locations of dams, and also the running of off-sets from the main line to the river-bank.

It will be seen further on how admirably, upon the result of the survey of this section, the engineering skill of Mr. Menocal has solved that part of the problem which gave us most discouragement while the survey was progressing.

The country was so much more broken than had been supposed, even, that a canal built through it would be enormously expensive, while it seemed as if the improvement of the river would be still more so. A happy combination of the two methods, however, has overcome the difficulties, and the section, instead of being the most expensive and troublesome, bids fair to be the least so.

A bench-mark was established on the left bank of the river about one-half mile above Castillo Rapids, and the work was fairly begun on the 6th March. The party made their first encampment in some farm-buildings belonging to Don Nicolas Osorno, but ever after had to rely upon their shelter-tents.

The line led through an unbroken virgin forest, so interlaced with parasites and undergrowth as to be almost impenetrable, and in most places altogether so without the vigorous use of the macheta, making it necessary to cut a trail for every foot of advance, passing sometimes three or four times a day over hills of greater or less height, and through small streams in every valley. Although at this season of the year we had reason to expect the driest weather, scarcely a day passed without one or more showers, which converted the overlying stratum of clay into a stiff, clingy mud, particularly upon the hill-sides, where it was less covered with vegetable deposit. The labor upon the west side of the lake had seemed to be, and was, very severe, but it was looked back upon as very light in comparison to what was now endured, more particularly as the parties, always organized with the minimum number consistent with efficiency, were now, as has been mentioned, short, one five men and the other three. I might mention that no servants were allowed to officers, from commander down, as the small appropriation made it necessary to economize in every way possible. Indeed, after leaving the vicinity of Castillo Viejo, the officers were obliged even to wash their own clothing, being out of the reach of anybody who could be hired for the purpose.

It would be impossible for me to express my appreciation of the untiring energy and zeal displayed by both officers and men, and of the cheerfulness with which they submitted to the hardships and discomforts of the seventy-six days spent in running the line to Greytown.

A general compass-course was taken from the map, and followed as nearly as the conformation of the ground would permit; constant reconnaissances on either side being made to take advantage of any low ground, which by diminishing the profile would compensate, or more than compensate, for the increase in length caused by deflections. This required a great deal of judgment, and was usually done by Mr. Menocal when present, and at other times by the officer in charge of the party, though there was ample employment for the latter without this extra duty; in fact it would always be better to have at least four officers in each party, so that when the officer in charge was absent upon a reconnaissance there would be another to lead the line without calling the officer in charge of either the transit or of the level to divide his attention between that duty and his own.

Mr. Menocal remained with party No. 2 until the line reached Machuca, and was indefatigable in his labors, saving many a mile of useless work by examining the country ahead of the instru-

ments, though with every precaution the line would occasionally get into a nest of hills and spurs, impossible to pass, when it would become necessary to retrace a greater or less distance and take a new departure, a most disheartening operation to a party with a long distance ahead and a limited time to accomplish it in.

With every exertion, under the existing circumstances, a mile a day was good progress, while in some few cases of unusually rainy days not more than 2,000 feet were made.

The line was so near the river that it was always convenient to locate the camps on its banks. This was a fortunate circumstance, as the only means of transportation was by boats or upon men's shoulders. A flat-boat, lent to us by Mr. Hollenbeck, and a large canoe, were used for shifting camps, which was done whenever the line extended so far that it was inconvenient to walk back at night. At first a new camp was made for about every four miles of survey, but later not more than one for each eight miles, the new camp always being carried some distance ahead of the end of the line.

The Messrs. Hollenbeck, Runnels, Chamorro, and Benard,* Colonel Sonnenstern, under his familiar title of "Don Max," and Commander Hatfield were all remembered in giving names to the camps.

A number of rooms in the custom-house and barracks, at Castillo Viejo, were placed at our disposal by Don Saturnino Reyez, the administrator of customs, and by Colonel Sandoval, the commandant. These were fitted up as draughting-rooms, hospital, and quarters. Our general camp at the Zavalo was then broken up, and the stores and other property were shifted to Castillo, much to the relief of Mr. Pohlers, who found a tent but poor accommodation for his draughting table.

After a few days at the level, Mr. Hawley was taken with a severe attack of fever and obliged to give up; he was, however, sent to Greytown to relieve Mr. Reilly in charge of the bulk of our provisions, which had been left there in store. Requisition was made upon Commander Reed, of the Kansas, for another officer and also for five seamen. In the mean time Lieutenant Leutze took charge of the level in addition to all his other duties. About the same time Lieutenant-Commander Schulze was prostrated by a sunstroke, and so severe was the shock upon his system that the surgeon advised his being sent north as the only chance of recovery. Messrs. Schulze and Hawley had been a great deal in the West Indies of late, both serving in the first two expeditions under Commander Selfridge in Darien; neither was in a fit state of health to go on the present expedition, and we were deprived of the services of two experienced and zealous officers at the very time when they were most needed. Mr. Hawley was very useful in his new position, however, which compensated largely for his loss in the field.

While the topographic parties were progressing toward Machuca, Lieutenant Miller made his preparations for beginning the survey of the river proper, fitting out for the purpose a little flotilla consisting of a flat-boat borrowed of a Colonel Hanger, at the mouth of the Zavalo, a dinghy belonging to the Kansas, a balsa designed by Commodore Ammen, United States Navy, and a canoe; the flat-boat was designed to carry provisions and equipments, and also to be used as quarters for the officers and part of the men, and was fitted up with awnings and bunks; the rest of the men lived in the other boats.

The survey of the river was directed to be done with the gradienter, an instrument combining the functions of the transit and level, and also fitted with a micrometer-attachment, by which distances are obtained by measuring the angle subtended by a rod upon which two targets are fixed 12 feet apart. The level was to be run from the lake to Castillo, where it was to be connected with Mr. Moser's initial bench-mark, in order that we might have a connected line of levels from the lake to the sea. On the 29th of March an officer came up the river from the Kansas with five seamen, two of whom were sent to Mr. Leutze, and the other three to Mr. Miller, making his party complete. About the same time Colonel Sonnenstern arrived from Granada with a number of natives, who were distributed between the two topographic parties, making them also of full strength.

In the hydrographic party the following distribution of work was made: Lieutenant Miller, with the balsa, took charge of the gradienter, recording the courses and distances and sketching

* Don Emilio Benard, Nicaraguan minister to the United States.

in the topography. Master Niles, with the dinghy, took and recorded the soundings. Ensign Bull, with the canoe, took charge of the level and gradienter rods, and recorded the levels.

The work was done as follows: A bench-mark was established at the water's level on the wharf of the Navigation Company, at San Carlos. The rods were sent to the bench-mark, the gradienter set up, and back observations taken for course, distance, and height of instrument. The rods were then sent to the opposite bank of the river and somewhat down stream, when fore observations were taken for course, distance, and height of station. Next, the instrument was carried down a convenient distance, but on the same side of the river, and back-sights were again taken as before. A line of soundings was run from instrument-station to rod-station, and thence to the next instrument-station, and so on. Mr. Browne, with the flat-boat, dropped down each day to a point abreast the last station, where a convenient place on shore was sought for building a fire, and the cook set to work to prepare dinner. By the time that was accomplished, which was generally about sunset, the boats were anchored in the middle of the river, to avoid as much as possible the mosquitoes, which came out in swarms as night approached. Dinner dispatched, all hands were generally ready to spread their mosquito-nets and go to bed. Before daylight in the morning everybody was astir, breakfast and the midday luncheon were cooked at the same spot which had served the night before, and the traverse was again started.

From San Carlos to the mouth of the Zavalo the banks of the river were low and swampy, though the water was at about its lowest stage—earlier in the season the work could scarcely have been done at all—heavily fringed with grass, and overgrown with trees, brush, and parasites. The last are always particularly luxuriant near the water, and assume the most fantastic and often beautiful shapes, forming screens and bowers of dense foliage of all colors and varieties, very charming to the eye, but anything but agreeable to those who have to cut through them to find a setting for an instrument or rod and an outlook to the opposite bank, and who often find themselves covered with ants and other insects by the time they have finished.

The topographic parties reached Machuca April 2. It was now determined to divide the remainder of the work into two sections, giving to Lieutenant Leutze's party the line from the mouth of the river Serepiqui to Greytown, and to Lieutenant Rhoades' that from Machuca to the initial point of Mr. Leutze's section.

Mr. Leutze and party, accompanied by Mr. Menocal, started in the flat-boat on the 3d and arrived on the following day at Serepiqui, established their camp some two miles below its mouth, and commenced their line at once.

On the 9th of April Master J. B. Briggs, of the Kansas, joined Mr. Leutze, and was placed in charge of the spirit-level.

My first intention had been to run the line for a canal continuously from Castillo to Greytown, leaving it to be decided afterward how much of it should be used, and how much of the river itself, a little further examination convincing us that with slight improvement the Agua Muerta could be made fit for ship-navigation; and the time being very limited I determined to let Mr. Rhoades bench off where he now was, (April 16,) about four miles below Machuca, and to recommence opposite the mouth of the San Carlos, directing Mr. Miller on his arrival to take up the level and connect Mr. Moser's two bench-marks.

By April 19 Mr. Rhoades and party had established a camp and commenced their new line.

At a good stage of water the river-steamers run from Greytown to the foot of Castillo Rapids. As the dry season advances the river-boats are first prevented from going nearer to Greytown than the forks of the Colorado, and soon after are unable to go above Machuca Rapids. A small flat-bottomed steamer, of about fifteen tons burden, is then brought into requisition to navigate the rapids, and even she has great difficulty in doing so. This state of affairs occurs at the very time when the freights on the lake and river are heaviest; when the coffee and indigo crops are being moved, together with large quantities of India rubber and hides. No little nerve is required in navigating the rapids at this season of the year, as the tortuous channels make it very dangerous to property, if not to life. The river is strewed with the wrecks of steamers that have been lost in the last twenty years. Without the constant personal exertion of Mr. Hollenbeck the Steam Navigation Company would have been brought to a stand-still this year; and as it was, on account of the necessarily irregular trips of the boats, it became sometimes a difficult matter to keep our parties

supplied with provisions, though Mr. Hollenbeck did everything in his power to aid us. I was obliged, on one occasion, to carry a load to Mr. Rhoades by canoe, a distance of sixty miles, against the strong current of the river, arriving just in time to save the party from being out of almost everything.

While our work was progressing, Commander Reed, of the Kansas, assisted by Mr. Hollenbeck, attempted, with partial success, to blow out by means of torpedoes one of the worst rocks in the Machuca Rapids. Commander Reed's report upon the subject is herewith appended. Had they been furnished with more suitable means they would have succeeded in conferring a great boon upon the navigators of the river by clearing the channel of one of its ugliest obstructions.

Lieutenant Miller's party reached the head of Toro Rapids with their survey by April 26, after which, the river banks becoming higher and firmer, they commenced to have somewhat easier work per mile, but made up for it by making more miles a day.

We are now beginning to experience the weather that we had expected earlier in the season, showers becoming more rare day by day, contrary to the predictions of the inhabitants, who had expected an early return of the wet season. All the parties were in consequence making exceptionally good progress, and were straining every nerve to complete the work before it should be interrupted by the rains.

Mr. Rhoades' section, between the San Carlos and Serepiqui, was developing very favorably for the canal, but was passing through a great deal of swamp, which made the work very severe; indeed, had it not been for the very dry weather it would have been impossible, in many places, for Messrs. Greene and Moser to set up their instruments at all. The party were availing themselves of the sand-banks left dry by the falling waters as locations for camps. These were very pleasant, being clear and free from vegetation, while the breeze had free access, making them much cooler than while surrounded by trees; but to pay for these every officer and man suffered more or less from the inigua, or jigger, as it is sometimes called, and the mosquito-worm. These, or rather their germs, are both deposited under the skin by insects, the former generally located in the feet, where the young are developed in large numbers inclosed in a sack. If these are not extracted or destroyed they produce ugly sores. The most of us before leaving the country became quite skillful in removing them, and, following the native rule of putting a little of the ash or juice of tobacco in the cavity which had been occupied by the sack, none of our number suffered any ill consequences from them. The mosquito-worm is much more troublesome. It attacks all parts of the person. The worm grows rapidly, and its gnawing is quite painful. The method used by the natives to extract it is to lay over it, on the skin, for a few minutes, a piece of tobacco saturated in oil, after which it can generally be squeezed out without trouble. Calomel instead of tobacco is more efficacious still, and will sometimes succeed when the other fails. Mr. Greene removed two by it from his head, where they had been annoying him for several days. The theory is, that the tobacco or the calomel makes the worm come to the surface.

I was never able to discover exactly what insect it was that produced either of these. The jigger is supposed to be deposited by a small sand-fly, and the worm, as its name indicates, by a peculiar kind of mosquito.

Insects, lizards, &c., had been so common from the first that the most of them had ceased to be annoying. Mosquitoes at night, and in the swamps at all times; and by day wasps, hornets, and congo-flies, particularly a large yellow species, which drew the blood every time it alighted upon the skin, no one could become so accustomed to as to produce indifference; our parties had plenty of opportunity if it had been possible. Garapatas, though not uncommon, were so much less plentiful than they had been on the west side as not to be taken into account. On the other hand, mosquitoes, which, except in the swamps, had never troubled us there, were here in countless swarms. Another of the pests of nearly every camp was the alligator-ant, which attains a length of nearly an inch, and whose bite is as painful as the sting of the hornet, and apparently even more poisonous. Hartshorn was always carried by some member of the parties as a remedy for bites and stings. Among the many favors which had been bestowed upon us by Mr. Runnels and his family, of Virgin Bay, was a present to each officer of a cedron-bean, said to be a certain remedy for the bites of venomous snakes or the sting of tarantulas; fortunately we never had occasion to test its merits, though there were many narrow escapes. Parasite vines of all sizes

and colors, and festooned in every imaginable form, were so common that a snake hanging from a limb of a tree would often be unnoticed by the officers and sailors, though never by the macheteros, who seemed to be on the constant lookout for them. Occasionally one of the former would suddenly feel himself seized and jerked back, and would find that the keen eye and the strong arm of one of the natives had rescued him from an enemy that he himself had not seen, though perhaps looking directly toward it and not a yard from it.

Toward the last of April Mr. Leutze's line had reached the San Juanillo, and was extending down its valley toward Greytown. The ground was very swampy, with heavy cutting, while the river itself at its head was impassable even for the smallest canoe, being full of drift-wood, and at that season having scarcely any water. After extending the line some three miles from the main river, returning each night to the camp, which was still on the banks of the latter, it became impossible to proceed farther without obtaining a nearer camping-ground, as the six miles' walk going and coming was a fair day's work of itself. As it was quite impossible to transport the camp-equipage, provisions, &c., to the end of the line, even if there had been a suitable location for a camp, it was concluded to cut a trail through, striking the main river some distance lower down, (the two streams, near their forks, running at an acute angle with each other.) This picket proved to be over a mile long, passing over several steep-sided hills, fortunately none of them very high, and through swampy ground in their valleys. It was some improvement in point of distance, however, and the camp was shifted down to where the picket struck the river-bank. The line was now extended some three miles farther on a compass-course, leading over hills, across runs, through swamps and mire, across several sloughs, and across three lagoons. Some of the streams could be forded, others had to be bridged by felling trees across them; logs had to be dragged and laid to make a footway across the sloughs, and generally the best that could be done made but a precarious one. Each time the party passed over the line it would be found that much of the work had to be done over again. The lagoons were overgrown with a tall, thick water-grass; this was beaten down until a sort of floating island was made, when by stepping lightly and quickly over it, the party succeeded in getting across, not without an occasional mishap attended with a good wetting and no little danger, as it was impossible to swim, and next to impossible for one to aid another.

It was hoped every hour, as the line advanced, that the San Juanillo would again be intersected and found navigable, when it was proposed to move the camp to its banks, by taking the boats down the lower San Juan to the junction, and up the former stream to the camping-place. After going about three miles a sluggish stream flowing to the southward and eastward was crossed. According to the best maps in our possession this should have been the desired river; it was still too shallow for the boats, and too muddy to be waded; so full of logs and other obstructions that, even if the bottom had been hard, it would have been a tremendous task to follow its bed. There was nothing left to do but to try and strike the stream again lower down. Lieutenant Leutze and Mr. Crowell, with the macheteros, now spent one day cutting a trail to intersect the river. A mile and a half was run, showing no signs of it, and finally coming into a nest of hills; the party now returned to the main line, and extended that for 3,000 feet, when the lateness of the hour compelled them to start for camp. The work accomplished, together with the walk from the camp and back, had made a very severe day's labor, but there was worse to come. Mr. Leutze now resolved to cut through on the compass-course which he had been following, until the river was reached, and to run the instruments over it afterward. Accordingly, on the morning of May 3, he, with Mr. Crowell and the macheteros, set out before daylight. The end of the line was nearly five miles from camp, and the trail, made worse each time it was passed over, was exceedingly heavy. On reaching it the men were divided into two reliefs, and, working an hour each at a time, the line was advanced 13,600 feet, passing for a couple of miles over the same swamp and mire, after which it intersected seven different hills, from 80 to 150 feet high, with very steep sides; then a valley was followed for some distance, whose water-course had to be forded in numerous places; next, a wide, shallow stream was reached. This obstacle at first seemed insurmountable; the stream was too shallow to be crossed by swimming, its muddy bottom afforded no footing, and its width precluded the usual method of bridging by felling a tree across it. Finally all hands set to work to cut and bring branches; these were thrown into the water, and

confined in place by logs until sufficiently firm to bear a man's weight; then some of the number, occupying that which was already laid, built farther in the same manner, till a sort of causeway extended from bank to bank. The party then crossed over, but so little sustaining-power was there in the structure that the last man was nearly up to his waist in water before he reached the bank.

The party now proceeded on a short distance farther, when they suddenly came out upon the shore of a beautiful lagoon. The map showed a nest of lagoons in the vicinity, all connected with the San Juanillo, but whether this was one of them or not could not be told. Hoping that it might be, a signal was erected at the end of the picket and the party turned their steps homeward. Mr. Leutze hung up his blue flannel shirt upon the signal, to make it more conspicuous. They reached the camp some time after dark, some of the number so exhausted that it was feared they would not be able to reach it at all. The day had been intensely hot, the breeze being entirely cut off by the dense vegetation. Myriads of insects filled the air; the yellow congo and the mosquitoes seemed unusually vicious. The fifteen miles of tramping, wading, climbing hills, scrambling over fallen trees and through the jungle would have been a severe day's work alone, without the additional labor of cutting and road-building.

The limits of this report make it impossible to give anything like a detailed account of the labors of the different parties or of individual officers, but the above will give an idea of them, though candor compels me to say that the last day here described never had quite an equal; indeed a very few such would have broken down the strongest of our people. Throughout the expedition the officers not only directed but led the work, no matter how hard or disagreeable it might be, and were most cheerfully followed by the petty officers and seamen. Especially deserving of mention were Messrs. John Quevedo, Charles H. Mays, Paul Hoffmann, John Buck, Joseph C. Bruner, and Henry Butz, who enlisted, with petty officers' ratings, to do duty in the expedition as rod-men, pole-men, and chain-men, and exhibited great zeal and intelligence in the performance of their duties.

A couple of days after the events above narrated, Messrs. Leutze and Crowell went to Greytown, where they procured the services of an excellent guide, well acquainted with the Juanillo lagoons, and who, from their description, recognized the lagoon which they had found as the Silico, named from the silico palm which grows upon its borders; to this he guided them. The route led up the San Juanillo for about four miles, then through a small creek and into the lakelet; here, to their joy, the signal was found. A great many fallen trees, branches, &c., had to be cut away before even a canoe could be forced through the creek. They now selected a place for a camp and returned to Greytown. A couple of days later they had brought the party around, established themselves in their new camp, and set to work to run the instruments and chain over the trail which had been cut, as described. First, however, several reconnaissances were made to see if the seven hills could be avoided without too great deflection. It was found that they could not be, and the line was accepted as it had been originally run.

May 13, Colonel Sonnenstern and myself went in the Kansas to Monkey Point, examining carefully the intermediate coast for harbors, or locations where harbors might be formed, making, with the aid of Commander Reed and his officers, surveys of the angles in the shore-line at Punta Gorda and at Monkey Point to see if either of these could be utilized; both, however, proved hopeless for the character of harbor required for a canal terminus. The country between Greytown and Monkey Point was very broken, except the alluvial formation which extends only a little over one-half of the distance. Colonel Sonnenstern, who, in 1866, had passed over the route between San Miguelito, on the lake, and the mouth of the Rama River, had declared the country to be utterly impracticable even for a railroad, which was then projected; but, although having every confidence in the opinion of that gentleman, I thought it better to make such a personal reconnaissance in that direction as would fulfill the instructions of the Navy Department.*

By May 22 all the parties had arrived in Greytown—the work in the interior complete. The weather for the last month had been magnificent, and more had been accomplished than during the previous two months. On the 20th the weather changed entirely, bringing heavy and frequent showers.

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* See maps, Plates 17 and 18.

Several of the officers and men who had held out to the last day of the work, now that the strain was relieved, were attacked with fever. Mr. Rhoades was among the number. None of the cases were at all serious, and all were mainly due, probably, to overwork, and to sharp wettings during the last two or three days on the line.

There now remained only some hydrographic work to be done to supplement a survey of the harbor made the previous year, and to get the steam-launch down from the lake, the low stage of the water in the river not having permitted it before. The hydrographic work was entrusted to Mr. Hawley, who was assisted by Mr. Bull. As it was hoped that there might have been a rise, or soon would be, a small party under Mr. Leutze, accompanied by Mr. Browne, was sent after the launch. Colonel Sonnenstern, Dr. Bransford, and myself, went up the river at the same time to attend to other matters, part of which was to pay off at Castillo the soldiers who had served as macheteros, and also to deliver and pay for the use of some canoes which had been employed by the expedition.

In getting the launch over Toro Rapids she was unfortunately grounded in about the worst part of it, involving two days' labor for all hands in the water. We even had the doctor overboard up to his neck; although this was not exactly in his department, the doctor was always ready for hard work when it could be made useful. The cultivation which Mr. Leutze and Mr. Browne had each given to his muscle worked greatly to our advantage also. Our friend, Mr. Hollenbeck, finally came to our rescue, after we had, with only partial success, exhausted our own means. Coming by in the steamer Panaloya, he tied her up to the bank, took our line to his capstan, and, after two or three hours' work, succeeded in getting the boat off. He then piloted her safely over the rapids through a channel known to himself.

At Castillo Mr. Leutze rigged sheers and hoisted out the launch's boiler, Colonel Sandoval, with his soldiers, manning the falls of the tackle. Everything else was removed from the boat that could be, but as she still drew some 4 feet, it was found impossible to get her over the rapids. No rise as yet had taken place, though considerable rain had fallen. Mr. Hollenbeck promised to send the boat down the river by some of his people as soon as there was a sufficient rise. We therefore left her in charge of a watchman, and returned to Greytown. On our arrival I found awaiting us orders from the Department, directing me to send a number of the officers home by mail steamer, and the remainder of the expedition by the Kansas. The former arrived in New York July 3, and the Kansas, with her party, July 20. I am happy to say that not an officer or man was lost from any cause.

The work was constantly checked as much as possible. So long a traverse required extreme care to prevent its swinging out more or less. As has been said, this work was immediately intrusted to Messrs. Greene and Crowell, in the topographic parties, and to Mr. Miller, in the hydrographic. Offsets were frequently run from the main line to the river-bank, and were connected by Mr. Miller with his traverse. These gentlemen also sketched in the topography.

The levels from the lake to the sea, an aggregate distance of one hundred and nineteen miles, were run by three different officers, viz, Lieut. J. F. Moser and Master J. B. Briggs, on the main line, with intermediate sections by Lieutenant Miller, upon the river-banks. These, compared with the line on the Pacific side, showed the height of the lake to be absolutely the same above mean tide of either sea. When the character of the ground passed over is considered, this coincidence seems quite remarkable, and shows with what extreme care the work was executed.

Too much cannot be said in praise of Lieutenants Rhoades, Leutze, and Miller, the commanders of parties, for the intelligence, judgment, and zeal with which they performed their multifarious and often perplexing duties. Lieutenant Miller speaks in the highest terms of his assistants, Messrs. Niles, Bull, and Browne.

Mr. McCrea, commander's clerk, volunteered for the duty of rodman, and continued to perform it until taken down with fever.

Dr. Bransford, in addition to treating the sick in the most successful manner, was indefatigable in collecting specimens of plants, animals, insects, &c., and in acquiring a knowledge of the peculiar diseases of the country, and in determining what differences of treatment were necessary in the case of the natives and of foreigners, for this purpose treating gratuitously all who applied to him. His report will doubtless be very interesting to medical men.

Mr. A. G. Menocal, the chief civil engineer, by his thorough knowledge of his profession and

his constant personal exertions, as much as possible accompanying that party who, for the time being, were operating in the most difficult section of country, contributed enormously to the success of the expedition. Indeed, with so able and zealous a set of officers, there was but little left for the commanding officer to do except to keep the parties in supplies, and failure was impossible. I beg to add that these remarks are not made, as so often is the case, for the sake of saying something agreeable, but as giving expression to a conviction which was of great comfort to me during the progress of the work. As I could not be with each of the parties all the time, it was very pleasant to know that the work went on quite as well when I was not present as when I was, and possibly better.

The journals of the several parties, herewith given, will present a better idea of the detailed operations than I have been able to do in this brief account.

THE PROPOSED CANAL AND IMPROVEMENTS.

The surface of Lake Nicaragua is 107 feet above mean tide in either sea. It is proposed to make this the summit-level of the canal, and to connect the lake with the Pacific by canal, and with the Caribbean Sea by a combination of canal and slack-water navigation.

WESTERN DIVISION.

The first section of the proposed canal, from the lake to the Pacific, leaves the lake at the mouth of the Rio del Medio, and extends for a distance of 7.58 miles, with an average depth of cutting of 54 feet. This section is by far the most expensive part of the whole work. The second section extends from the end of the first to Brito, a distance of 8.75 miles, making the total distance from lake to sea 16.33 miles. The line has been laid down as nearly as possible to correspond to the lowest profile. It consists, however, of straight reaches and of curves which are arcs of circles. The smallest radius admitted is 2,200 feet. The excavation in the second section will be, throughout, less than the prism of the canal; in other words, the proposed surface is higher than the profile of the ground. The material taken out will be used to build up embankments. There will be ten descending locks, all in this section, and located in the straight reaches. There will be at Brito a tide-lock, to admit ships at any stage of the tide. The locks will have a lift of 10.31 feet each; the tide-lock, 9 feet.

The line of the proposed canal follows the immediate valley of the Rio del Medio for a distance of 4.8 miles, when the brook is taken into the canal by means of a cess-pool; thence it continues across the divide through Hatfield's Pass, a depression forming a transverse valley some 2,000 feet wide, the culminating point of the line being at a distance of 5.84 miles from the lake. At a distance of 7.76 miles from the lake the surface of the ground falls to the level of the lake. The brook Chacolata is received into the canal at a point 4,300 feet from the summit. At a distance of 8.33 miles from Brito the line intersects the Lajas line, and coincides with it for the rest of the distance, with several improvements of the route as laid down by Childs, however. Three very small streams and one brook, the Tola, are intersected by the line, and it is proposed to pass all of them by culverts under the bed of the canal into the Rio Grande, their beds being sufficiently below the proposed bed of the canal to admit of its being done.

In three different places the line crosses short bends of the Rio Grande, and new channels are made for the latter. At La Flor, about three miles from Brito, the canal, for a short distance, will occupy the bed of the river, which is again diverted into a new channel.

Throughout the distance the canal, while having ample place of deposit for the material removed, is the ultimate drainage of a very limited portion of territory.

It happens that the section requiring the deep excavation is located in the best cultivated part of the country and where there are most roads. A little exercise of judgment on the part of the person directing the work will enable him to get rid of the most of his material even there, without carrying it any great distance. The crest of the divide is but a few yards wide, and the descent is quite rapid on either side. By commencing the work at different elevations turnouts will be found near at hand.

LAKE NAVIGATION.

From the mouth of the Rio del Medio to Fort San Carlos, at the head of the San Juan, the distance is fifty-six statute miles. Twenty-six feet of water can be carried to within 1,200 feet of the mouth of the Del Medio. Some under-water blasting will have to be done to deepen the channel to the entrance of the canal.

On the east side a channel will have to be deepened by dredging, for a distance of about seven miles, a mean depth of about 8 feet. The bottom is a firm mud, with no rock. As the water is always perfectly smooth on this side of the lake, a dredge can work every day of the year. The material may be deposited immediately abreast of where it is taken out, only taking care to remove it far enough to prevent its washing back into the channel.

EASTERN DIVISION.

SLACK-WATER NAVIGATION.

It is believed, for reasons which have already been given, that slack-water navigation in the upper part of the San Juan is entirely practicable.

It is proposed to improve the river by the construction of four dams, the first at Castillo, the second at Balas, the third at Machuca, and the fourth near the mouth of the San Carlos. Most excellent locations for dams exist and have been selected at the first three places, with solid rock foundations, shallow water, and a wide channel-way in proportion to the general width of the river, thus subjecting the dams to the minimum risk from the force of the water. The location at San Carlos would be called good, except in comparison with the others, which are exceedingly favorable. It has a solid bed of gravel at the bottom, which it is believed overlies a ledge of rock; but as we had no means of ascertaining this point, the estimate has been made for bearing piles to support the dam. Should it be found that there is rock, the cost will be much less than the estimate.

Dam No. 1, at Castillo, will be 940 feet long and 21 feet high, raising the water in front 18.87 feet.

Dam No. 2, at Balas, will be 1,196 feet long, and 31.92 feet high from the bottom of the river. The water will be raised in front 22.82 feet above present mean height.

Dam No. 3, at Machuca, will be 824 feet long, 33.99 feet high from the bottom, and will raise the water in front 26.84 feet.

Dam No. 4, a short distance below the present mouth of the San Carlos, will be 1,000 feet long, and 30.97 feet high from the bottom, raising the water in front 23.87 feet.

The fall of water over each of the first three dams will be but 10.28 feet, in consequence of the water's being backed up in each case by the dam next below. Dam No. 4 will have a fall of 23.87 feet. Mr. Menocal has designed in this case an apron to receive the fall, and prevent its cutting under the foundation. (See Plate No. 9.)

In order to get around the dams, there will be required sections of canal of the following lengths, respectively, each containing one lock of 10.28 feet lift, viz: at Castillo, 0.78 mile; at Balas, 1.57 miles; and at Machuca, 1.16 miles.

The channel of the river will require some deepening from the outlet of the lake to the foot of Toro, about 5 feet on the average, and also for short distances between dams Nos. 1 and 2, and Nos. 2 and 3. This will be mainly accomplished by dredging, though there will be required some under-water rock-blasting, all of which will be found estimated for. Below dam No. 3 we come to the Agua Muerta, which will have a depth of from 40 to 80 feet.

It is proposed to divert the channel of the San Carlos, so that its waters shall be received into the main river below the proposed dam. The conformation of the ground admits of this.

CANAL.

From the mouth of the San Carlos to Greytown, a canal of 41.9 miles in length is proposed. This line has been laid down to correspond with the lowest profile, except when the increase of

length required to make it do so was too great to be compensated for by the diminution in the depth of excavation. The curves, as in the western division, are all arcs of circles. The least radius is 2,500 feet. The profile is so favorable that 36.96 miles out of the 41.90 will require excavation less than the prism of the canal, the material being used for embankments. The remaining distance is made up of several short reaches, where the line cuts through hills. The line follows the general course of the river, cutting off bends wherever the conformation of the ground will permit, until it arrives at the head of the San Juanillo; from there to Greytown Harbor it makes nearly a straight course.

Seven locks, in addition to those abreast the dams, will be required, making ten in all. These will be located in the hills just mentioned, in order to render available the rock foundation, the advantage of which will be enormous. The last two locks will be placed together, and will drop the canal to the sea-level, just as it enters the Silico Lagoon; from there to Greytown it will only be necessary to dredge out a channel, without even providing for embankments. The seven locks will have each a lift of 10.87 feet.

The total length of canal will thus be 61.74 miles; of this, 47.37 miles will be in excavation and embankment combined, leaving but 14.37 miles in which the excavation is greater than the prism of the canal. Six and fifty-hundredths miles of the deep cutting is in one section, *i. e.*, in the first of the western division; the rest is composed of the cuts through hills and parts of the sections around the dams. In all cases on the east side there will be convenient places of deposit close at hand for the material taken out; where embankments are made, the whole of the material removed will be placed directly abreast the place from which it is taken.

The eminent American engineer, Mr. J. C. Trautwine, estimates that where excavation costs 19 cents per cubic yard when deposited within 25 feet, it will, if carried one mile in carts, cost 57.09 cents; and if carried two miles, will cost 95.57 cents per cubic yard. This exhibit of the rapid rate of increase in cost will show how immense is the advantage in a work of such magnitude of having the place of deposit so close at hand.

In comparing the relative merits of any two proposed routes for a canal, nothing can be less satisfactory than the mere statement of their relative lengths, without also stating the average depth of excavation; thus, were the sides vertical, then would a canal ten miles long, with an average depth of 40 feet, be equal to one twenty miles long, with a depth of but 20 feet; but in fact, the banks must always have an outward slope, in order to be self-sustaining; the least slope admissible in canals of the character here considered is in earth 1½ feet to 1, or, as both sides are the same, the cross-section widens 3 feet for every 1 foot of increased depth. The canal here estimated for has an average depth of cutting of but 9 feet above the prism, or the proposed water-surface; the 61.74 miles are equal to but twenty-two miles of one whose average depth above the water-surface is 40 feet.

It will be seen that prisms of two different widths are estimated for. The reduced is proposed for those portions which require deep cutting, and, except that the proposed depth of water is one foot greater, does not differ materially from the dimensions proposed for the Darien Canal. The broader is proposed for all the rest of the canal, *i. e.*, for those portions where excavation and embankment are to be used. The difference in the shape of the prism for earth and for rock is due to the different slopes required.

DIMENSIONS OF CANAL PRISM.

Reduced.

	In rock.	In earth.
Width at bottom	60 feet.	50 feet.
Width 10 feet above bottom	90 feet.	
Width at surface of water	106 feet.	128 feet.

Broad.

	Earth.
Width at bottom	72 feet.
Width at surface of water	150 feet.
Width 10 feet above surface	180 feet.

The depth of water throughout is 26 feet.

The dimensions of the locks are: length between miter-sills, 400 feet; width of chamber, 70 feet.

HARBORS.

ARTIFICIAL HARBOR AT BRITO.

On the right bank of the Rio Grande there is a high rocky hill, which juts out into the sea in the form of a promontory for a distance of 1,600 feet. The sides are steep-to. There are near the outer extremity 18 feet of water at low tide close alongside the rocks.

The left bank of the river terminates in a sandy beach, bearing to the south-southwest. An angle is thus formed in the coast, which we propose to convert into a harbor, by running a breakwater from the end of the point in a southwest direction for a distance of 1,200 feet. The outer end will be in 6 fathoms of water. The rock can be blasted right at hand and dumped into the sea, being allowed to take its own slope. The bottom is firm sand, but no doubt overlies a bed of rock, judging from the formation of the coast. The deep water extends to within 200 feet of the beach, where some dredging will have to be done.

A second jettee, from the beach on the left of the entrance, to project out 500 feet, is also estimated for, to prevent shifting sands from choking the mouth of the harbor. It is then proposed to dredge out a basin of 67 acres area, and to divert the mouth of the Rio Grande, allowing it to empty a short distance farther to the southward.

RESTORATION OF HARBOR AT GREYTOWN.

A commodious and excellent harbor once existed at Greytown. The strip of sand which formed its outer limits has now extended across what was the entrance, and has converted the harbor into a lagoon. This has been gradually silting up, until there are islands where twenty years ago there was water enough to float a frigate.

The silt which has been destroying the harbor is a volcanic sand, so light as to be held in almost complete suspension by rapidly flowing water; it is the material of which the whole delta of the San Juan has been mainly formed, and, indeed, the entire alluvial district in the vicinity.

A quantity of sand taken from the outer beach at Punta Arenas (as it is still called) was recently submitted, with some from the sea-beach at Monkey Point, thirty-two miles north of Greytown, to Professor Henry, of the Smithsonian Institution. Under his direction the two specimens were examined and compared by Dr. Endlich, the mineralogist of the institution. As will be seen, they were found to be quite different in composition and structure, showing clearly that the sand from Punta Arenas was not thrown up by the sea, but deposited by the river.

The constituents and peculiarities are as follows, viz:

No. 18.

Sand from Punta Arenas.

Constituents:
- Quartz, a small quantity.
- Tourmaline.
- 10 per cent. magnetic sand.
- Feldspar, small percentage.
- Hornblende, probably.

Color, dark grayish-brown.
Grains fine, but coarser than No. 19.
No fragments of shell in this specimen.

No. 19.

Sand from Monkey Point.

Constituents:
- Quartz, chiefly.
- Tourmaline.
- 3 per cent. magnetic sand.
- Feldspar, small quantity.
- Fragments of marine shells.

Color, light grayish-brown.
Grains very fine.
This sand has evidently been subject to the action of water longer than No. 18.

The question is, can the harbor of Greytown be restored?

The first idea which seems to present itself to every mind as a solution to this problem is, that if the water of the Colorado be turned into the Lower San Juan by a dam placed across the head of the former, this will scour out the harbor and keep open its entrance.

Before we had fully examined the subject this idea was very generally shared by the officers of the expedition. Its utter impracticability soon demonstrated itself.

For several years the Lower San Juan has been filling up and the Colorado widening and deep-

ening. Just below the forks the former is now, at the lowest stage of the water, but 324 feet wide and 6 inches deep; the latter is 1,200 feet wide and 10 feet deep. Its banks and bottom are of the silt already described. It is doubtful whether it would be possible to dam the Colorado at all; but if it could be done, the water would be more apt to cut around or under the structure than to make for itself a channel through the Lower San Juan.

A committee of the National Academy of Sciences in 1867 proposed, as a partial remedy for the decay of the river and harbor, the dredging out of the channel of the Lower San Juan and the construction of a weir from Leaf's Island to Concepcion Island. The latter of these is in the main river, near its right bank, and above the forks. The former has now become joined to the angle or point of the main-land between the two branches. Concepcion Island is 2,000 feet from the point. The strongest part of the current runs between the two. The island is constantly cutting away at one place and forming at another, being composed entirely of silt banked around drift-logs which have lodged in the shoal water.

The weir, if indeed it could be constructed at all with such a combination of unfavorable conditions, viz, the depth and strength of the water, and the yielding character of the bottom, would be quite as likely to fail in, as to effect, the object in view, *i. e.*, the turning of the current into the Lower San Juan, unless the latter was dredged out to a sufficient width and depth to prevent, by drawing it away, the water from cutting around the dam. This would have to be done for a distance of thirteen miles. I confess myself to have been very much discouraged when these facts and convictions impressed themselves upon my mind.

A thorough examination of the river, made subsequently, showed us that all the silt comes from the San Carlos and other Costa Rican rivers having their confluences lower down. This is the reason why the San Juan, below the mouth of the San Carlos, is filled with shoals and sand-bars. Before this fact had been established, other considerations, already detailed, had forced us to the conclusion that this part of the river could not be used, and that a canal must be built instead.

It is quite clear that, so long as the silt-bearing water is permitted to flow into the harbor, although by adding to the current it may assist in scouring at the entrance, it will certainly deposit in the still places, and indeed all over the broader parts of the harbor. Our plan is therefore to cut off the Lower San Juan, and send all the water of the San Juan and its lower tributaries through the Colorado mouth, admitting to the harbor only the waters which come through the canal and through the San Juanillo, which will be perfectly clean. The harbor will then have to be dredged out to the proper size and depth; after which there will be nothing to again destroy it. A breakwater or jettee is estimated for to protect the entrance from the surf. The narrow strip of bare sand which divides the bay, if bay it may be called, from the sea, now shifts with every strong breeze that blows, and should be made permanent by covering it with mangrove and tough water-grasses and vines. This might require several years for its accomplishment, but could be done with proper care. The planting should be done at the beginning of the rainy season, and those portions that did not take hold should be supplemented the next year, and so on till the work was complete.

The sand would no doubt bank up rapidly against the off-shore side of the jettee out to the present 10 or 12 feet depth, and in course of time might even pass the end of the jettee; but, the supply being cut off, this could not last many years, and one extension of the jettee would, I am confident, be the last trouble experienced from it.

The material dredged from the harbor could all be deposited near at hand, in the shallow portions of the present basin, not one-fifth of whose whole area will ever be required.

A small pier on either side of the entrance to the canal from the harbor is estimated for.

A description of the line of the proposed canal, in much more minute detail, will be found in the accompanying report of the chief civil engineer, Mr. Menocal.

ESTIMATES.

Close computations have been made of the required amount of excavation in rock and in earth and of embankments; of dredging and under-water rock-blasting; of the material and labor neces-

sary for building lift and tide locks and lock-gates, dams, jettees, piers, bridges, light-houses, &c.; and upon these computations careful estimates have been prepared by Mr. Menocal of the whole cost of the work.

In computing the rock-excavation care has been exercised to allow more than is likely to be met, in order to be on the safe side. A complete set of borings, from one end of the line to the other, will be necessary before arriving at the exact amount. Our judgment has been based upon the few borings we were able to make, and upon observations taken in wells, in ravines, river valleys, &c. On the crests of hills we have estimated the earth to overlie the rock about 40 feet; in other places not more than 20 feet. We feel confident that less rock will be found in the actual excavation than has been here assumed to exist.

The prices allowed for the various works we believe to be ample, though there is always, of course, great uncertainty in all such estimates in a country where no similar operations are in progress from which to judge of probable cost. The 10 cents per cubic yard allowed for embankments are for the mere sloping and otherwise shaping the banks, the materials for which are all taken from the excavations immediately abreast of where required. So that, in reality, it amounts to allowing so much more per cubic yard for the excavation itself.

The following is a summary of the estimates, which will be found in detail in the accompanying report of Mr. Menocal, viz:

WESTERN DIVISION.

From the mouth of the Rio del Medio to Brito, a distance of 16.33 miles:

2,915,812 cubic yards excavation in rock, at $1.50	$4,373,718
7,907,812 cubic yards excavation in rock, at $1.25	9,884,765
6,583,788 cubic yards excavation in earth, at 35 cents	2,304,326
2,247,565 cubic yards embankment, at 10 cents	224,757
Locks Nos. 1 to 8, inclusive, at $391,699 each	3,133,592
Lock No. 9	413,236
Lock No. 10	410,990
Tide-lock at Brito	421,306
Diverting the channel of the Rio Grande in five places	179,024
Culvert to pass the Rio Tola	87,725
Culverts for passing three small streams	51,281
Cesspools for receiving Rio del Medio and Rio Chocolata into canal	18,957
3 swinging bridges	60,000
Side-drains at foot of embankment	35,200
819 acres clearing and grubbing, at $100	81,900
Total, western division	21,680,777

MIDDLE OR LAKE DIVISION.

From the mouth of the Rio del Medio to Fort San Carlos, distance 56 miles:

West side:	
78,428 cubic yards excavation in gravel under water, at $2	$156,858
10,807 cubic yards excavation in rock under water, at $5	54,035
East side:	
2,523,827 cubic yards dredging in mud, at 20 cents	504,765
Total, middle division	715,658

EASTERN DIVISION.

From Fort San Carlos, at the lake, to Greytown: slack-water navigation, 63.02; inland canal, 45.41 = 108.43 miles:

Improvement of river for slack-water navigation.

Dam No. 1, at Castillo Viejo	$260,696
Dam No. 2, at Balas	341,871
Dam No. 3, at Machuca	347,142
Dam No. 4, at San Carlos River	593,824
2,253,680 cubic yards dredging in mud and gravel, at 40 cents	901,470
834,912 cubic yards rock-excavation under water, at $5	4,174,560

Inland canal.

2,165,872 cubic yards excavation in rock, at $1.25	$2,707,340
1,445,981 cubic yards excavation in rock, at $1.50	2,168,971
25,910,009 cubic yards excavation in earth, at 35 cents	9,068,503
5,015,064 cubic yards embankment, at 10 cents	501,506
157,600 cubic yards excavation, earth, in side drains, at 25 cents	49,400
12 cesspools, for receiving small streams into canal	96,000
13 culverts, for passing small streams under canal	195,000
Diverting mouth of river San Carlos to point below dam No. 4	283,578
10 lift-locks, complete	3,093,160
2,379 acres clearing and grubbing, at $100	237,900
Total, eastern division	25,020,914

HARBORS.

Artificial harbor at Brito.

2,835,185 cubic yards excavation and dredging, at 35 cents	$992,315
Breakwaters	1,150,672
Piers	164,752
Light-house	30,000
Total	2,337,739

Improvement of harbor at Greytown.

4,080,100 cubic yards dredging in sand, at 30 cents	$1,224,030
Crib-work and breakwater	1,258,600
Closing Lower San Juan River	100,000
Piers at entrance of canal	200,000
Light-house	40,000
Total	2,822,630

RECAPITULATION.

Western division	$21,680,777
Lake division	715,658
Eastern division	25,020,914
Harbor at Brito	2,337,739
Harbor at Greytown	2,822,630
Total	52,577,718
Add 25 per cent. for contingencies	13,144,429
Grand total	65,722,137

Rock, lime, sand, and clays needed for construction are to be had in great abundance. It is proposed to use concrete mainly in place of dimension-stone in the construction of locks, dams, &c. Material for this can be had immediately at hand in almost every case.

RECAPITULATION OF DISTANCES.

Canal.

	Miles.
Mouth of Rio del Medio to Brito	16.33
Around dam at Castillo	0.78
Around dam at Balas	1.57
Around dam at Machuca	1.16
From mouth of San Carlos River to Greytown	41.90
Total canal	61.74
Lake navigation	56.00

Slack-water navigation.

	Miles.
Fort San Carlos to Castillo	37.00
From foot of canal at Castillo to canal at Balas	6.39
From foot of canal at Balas to canal at Machuca	4.06
From foot of canal at Machuca to canal at mouth of San Carlos	15.57
Total slack-water navigation	63.02
Total distance from Brito to Greytown	180.76

DESIGN FOR LIFT-LOCKS.

Mr. Menocal has made a most admirable design for a lift-lock. (Shown in Plate XII.) As feeding a lock of so large dimensions in the ordinary manner, through the upper gates, and with the rapidity necessary, would cause an ugly commotion in the water, Mr. Menocal proposes to lay parallel to the side-wall on either side a 60-inch pipe, communicating by three ports, one at the head, one in the middle, and one at the foot, with the lock-chamber, and on a level with the floor of the same. Valve-gates at the head and foot of these pipes cut off or admit the water from the reach above, and retain or allow the discharge of the water into the reach below, respectively. Thus, by closing the lower valves and opening the upper, the water from above enters the lock-chamber through the ports, until the surface reaches the level of that in the reach above. By closing the upper valves and opening the lower, the water passes out of the ports, through the pipes, and into the reach below, till the surface has fallen to the level of that of the latter. It is computed that the locks may be filled or emptied in from 15 to 17 minutes.

THE LAJAS ROUTE.

It will be observed that no estimate has been given for a canal from the lake to the Pacific by the Lajas route. This line is regarded as bearing no comparison with that by the Rio del Medio, for the following reasons: First, the distance is greater by 1.49 miles; second, the valleys of the Rio de las Lajas and of the Rio Grande, above the point where it is entered by the Medio line, are exceedingly narrow and tortuous. The banks of the Rio Grande are from 50 to 70 feet high, steep and rocky. The bends are too sharp to admit of locating curves of sufficient radius for a ship-canal, even if the valley were wide enough to contain the canal, which it is not. The Rio Grande, which is at times a powerful torrent, would have to be taken into the canal, or else a new channel must be provided for it; the latter could only be done at very large expense. In addition to the Rio Grande, two other considerable streams, the Guscoyol and the Espinal, besides eight smaller ones, would have to be taken into the canal, generally, under very unfavorable conditions. The line of the canal thus becomes the ultimate drain of a large extent of country, a feature very undesirable anywhere, but particularly so in the tropics. It will be remembered that in the Medio route but two streams, and they quite small, are met under such conditions as to make it necessary to receive them into the canal. Neither of these is subject to freshets of any moment. Their waters will never more than compensate for waste, filtration, evaporation, &c.

Although the amount of excavation in the Lajas route might be somewhat less than in the one chosen, the percentage of rock would be vastly greater. We believe that a simple inspection of the two lines would convince any engineer that they are not to be compared with each other, either in regard to the probable original cost or the subsequent permanence of the proposed work.

WATER-SUPPLY.

Lake Nicaragua has a surface area of two thousand seven hundred square miles, and drains a territory of not less than eight thousand square miles. It would therefore seem unnecessary to consider the question of water-supply, except to show that it has not been forgotten.

Careful gauges of the San Juan River at numerous points were taken by Lieutenant Miller and party, using a delicate current-meter for the purpose. The least water found, and at about the lowest stage, was 11,390 cubic feet per second, or 984,096,000 cubic feet per day. Against this supply we have the following as the maximum demand: Allowing forty lockages a day, or, counting the ascending and descending, say eighty per day, without deducting the displacement of the vessels, which in descending we have the right to do, we have—

	Cubic feet.
Eighty lockages per day	2,240,000
Allowing 1,000 per cent. for leakage, filtration, waste, and evaporation	22,400,000
Total demand	24,640,000
Total supply	984,096,000
Excess of supply over demand	959,456,000

Or, to put it in another form, there is a supply equal to thirty-eight times the maximum possible demand.

CLIMATE, HEALTH, ETC.

The year in Nicaragua, as in the rest of the Isthmus, is divided into two seasons, the wet and the dry; the latter begins about the end of November and lasts until May or June, when the rains begin, and continue with more or less force during the remaining months of the year.

Unlike the more southerly portions of the Isthmus, the rains here begin earlier and last longer near the Atlantic coast than in the interior. The annual rain-fall differs in different parts of the country, and in the same part differs for different years. No regular system of meteorological observations, continuing from year to year, has ever been maintained, as far as I have been able to ascertain. The present expedition found at Virgin Bay an aggregate fall of 47.79 inches from July 1, 1872, to March 1, 1873. As this period included the whole of the wet season, the result probably does not differ very widely from the average annual rain-fall in that section. In the valley of the San Juan it is probably twice as great. This will, of course, be greatly modified in the event of extensive clearing at any future time.

In the following tables are compared the results obtained by Childs in 1851 with those of observations continued for the eight months above referred to, by the present expedition. Childs' observations were taken at Rivas from September 7 to March 11, and afterward in the valley of the San Juan. We have therefore only six corresponding months' observations taken in the same locality; these, though giving different results for individual months, aggregate nearly the same:

[*Table exhibiting in inches the rain-fall in Nicaragua from September* 7, 1850, *to September* 25, 1851.

Day of month.	Sept., 1850.	Oct., 1850.	Nov., 1850.	Dec., 1850.	Jan., 1851.	Feb., 1851.	Mar., 1851.	April, 1851.	May, 1851.	June, 1851.	July, 1851.	Aug., 1851.	Sept., 1851.
1	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.110	.030	.....
2	.....	.130	.....	.....	.....	.....	.....	.....	.....	.....	.020	.090	2.710
3	.....	2.720	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	4.710
4	.....	.030	.....	.....	.190	.....	.....	.....	.....	.460	.600	.960	.....
5	.....	.290	.240	.....	.....	.....	.....	.....	.....	.920	1.950	1.320	.640
6	.....	.210	.....	.....	.....	.....	.....	.....	.....	.....	.490	.770	.....
7	.....	.....	.310	.600	.....	.....	.....	.....	.....	.350	.720	.....	.160
8	.....	.....	.....	1.270	.....	.....	.....	.....	.....	.....	.700	.....	.....
9	.....	.....	.....	.010	.....	.....	.....	.250	.....	.730	.....	1.260	.300
10	.010	.....	.....	.....	.....	.....	.....	.....	.....	.660	1.230	1.510	.....
11	.....	.....	.....	.270	.....	.....	.....	.....	.660	.060	2.650	.540	.....
12	.440	1.300	.020	.....	.....	.....	.....	.....	.660	.240	.270	.630	1.110
13	.060	.090	.....	.....	.....	.....	.....	.....	.....	.....	.070	.040	.....
14	.750	1.900	.....	.490	.....	.....	.....	.....	.130	1.380	.290	.....	.....
15	.....	2.230	.....	.....	.....	.....	.....	.....	.....	1.820	.580	.490	.....
16	.260	2.790	.....	.....	.....	.....	.....	.....	.040	.160	.780	.640	.....
17	.260	.290	.....	.....	.....	.....	.....	.....	.840	.....	.....	.....	.....
18	.310	1.150	.....	.350	.....	.....	.....	.....	.140	.....	.190	.050	.470
19	1.030	.040	.180	.....	.....	.....	.....	.....	.....	.350	.520	.....	1.720
20	.090	.140	.....	.....	.....	.....	.....	.....	.920	.....	.....	.530	.....
21	.930	.010	.....	.....	.190	.....	.120	.....	.270	.990	1.340	.....	.....
22	.290	.....	.....	.....	.....	.....	.....	.....	3.030	.....	.....	.240	.270
23	.190	.....	.....	.....	.....	.....	.....	.....	.120	.710	.....	.....	.080
24	.....	1.740	.....	.....	.....	.....	.550	.....	.....	.....	.....	1.010	.....
25	.....	.....	.....	.080	.....	.....	.....	.....	.....	.090	.450	.....	.070
26	.....	2.040	.....	.140	.....	.....	.....	.....	.760	.100	5.920	.500	.....
27	.230	.....	.045	.....	.....	.....	.470	.....	.425	.830	.410	.610	.....
28	.170	.....	.....	.....	.....	.....	.....	.....	.500	2.770	.....	.090	.....
29	1.600	.070	.600	.....	.....	.....	.....	.....	.130	.300	2.290	.500	.....
30	.385	.690	.....	.....	.....	.....	.....	.180	.270	1.390	.510	.....	.....
31	.....	.....	.....	.....	.....	.....	.....	.....	.250	.....	.520	.....	.....
	7.005	17.860	1.395	3.210	.380	.....	1.410	.430	9.145	14.210	22.640	11.810	13.240

Total ..... 101.735 inches.

Table exhibiting in inches the rain-fall in Nicaragua from July 1, 1872, *to March* 1, 1873.

Day of month.	July, 1872.	Aug., 1872.	Sept., 1872.	Oct., 1872.	Nov., 1872.	Dec., 1872.	Jan., 1873.	Feb., 1873.
1	.....	1.30	.60	3.01	.24	.81	.....	.03
2	.25	.20	1.00	.12	.....	.....	.....	.02
3	.....	.40	.60	.....	.....	.....	.....	.02
4	.....	.....	.60	3.73	.01	.....	.....	.02
5	.....	.....	1.00	.83	.15	.07	.....	.04
6	.15	.60	.10	.....	4.07	.11	.....	.....
7	.20	.10	.....	.....	.16	.....	.....	.02
8	.....	.30	.....	.....	.24	.....	.02	.....
9	.....	.....	.....	.....	.....	.05	.....	.....
10	.20	.10	.....	.....	.....	.....	.....	.....
11	.15	.....	.10	.03	.34	.19	.....	.02
12	.10	.10	2.10	.....	.07	.....	.10	.....
13	.25	.30	.60	.....	.03	.....	.03	.....
14	.....	.20	3.10	.65	.....	.....	.....	.....
15	.....	1.50	.....	.....	.....	.21	.....	.03
16	.....	.50	.10	.35	.12	.....	.....	.....
17	.35	.10	.....	.....	.....	.....	.....	.....
18	.10	.50	.....	.....	.....	.....	.03	.....
19	.40	.40	.10	.06	.06	.....	.....	.02
20	.30	.70	.....	.24	.36	.....	.....	.....
21	.25	.....	.....	.06	1.02	.....	.....	.....
22	.10	.....	.....	.35	.52	.....	.....	.....
23	1.30	.....	.30	.....	.19	.....	.....	.....
24	.10	.....	.10	.56	.....	.....	.....	.04
25	.10	.30	.....	.....	.03	.....	.....	.....
26	.50	.....	.....	.30	.35	.....	.....	.....
27	.....	.20	.10	.64	.....	.....	.05	.....
28	.....	.70	.....	.10	.21	.....	.....	.02
29	.....	.20	.10	.40	.48	.....	.08	.....
30	.....	.10	.40	.20	.13	.....	.04	.....
31	.10	.10	.....	.46	.....	.....	.05	.....
	4.90	8.90	11.00	12.09	8.78	1.44	0.40	0.28

Total..... 47.79 inches.

Nicaragua lies wholly within the trade-wind belt, and during the dry season, when the trades "blow home," the climate is certainly delightful. In the vicinity of Rivas the thermometer seldom stands higher than 82° Fahrenheit in the shade at midday; at night it often falls to 68°. In the valley of the San Juan it is somewhat warmer, but even there one can rarely sleep comfortably at night without a woolen blanket. During the rainy season, though the trades are often interrupted for a few days at a time, yet even then they are the prevailing winds. It is safe to say that the trades blow for ten months in the year.

There is a very general impression abroad that the whole American Isthmus is exceedingly unhealthy, and this, as I conceive, very incorrect idea is entertained by many intelligent persons who have spent longer or shorter periods upon the Isthmus. It is true that in former years a large percentage of foreigners who remained there for any length of time died or were broken down in health, but nine out of ten of these cases were due to dissipation, or to the neglect of the simplest sanitary precautions, or generally to both. Dissipation will certainly kill much more surely and quickly in the tropics than in a temperate climate, and to just that extent and no more was the climate responsible for these cases. There have been, during the last four years, three exploring expeditions in Darien and two in Nicaragua. There have been as high as three hundred men employed at once, counting ships' companies, subjected to severe labor and exposure. Not a single officer or man has been lost from climatic disease. Under Providence, I ascribe this entire immunity from death and serious disease partly to the following of a few sanitary rules, which anybody

may do without inconvenience, but mainly to the strictly temperate lives led by officers and men (some voluntarily and some perforce) while operating upon the isthmus.

The percentage of deaths due to climatic causes alone, I am fully convinced, is smaller than in any other part of the world.

The prevailing diseases are few in number, simple in character, and generally yield most readily to treatment, unless the patient's blood is vitiated by alcohol.

Cleanliness, temperance in eating and drinking, sleeping under shelter and in dry clothing, wearing flannel next the skin at all times, avoiding heavy night-dews, and avoiding bathing immediately after meals or while much heated, are all the precautions necessary to preserve health; and with these any foreigner will be as safe upon the isthmus as anywhere else.

That a large amount of excavation, while in progress, might increase the tendency to malarial fevers is very probable, but, as the treatment of those fevers is now understood, I see no reason to fear increased mortality.

INHABITANTS, PRODUCTS, ETC.

The population of Nicaragua is variously estimated at from 250,000 to 300,000, and consists of whites, Indians, and negroes, and of mixed bloods in all degrees. Many of the Indians are civilized, and among their number are some of the worthiest citizens of the state. There are several tribes, however, in as savage a state as when the country was first discovered. These occupy the northeastern part of the territory.

The state is politically divided into departments. Of these the departments of Rivas, Granada, and Leon, bordering upon the Pacific, contain the bulk of the population and wealth.

The most numerous class of the inhabitants is formed by the Ladinos,* a mixture of white and Indian. Next to these, probably, are the pure Indians. The least numerous of all are the whites.

The laboring classes, both among the civilized Indians and the mixed races, are honest, docile, hardy, and not averse to hard work when occasion requires it, but so few are their natural wants, (they have no artificial ones,) and so easily supplied, that they generally have no need of it. I estimate that, in the event of the construction of a canal, Nicaragua and the neighboring states would supply from 3,000 to 5,000 laborers; but this is very difficult to get at with any degree of accuracy, particularly in view of the probability that many new industries would be developed, each with its demand for operatives. Agriculture and grazing especially would receive an immense impetus.

The average wages of farm-hands and other out-door laborers, at the present time, is $16 per month, and the cost of subsistence at the present rate is $6 per month.

Nicaragua is full of undeveloped sources of wealth; some of these have been experimented with in a limited degree, but nothing to a beginning of its full capacity. Coffee, indigo, cacao, and sugar are raised, and the amount of each is increasing yearly. The first three of these, with hides, India rubber, and furniture-woods, form the principal articles of export of the country. The machinery used in the manufacture of sugar is of the rudest sort, and the quality produced is very inferior, though the cane is so rich that, with proper means, the very best in the world might be rivaled. Very recently, at least three estates have been supplied with modern machinery of European manufacture, and this is no doubt but the beginning of many similar improvements.

Numerous large cattle-estates exist in the country, some containing as high as five thousand head. The animals are generally very ill cared for, are allowed to roam in the woods, and to pick up their subsistence as best they can. The dense shade of the forests prevents the grass from growing, so that browsing is their main resort. But very little milk is obtained, and even on the largest estates is rarely to be had in the evening. A coarse cheese is made from the milk. I have never heard of native butter.

The cattle are rather small, and seldom dress more than 200 pounds of beef when killed, and much more often not more than 125 pounds. In first-rate condition the same animals should yield from 400 to 500 pounds. Within a few years the system of forming pastures by clearing off the land and leaving only trees enough for shade has been introduced. The advantages of the system

* This word is used in a different sense in other parts of Spanish America.

are so apparent, that it is growing into very general favor. A rich grass springs up, upon which the cattle fatten wonderfully. Large herds of cattle are driven from time to time to Costa Rica, where there is at present considerable demand for them.

In the event of the construction of a canal, not only could an unlimited supply of beeves be furnished by exercising proper care in raising and fattening them, but an enormous source of wealth would be opened to those who own or should establish estates for the purpose.

SUBSISTENCE.

Nicaragua is capable of producing all the subsistence required by the operatives in the event of the canal's being built. In addition to those products already mentioned, are raised Indian corn, rice, beans, yams, cassava-root, quiquisque, (a superior sort of yam,) plantains, bananas, tomatoes, oranges, limes, pine-apples, cocoa-nuts, mangoes, watermelons, cantaloupes, jocotes, (a species of plum,) nisperas, and numerous other fruits and vegetables. In the valley of the San Juan, below the mouth of the Serepiqui, the delicious bread-fruit flourishes, but thus far it has been found impossible to raise it in the interior. In the highlands, in the northern parts of the State, wheat and potatoes are raised, the latter of excellent quality.

Many of these articles yield two crops per annum; others yield perpetually. All the essential articles being among the rapidly-maturing kinds, the quantity of each could be increased indefinitely, particularly as there is so much unoccupied land available in the most accessible and otherwise favorable localities.

Among the domestic food-animals and birds there are, besides beeves, sheep, hogs, goats, turkeys, ducks, common fowl, &c. The forests abound in game, among which are deer, wild hogs, tapirs, wild turkeys, pajuiles, (*Crax globicera*,) wild ducks, rabbits, squirrels, monkeys, pigeons, guatusas, armadilloes, iguanas, &c. The manatee is found in the rivers and lagoons, and its flesh is highly esteemed as an article of food.

Numerous varieties of fish inhabit the rivers and adjacent seas, and fine turtle are taken upon the coasts.

Most domestic animals, as I have already said of beeves, are allowed to raise themselves. The quality of all could be much improved, and the quantity increased, by bestowing upon them some little care; not nearly so much, however, as is needed in northern climates.

Pasturage is available throughout the year, while no housing of animals is needed, except thatched sheds during the rainy season, to protect them from the rains. Materials for thatch are to be had for the gathering almost anywhere. Fowls find ample food from the insect-life, and only need protection from wild animals.

There are a great many horses and mules in the country, the former mere ponies; but the latter, though not large, are strong, hardy beasts. Horses are trained to the saddle almost entirely; mules either as saddle or pack animals. Pretty much all draughting is done by oxen; the ox-yoke is always lashed to the animal's horns.

The common food of the people consists of rice, beans, plantains, cheese, chocolate or coffee, eggs, any meat which is available, and the *tortilla;* this last is made of Indian corn, boiled with wood-ashes to remove the hulls, and afterward ground by hand upon a concave stone, for which operation another stone, shaped like a common rolling-pin, is used. The corn is kept moistened while the grinding is in progress, and when it is sufficiently reduced is patted into a sort of flat cake and laid into a shallow earthen bowl, over a brisk fire, to bake.

It is said that Walker, during his occupation of the country, introduced mills to grind and bolt corn, thinking he was conferring a boon upon the people by saving the tedious labor of grinding by hand; but the ordinary process had too strong a hold upon their affections, and the prepared article never became popular.

The above is a very full bill of fare, for among the laboring classes rarely are more than two or three of these articles found at a time, and not unfrequently the plantain alone furnishes what they regard as a perfectly satisfactory meal, if they have to provide it themselves. Let not him who hires any of them, however, expect to solve the problem of subsistence in any such simple manner.

In the event of the construction of a canal, the extensive cultivation of the plantain would be a measure of great importance; it is very nutritious, as well as palatable; is an excellent antiscorbutic, and takes the place of both bread and potatoes. It is eaten either boiled or fried when ripe, and in the green stage roasted, when it has a taste not unlike coarse corn-bread.

OTHER SOURCES OF WEALTH.

Cotton has been raised to some extent, but thus far it has not been very profitable; it is, however, among the undeveloped riches of the country, to be called out with the influx of population and increased facilities of transportation.

Tobacco, said to be of excellent quality, can be raised in any part of the country; but being a government monopoly, its cultivation is restricted. Judging from the amounts raised surreptitiously, however, it seems altogether probable that the removal of the legal impediments would soon place tobacco among the leading products of the state.

India rubber, or caoutchouc, is extensively gathered and exported, and is inexhaustible in quantity. The rubber hunters, unlike those of Darien, who always cut down the tree when they find it, thus getting a little more for that occasion, but, of course destroying the future supply, are satisfied to tap the tree, whose locality they mark, returning to it six months later to find it ready to yield again. The milk is caught in large tin-pans, and is then coagulated with the sap of a peculiar vine which grows everywhere. The rubber produced is much cleaner than any I have seen in other portions of the Isthmus.

Gutta-percha is found in the department of San Juan, and in some other localities. The natives have not yet learned the secret of preparing it, so that it is gathered in very limited quantities.

Ivory-nuts, now becoming a not inconsiderable article of commerce, are found in Nicaragua, as well as in all parts of the Isthmus.

Numerous valuable furniture and dye-woods abound in the country, some of which are exported. Notably among the former are rosewood, mahogany, moran, and the rich cedar. The last, although easily worked, takes a polish equal to that of mahogany. Among the dye-woods are Brazil-wood, moran, fustic, and others.

A very great variety of medicinal trees and plants exist in Nicaragua, but, like many others of their possessions, little or no use is made of them by the people, who import from abroad medicines and drugs which they might easily obtain within their own national limits.

A very handsome little collection of specimens of the most important cabinet and construction woods was prepared under direction of Mr. Runnels, of Virgin Bay, and presented by him to the expedition, with the following list, naming the uses and the dimensions of timber which can be obtained from the different varieties, viz:

No. 1. "Mahogany, (*Swietenia mahogani*, L.*) Three to 4 feet in diameter; generally straight; reaches an altitude of from 20 to 40 feet; good for construction of buildings or for furniture."

No. 2. "Cedar, (*Cedreda odorata*, L.) Dimensions and uses the same as No. 1."

No. 3. "Moran, (*Morus tinctoria.*) Twelve to 18 inches in diameter; 15 to 20 feet long; very durable either in earth or water."

This is both a furniture and a dye-wood, and very beautiful.—E. P. L.

No. 4. "Guachipilin. Dimensions and properties of No. 3."

This wood is particularly well adapted to use as railroad ties.—E. P. L.

No. 5. "Nispera, (*Hymænea courbaril*, L.) Of the diameter and properties of Nos. 3 and 4, but reaching a height of 50 feet."

Lévy says of this wood that it is excessively tough and heavy; in cabinet-work it rivals mahogany; in the water it lasts indefinitely, and acquires the hardness of iron. In Chontales, not only is the quantity of nisperas enormous, but the tree is noted for its height and for the straightness of its trunk.—E. P. L.

No. 6. "Jenisero, (*Pithecolobium lamon.*) Five to 6 feet in diameter; 20 to 30 feet in length;

* The Latin names are interpolated, and are given on the authority of Mr. P. Lévy, who has recently published an elaborate work on the geography of Nicaragua. E. Denné Schnitz: *Paris*, 1873.—E. P. L.

good for construction of buildings and for cabinet-work. Its actual use in the country is for cart-wheels."

The dimensions, particularly the length, of this tree are often much greater than above given. The "jenisero of Nagarote," of which mention has been made, is at least 7 feet in diameter and over 90 feet high.—E. P. L.

No. 7. "Laurel hembra. Twelve to 16 inches in diameter, and from 25 to 30 feet long; good for construction of houses and carriages."

No. 8. "Laurel macho. Dimensions the same as those of No. 7, but the wood much more tough."

No. 9. "Roble, (*Tecoma mexicana*, Mast.) Eighteen to 20 inches in diameter, and from 35 to 40 feet long; good for house-building."

This wood is also recommended for wagons and for barrel and cask staves.—E. P. L.

No. 10. "Rosewood. Good for house construction, cabinet-work, and for machinery."

No. 11. "Cortes, or iron-wood. Dimensions of No. 10; good for wagons and machinery."

No. 12. "Guayacan, or lignum-vitæ. From 10 to 12 inches in diameter, and from 12 to 15 feet long; its uses are well known."

No. 13. "Ronron. Dimensions of No. 12. A cabinet-wood."

No. 14. "Grenadillo. From 5 to 8 inches in diameter, and from 10 to 12 feet in length; used for small furniture, and particularly for turner-work."

There are many other woods, not mentioned in the above list, valuable for various purposes. Among these may be mentioned madera-negra, an exceedingly hard and tough wood, extremely durable either in wet or dry places; unfortunately, however, not attaining very great dimensions, not often exceeding 8 inches in diameter; the espanel, said to be impervious to the *Teredo-navalis*; the sapote-mico, which attains great altitude, and is often from 40 to 50 inches in diameter; guapinol; pichote, a species of cedar; guanacaste; ceiba; madroña; jicara, and many others. The guapinol produces a gum said to be equal to the copal of Ceylon. The jicara, or palo de Melon, produces a fair, though small, knee for ship-building.

There are many plants whose fibers are valuable; among these are cotton, pita, piñuela, tule-palm, and cocoa-nuts. Hats, cordage, hammocks, and some other articles are made from these with rude appliances.

MINERAL WEALTH.

Gold and silver are found in paying quantities. The richest mines now being operated are in the department of Chontales, on the east side of the lake. This region has been so little explored as to make it altogether improbable that a tithe of its mineral wealth has been discovered.

CONCLUSION.

An interoceanic ship-canal across the American isthmus, or through Central America, has been a subject of discussion for three hundred and seventy-five years, among statesmen, navigators, geographers, and merchants. Its desirability has been often proved by able pens. The enormous saving of distance, time, cost, and risk, which it would give to the world, has been carefully tabulated. There seems to be nothing left to show, therefore, but its feasibility; this, I believe, the information herewith forwarded amply does.

The whole region has been very carefully explored, and I am fully persuaded that nowhere is there so favorable a combination of advantageous conditions as in the line through Nicaragua. As has already been stated, the line actually located by the present expedition may be improved upon by a more exhaustive survey; but it is hardly possible that it can be found less favorable than here represented.

I have the honor to be, sir, your most obedient servant,

EDWARD P. LULL,
Commander, Commanding Nicaragua Surveying Expedition.

Hon. GEO. M. ROBESON,
Secretary of the Navy, Washington, D. C.

NOTE.—The following officers and others have been engaged in office-work, viz:

Plotting.—Mr. A. G. Menocal, chief civil engineer; Mr. George M. Greene, passed assistant engineer, U. S. N.; Lieut. Jacob W. Miller, U. S. N.; Mr. J. Foster Crowell, civil engineer.

Reducing.—Mr. A. G. Menocal, Mr. George M. Greene, Mr. J. Foster Crowell.

Computations.—Mr. A. G. Menocal, civil engineer; Lieut. Jacob W. Miller, U. S. N.; Lieut. Jefferson F. Moser, U. S. N.; Mr. J. Foster Crowell, civil engineer.

Draughting.—Mr. A. G. Menocal, civil engineer; Mr. George M. Greene, U. S. N.; Lieut. Jacob W. Miller, U. S. N.; Mr. A. Pohlers, draughtsman; Mr. J. B. Philp, draughtsman.

WASHINGTON, D. C., *June* 8, 1874.

SIR: The following reports and papers are respectfully forwarded, viz:

1. Report of the chief civil engineer.
2. Journal of Lieut. E. H. C. Leutze, in charge of party No. 1.
3. Journal of Lieut. W. W. Rhoades, in charge of party No. 2.
4. Journal of Lieut. Jacob W. Miller, in charge of hydrographic party.
5. Report of Midshipman John D. Keeler, hydrographic work in Lake Nicaragua.
6. Report upon health, climate, &c., by Dr. J. F. Bransford, U. S. N.
7. Extract of proceedings of the Philadelphia Academy of Natural Sciences. Classified lists of Dr. Bransford's collections.
8. Report by Dr. F. M. Endlich upon lithological and geognostic specimens collected in Nicaragua.
9. Report of Commander A. V. Reed; six months' observations on weather, &c., off Greytown.
10. Report of Commander A. V. Reed; attempts to blast out rock in channel of the San Juan.
11. Memoir by Prof. J. E. Nourse, U. S. N. Interoceanic communication through the Great Isthmus.
12. Index of maps, &c.
13. Maps, &c., as per index.

Very respectfully, your obedient servant,

EDWARD P. LULL,
Commander.

Hon. GEO. M. ROBESON,
Secretary of the Navy, Washington, D. C.

REPORT OF A. G. MENOCAL, CHIEF CIVIL ENGINEER, WITH ESTIMATES OF COST OF PROPOSED CANAL AND OTHER IMPROVEMENTS.

WASHINGTON, D. C., *December* 18, 1874.

SIR: I respectfully submit the following report of the results obtained by the surveys made in the state of Nicaragua, by the expedition under your command, with the object of locating a favorable route for the construction of a ship-canal across the Isthmus, from the Atlantic to the Pacific Ocean, and also an estimate of the cost of the work.

Your familiarity with the lines surveyed will render unnecessary any particular description from me, further than such as may be requisite to define the most prominent features of the results obtained in the operations and the plan adopted for the construction of the canal upon the selected route.

The Lake of Nicaragua occupies an area of about one hundred and ten miles long by thirty-five miles wide of a valley extending northwesterly from the Bay of Fonseca, on the northern boundary of the state of Nicaragua with that of Honduras, to its southern limits with Costa Rica. From its southeastern end the river San Juan, the only outlet to the lake, runs through an irregular valley to the Atlantic. Its closest proximity to the Atlantic is near the southern extremity, where Fort San Carlos, at the origin of the outlet, is by straight line sixty-five miles from the coast and seventy-six miles from the harbor of San Juan del Norte, or Greytown, the mouth of the river San Juan. Its nearest proximity to the Pacific is about the middle of the department of Rivas and opposite to the island of Ometepet, where the western coast of the lake is by straight line ten miles from the harbor of San Juan del Sur.

From this description and an inspection of the map it will be perceived that the lake is a necessary and, we may add, a favorable element in any project for a ship-canal across the country. The first on account of its position; the second because of its moderate elevation above the sea affording an extensive summit-level, a saving of distance in the actual canal to be built, and an inexhaustible supply of water for the working of both branches of the canal, starting from its shores to the Atlantic and Pacific. The first object of the expedition under your command was, therefore, to look for a favorable route upon which a line could be located from the lake to the Pacific and to the Atlantic afterward. This could be accomplished either by proceeding northwesterly from the Lake of Nicaragua up the estero of Panaloya to Lake Managua, and from the northern extremity of the latter lake across the valley of Leon to the Gulf of Fonseca, the port of Realejo, or some other point on the Pacific coast; or by cutting across the department of Rivas from the Lake of Nicaragua to some point on the Pacific, and by following the river San Juan as far as could be made navigable, and thence by an artificial canal to the Atlantic.

To facilitate the description and estimates the work has been divided into three divisions: Western, middle or lake, and eastern; the first extending from the lake to the Pacific, the second comprising the lake navigation, and the third that portion east of the lake.

WESTERN DIVISION.

Proceeding north from Costa Rica there are several transverse valleys across the Cordillera, which here has a moderate elevation, leading from the lake to the Pacific; and to their examination the efforts of Commander Chester Hatfield, commanding the surveying expedition of 1872, were first directed.

The most southerly of these depressions is that through which runs the river Sapoa, extending from the mouth of this stream, at the lake, to the summit, and thence to the bay of Salinas, on the Pacific. A compass and level line was carried from the lake to the summit and a reconnaissance without instruments extended to the bay, and the results obtained were so unsatisfactory that the

line was at once abandoned as impracticable. The culminating point of the pass was found to be about 900 feet above the lake or 1,000 feet above the Pacific, requiring at least 1,600 feet of lockage to overcome this elevation above the lake, as the depth of cutting required to extend the level of the lake to the Pacific slope would be too formidable and a tunnel of the necessary dimensions to meet the traffic of the canal altogether too expensive. A large reservoir would also have to be constructed at the summit to feed this branch of the canal, with so limited a water-shed that the supply obtained would be entirely insufficient for the demand. The length of the line would be about twenty-four miles; and lastly, an extensive excavation in rock, under water, would be necessary in the Bay of Salinas to reach the desired depth for the proposed canal.

The next pass where promising features invited an examination is that leading from the mouth of the river Lajas, at the lake, about a mile and a half north of Virgin Bay, along the valley of this stream to the estate San Pablo, the creek Guscoyol, down the tortuous and narrow valley of the Rio Grande, and across the more extensive plane of Tola to the harbor of Brito. This line had been surveyed by Colonel Childs in 1851, and the results obtained by him agree in the main with those established by the expedition under Commander Hatfield. The survey was commenced at the mouth of the river Lajas and carried by the most favorable points to the harbor of Brito, giving a total length for the line of 18.52 miles, an extreme elevation of the natural surface of the ground of 49.28 feet above the surface of the lake as it stood in May 2, 1872, and a total fall from mean high lake to high water at Brito of 103.14 feet and 107.63 feet to mean tide.

In leaving the lake the line occupies the charnel of the river Lajas to the estate San Pablo, 1.54 miles from the lake, where the stream turns to the left, and is proposed to be diverted by means of an embankment and artificial channel about two miles long, and made to discharge into the lake about one mile south of its present mouth. After leaving San Pablo the line crosses a plane of moderate elevation, and at about two and one-fourth miles from its origin falls into the valley of the Guscoyol, a tributary of the Lajas, proceeding from the summit, and which, with its numerous tributaries, will have to be taken into the canal, following the valley of the stream, and intersecting it at many points, to the summit. This point lies in a valley from one and one-half to two miles wide, 43.78 feet above high lake, and nearly horizontal in a direction perpendicular to the line. Immediately after crossing the divide the line falls into and pursues the ravine Cruz, which, as it descends at the rate of 9 feet to the mile, soon acquires large dimensions, when the line leaves it, and, after crossing a moderately broken country, at 6.87 miles from the lake, intersects the brook Espinal, coming from the north, and which has already received the ravine Cruz, much enlarged after diverging from the line. This brook becomes a torrent in the rainy season, and a receiving-weir would have to be constructed to take it into the canal. Some 2,000 feet after crossing the Espinal the line meets the Rio Grande. This river rises in and drains a large area of the eastern side of the Cordillera, and, descending with a rapid inclination and receiving in its way many precipitous gulleys coming from the high mountains, it crosses the ridge by a narrow, tortuous, and precipitous valley, confined by high spurs and rocky bluffs, which alternately approach it from both sides. There being no room in the valley for the creek and canal, the latter would have to take in the waters and occupy the channel of the former. A ship-canal of the dimensions proposed for the one under consideration could not, however, follow the sinuous course of this stream. Easier curves would have to be located cutting across the rapid bends, and in so doing, although a minimum radius consistent with the work be adopted, the line would have to intersect some of these high spurs and bluffs, producing deeper cuttings than would be required in crossing the divide or summit of the water-shed of the line located, and with but little or no room to deposit the waste materials resulting from the excavations without having it washed back into the canal by the gulleys, and the main portion of it would probably have to be hauled to the more extensive valleys east and west of the ridge. This cañon would have to be followed by the canal for a distance of one and a half miles. At its western end the line leaves the stream and runs over an undulating ground near the estate Las Serdas, and thence along the valley of the Rio Grande and across the plains of Tola and Brito, of gradual inclination and firm soil, to the harbor.

A reconnaissance made by the surveying expedition of 1872 from the mouth of a small stream called Rio del Medio, emptying into the lake three miles north of the Lajas, to a pass in the divide

at the estate Los Horcones, about six miles from the shore of the lake and four miles southwest of the city of Rivas, and connecting with the Lajas line, previously surveyed, at the place where the plane of the surface of high lake, if continued, would intersect the Pacific slope, gave promising results of obtaining a shorter, more direct, and less tortuous line, avoiding the necessity of admitting into the canal the streams Guscoyol, Espinal, and Rio Grande; and, although the culminating point of the new line was found to be higher than that of the water-shed of the Lajas, no deep excavations, as those encountered in the valley of the Rio Grande, would be met with; and, at any rate, the difference in length between the lines, and the simplicity and permanence, after construction, of the Rio del Medio route, offered advantages that could not be overlooked.

Under these favorable impressions and according to your instructions this line was carefully located and leveled from the lake to Brito, introducing convenient modifications in the Lajas line below the point of intersection, giving a total length of 16.33 miles from the shore of the lake to the entrance of the harbor. The brook Del Medio is a small stream, which has its origin in the dividing ridge, and after running about two miles in a southerly direction, at the estate Jesus Maria it turns to the east, and in a distance of 4.80 miles reaches the lake. The line located follows the general direction of the valley of the brook, of moderate inclination, confined by two continuous ranges of hills of variable elevations, limiting the water-shed of the stream to a very small area, but of sufficient width at every point to admit the canal and the material resulting from the excavations. At 3,080 feet from the lake the surface of the ground is 10 feet above mean high lake; it rises 10 additional in the next 4,000 feet, whence it gradually rises, with some undulations, as the line occupies the center of the valley or one of its slopes, to the estate Jesus Maria, 4.80 miles from the lake, where an elevation of 108 feet is attained. The brook here turns to the north, and is proposed to be taken into the canal by means of a cesspool, and the line, following its westerly direction, pursues the depression of a small stream coming from the culminating point of the line in the pass, 5.84 miles from the lake and 134 feet above the proposed level of the water in the summit-level of the canal. This pass is a valley about 2,000 feet wide, confined by high hills, and nearly level in a direction perpendicular to the line, and with but little rise and fall in 1,000 feet on the line each side of the summit. From this point the ground rapidly falls; at a distance of 4,300 feet the line meets the small ravine Chocolata, which is proposed to be taken into the canal; at 1.92 miles, or 7.76 from the lake, it falls to the plane of high lake, and at a farther distance of eight miles intersects the Lajas line, both coinciding thence to Brito, a distance of 8.33 miles. Along this latter distance the line runs through the most favorable places as to direction and elevation of the ground, and to obtain a better location it cuts across three sharp bends of the Rio Grande, and new channels are proposed for the stream, as shown on the maps. The difference of level between mean high lake and high water at Brito is 103.14 feet, and this elevation is proposed to be overcome by ten locks, each 400 feet long, 70 feet wide, and 10.31 lift. A tide-lock of 9 feet lift is also required at the entrance of the harbor, that vessels may get in or out of the canal at any state of the tide. Lock No. 1 is located at the end of the summit-level, 2,500 feet below the point of intersection with the Lajas line. From there to Brito the line runs on an inclined plane, with a fall of about 9 feet to the mile, and the surface of the water in the canal is at every point above that of the ground, and the amount of material obtained from the excavations will be but little in excess of that required for the embankments. The remaining locks are located wherever the surface of the water in the canal reaches an elevation above the ground equal to what has been adopted for the maximum height for the embankments. They will rest on a firm and dry foundation, except the last two and the tide-lock, which will probably have to be supported by piles. The different reaches of the canal comprised between locks could be drained into the Rio Grande; the last two only partially. At La Flor, a small estate about three miles from Brito, a high spur, projecting from the range of hills confining the valley of Tola, comes to the bank of the Rio Grande, and to avoid this deep cutting the canal is proposed to occupy a short distance of the channel of the stream, and this to be diverted by means of an embankment and a new channel across a sharp bend of low land. After leaving the river the line falls into and traverses the valley of Brito, of the same formation and inclination as that of Tola. From Las Serdas to Brito the line intersects three small streams, and the Rio Tola, a tributary of the Rio Grande, coming from the north. These are proposed to be passed under the canal into the Rio Grande;

the first three by small culverts and the Tola by a culvert with five arches of four feet radius, capable of discharging the greatest flow with an accumulation of less than 3 feet of water above the crown of the arches. A drain is also proposed at the foot of the embankments, to drain the country bordering the lower portion of the canal into the harbor. The average depth of cutting in the first 7.50 miles from the lake, which is the most expensive part of the whole line, is 54 feet above the water in the canal, and in the total distance of 16.33 miles to Brito 30 feet above the same plane.

From a point on this line last surveyed a line of levels was carried to another marked depression called Buena Vista, about five miles north of Rivas and west of the road leading from that village to Granada. Its elevation was found to be 186 feet above the lake. The survey was extended along the valley-line of the pass and down the valley of the Chacalapa to near its intersection with that of Tola. A line located upon this route, from the lake across this depression and the valleys of Talolinga, Chacalapa, and Tola, to the harbor of Brito, would be about twenty miles in length.

The valley of the river Gil Gonzales, some five miles north of Buena Vista, was next, by your orders, examined from its mouth, at the lake, up the base of the divide, 6.50 miles from and 119 above the lake. The most favorable pass leading from this plane to the Pacific was found to be about 430 feet above the lake, and, carrying us to the valley of the Chacalapa and connecting with the last line surveyed, reaches the port of Brito with a distance of about twenty-four miles.

As we proceed north from the Gil Gonzales the shores of the lake and Pacific diverge from each other; the Cordillera, running between them, becomes more continuous and uninterrupted and nearer to the latter coast, and the valley, extending along the western shore of the lake, increasing in width and rising with an inclination of about 10 feet to the mile, reaches the base of the divide with considerable elevation, diminishing the possibility of finding a favorable route from the lake to the Pacific.

A report had been in circulation, however, as to the merits of a line extending from the mouth of the river Ochomogo, on the shore of the lake, to some point on the Pacific coast. A compass and level line was carried along the valley of that stream for a distance of about ten miles, reaching at this point an elevation of 87.50 feet on the bottom and 107 feet on the banks of the river above the lake. A reconnaissance, made from this point toward the Pacific, proved that the only interruption in the ridge through which the line could be extended across to the Pacific was about two miles southwest from the estate San Marcos, at the head of the brook Güegüe, and about sixteen miles from and 225 feet above the lake. An examination was made of the Pacific slope for a distance of five miles along the ravine Tobillo, emptying into the river San Ygnacio, whose valley the line would follow to the bay of Albina, giving a total length of about twenty-eight or thirty miles from the lake to the Pacific. These unfavorable features, together with the considerable amount of rock that would have to be encountered in almost all the distance examined, proved the unfitness of the line as a practicable route for the canal; and all further investigation was, according to your instructions, abandoned in this locality.

There remained now only one more route to be examined, viz, that leading from Lake Nicaragua up the estero of Panaloya to Lake Managua, and from some point on the northern extremity of this latter lake across the valley of Leon to the bay of Fonseca, the port of Realejo, or some other point on the Pacific coast. As you bore a prominent part on this reconnaissance, and the results obtained are familiar to you, I will omit all details. The enormous amount of dredging required in both lakes and in the estero to obtain the requisite depth of 26 feet; the increase of 45 feet of lockage necessary to overcome the difference of level between the two lakes, amounting to 22.50 feet; and the uncertainty as to the possibility of keeping Lake Managua at the elevation required, owing to its limited water-shed and the changes its elevation has undergone during a recent period, particularly if we take into consideration the porous nature and the consequent absorbing power of the volcanic formation of the valley of Leon, together with the difficulties to be overcome in canalizing the estero from Pasquiel to Lake Managua, and the formidable amount of cutting, with an extreme depth of 119 feet above the water, from this lake to the Pacific, a distance of about twenty-two miles by the shortest line to Tamarindita and forty-two miles to Realejo, were

sufficient considerations to discontinue any further operations in this direction and abandon the line as impracticable, at least when compared with the more favorable ones surveyed in the department of Rivas.

On our return to Virgin Bay, a reconnaissance was made from that place to the harbor of San Juan del Sur, the close proximity of the shores of the lake and Pacific at these points suggesting the possibility of finding a line upon which the difference in length, as compared with others surveyed, might compensate with advantage for a greater elevation at the summit. The results obtained, however, did not correspond to the expectations, as the length of the line would be about 14.50 miles, and the elevation of the summit 605 feet above the Pacific, and so near to it that some difficulty would be experienced in the location of the locks in so short and steep a slope.

On due consideration of the results obtained by these operations it will be perceived that the two lines affording the most favorable features and greatest advantages are those connecting the mouths of the rivers Lajas and Del Medio, at the lake, with the harbor of Brito, and that it is from these two that the selection is to be made. An inspection of the maps and the description of the lines heretofore given will at once show that the Rio del Medio route possesses many advantages over that of the Lajas, and that the selection between the two is an easy task. From the point of intersection, at Las Serdas, to Brito, they coincide, and from one and the same line; therefore it is from that point to the lake that they should be compared to each other to establish their relative merits as a canal-route. Along that distance the Lajas line is 1.49 miles longer than the Medio, and although the culminating point of the former, as shown by the profiles, is 90 feet lower than that of the latter, it has been already said that it is along the narrow valley of the Rio Grande where the deepest cuttings will take place, and which, it is feared, will not be any less than those encountered on the Rio del Medio. Along that same distance three large streams—the Guscoyol, the Espinal, and the Rio Grande—and eight smaller ones are taken into the canal by the Lajas, while only two small ones—Del Medio and Chocolata—are taken in by the Del Medio route. Any stream, no matter how small, not required as a feeder, is always more or less injurious to a work of this kind, and those under consideration are particularly so, as they run only at the precise time of the year when the supply for the canal is most in excess. In the dry season what little water runs through them percolates through the sand and gravel deposited on their beds, and is only visible where the rocky bottom is uncovered or in occasional pools along the channels. On some particular occasions in the wet season they become, generally for a short time, precipitous torrents; and from the inclinations of their beds and the high-water marks observed on the banks their amount of flow has been estimated at 4,500 and 6,200 cubic feet per second, respectively, for the Espinal and Rio Grande. The easier curves and the great facilities existing along the Rio del Medio route for the deposit of the waste materials, and which the other line does not possess, are also points of the highest consideration. By the Lajas line deep water in the lake is reached at 2,900 feet from the shore, while by the other route the same depth is attained at 1,200 feet, the quality of the bottom being the same in both. We therefore consider the Rio del Medio route as the most advantageous of the two under consideration, even should its cost be the greatest.

MIDDLE DIVISION.

The middle division comprises the lake navigation a distance of about 56.50 miles, extending from the entrance to the canal, at the mouth of the river Del Medio, to San Carlos, at the origin of the San Juan River, the outlet to the lake. In front of the mouth of the river Del Medio, on the western side of the lake, 26 feet depth of water is reached at 1,200 feet from the shore, and along that distance an excavation, mostly in rock, under water, will be required to obtain the necessary depth. Opposite to San Carlos there is a mud deposit on the bottom of, and extending some seven miles into, the lake, which it will be necessary to remove by dredging to the mean depth of 10 feet. From the end of this mud deposit to the excavation at the western entrance there is a depth in the lake varying from 26 to 132 feet, and no improvements are required along that distance.

EASTERN DIVISION.

The eastern division extends from San Carlos, at the lake, to the harbor of San Juan del Norte, or Greytown. It is 108.43 miles in length, 63.02 miles in slack-water navigation by the river San

Juan, and 45.41 miles of inland canal. The San Juan is proposed to be made navigable by four dams, to be located severally at Castillo, Balas, and foot of Machuca Rapids, and the fourth about a mile below the confluence of the river San Carlos, and short canals around these dams, with a lock 10.28 feet lift in each. The first dam at Castillo, 37.34 miles by the river from the lake, is 940 feet long and 21 feet high; it is located nearly at right angles to the direction of the river, and rests on a rock foundation at a mean depth of 5 feet below the surface of the water in the river. It abuts on the right side against a steep, rocky hill, and on the left against an isolated, conical hill, conveniently situated for the purpose, leaving a sufficiently wide and favorable valley between the end of the dam and the main high land to the left for the location of the short canal 0.78 mile long. The river San Juan, at the time the survey was made, was found to descend 3.71 feet from the lake to the head of Toro Rapids, a distance of 26.89 miles, 7.41 feet in a further distance of 2.58 miles to the foot of the rapids, and 3.82 feet thence to the head of Castillo Rapids, at the site of the dam. By means of this dam the surface of the lake is proposed to be kept at the elevation of 107.62 feet above mean high tide, which it attains and preserves during the rainy season, and raise the water in the river 18.38 feet in front of the dam, 16.46 feet at the foot, and 9.05 feet at the head of Toro Rapids. At Castillo the surface of the river falls 4.66 feet in a distance of 0.78 mile, and from the foot of these rapids to the head of Mico Rapids 5.08 feet in 5.69 miles, and 4.66 additional feet to the location of dam No. 2, at Balas. By this dam the water is raised 22.82 feet in front of it, 17.84 feet at the head of Mico, 13.52 feet at the foot of canal around dam No. 1 at Castillo, and 10.73 feet immediately below the latter dam. Dam No. 2, at Balas, is 1,196 feet in length, and is located nearly perpendicular to the stream at the site. It rests on a solid rock foundation, in 7 feet mean depth of water, and on the right side abuts against a precipitous rocky hill, projecting to the edge of the river, and on the left against a favorable elevation 350 feet back from the bank. A canal 1.57 miles in length and a lock of 10.28 feet lift are proposed around this dam. From the foot of this canal to the head of Machuca Rapids the surface of the river falls 4.78 feet, and thence to dam No. 3, at the foot of the rapids, an additional descent of 9.48 feet takes place. This latter dam is 33.99 feet high and 824 feet long, and, as Nos. 1 and 2, it rests on a rocky foundation 6 feet below the surface of the water in the river, and abuts on both sides against steep hills a few feet back from the banks. Immediately in front of the dam the surface of the river is raised 26.84 feet and 17.36 and 12.49 feet, respectively, at the head of Machuca Rapids and foot of canal around Balas. A canal 1.16 miles long and a lock of 10.28 feet lift are designed around this dam. From the end of this canal to dam No. 4, about a mile below the river San Carlos, a large tributary of the San Juan, a fall of 1.34 feet takes place in the surface of the river. This latter dam is 1,000 feet long and 30.91 feet high, and rests in a trench cut 10 feet deep, in a firm bottom, 9 feet below the surface of the water. It abuts at both ends against favorable elevations, about 150 feet from the banks, and is provided with steps and an apron below to prevent the fall of nearly 24 feet, which here takes place, from undermining the foundations. The water in the river in front of the dam is raised 23.87 feet and 22.05 feet at the foot of short canal around Machuca. The following table will show the position and other particulars of dams:

Location of dams.	Distance from lake by river, in miles.	Distance from dam to dam, in miles.	Length of dam, in feet.	Height of dam above bottom of river, in feet.	Height to which the surface of water in the river is raised by dams.		Fall at dam, in feet.	Quantity of flow in cubic feet per second.	Thickness of volume of water on top of dam.	Mean velocity in miles per hour above dam.
					In front.	Below.				
Castillo	37.34	.....	940	21.01	18.87	13.52	10.28	12,453	2.93	0.46
Balas	44.69	7.31	1,196	31.92	22.82	12.54	10.28	12,943	2.56	0.54
Machuca	50.57	5.88	824	33.99	26.84	16.56	10.28	12,943	3.28	0.54
San Carlos	66.81	16.24	1,000	30.97	23.87	0.00	23.87	13,206	2.92	0.49

The river San Carlos, which, like the Serepiqui, another tributary of the San Juan, brings from the mountainous district of Costa Rica an immense amount of silt, which is constantly filling

the San Juan and changing the dimensions and course of its channel, is here diverted by means of an artificial channel, and made to discharge below dam No. 4, preserving only for the use of the canal the clean waters proceeding from the lake. From San Carlos, at the lake, a bar composed of mud and gravel, with occasional ridges of rock and bowlders, extends with but few interruptions to the foot of Toro Rapids, a distance of 29.47 miles, and a channel 80 feet wide at bottom, with slopes of 2 to 1 and mean depth of 5.8 feet, is designed to be excavated by dredging and rock-blasting, to obtain the requisite depth of 26 feet. From the foot of Toro to Castillo Rapids the depth in the river varies from 26 to 40 feet, and no improvement is required along that portion of the river. From the foot of short canal around Costillo dam to entrance of canal around dam No. 2 the river has nearly the required 26 feet depth, and only short excavations, not exceeding at any place 5 feet, will be necessary. At the end of this last canal a bar about 5,000 feet long, with a mean depth of 5 feet, will have to be removed, and thence to Machuca the river, as raised by the dam below, is over 26 feet deep. From canal around Machuca to dam No. 4, below the confluence of the San Carlos, the river, after the proposed improvements, will have a depth varying from 26 to 100 feet.

Below the river San Carlos the San Juan widens considerably as it approaches the Colorado, and its channel is subject to many changes from freshets and the materials brought down by the tributaries San Carlos, Serapiqui, and other smaller streams, proceeding from the high lands of Costa Rica, and the control of its regimen by means of dams or other structures is a problem involved in much uncertainty. The canal is, therefore, taken from the river about 1,500 feet above dam No. 4, and located by the most favorable points along the valley of the river to the head of the Juanillo branch of the San Juan, whence, by an almost straight line traced across the more extensive valley of the Lower San Juan, it reaches Greytown at a distance of 41.90 miles from the point of leaving the San Juan at San Carlos. Out of this latter distance thirty-six miles are in excavations and embankment combined, and the remaining six miles across low hills and short spurs of more or less elevation, projecting to the river from the main range in the interior, giving a general mean depth of cutting of 1.79 feet above the surface of the water in the canal for the total distance of 45.41 miles of inland canal in this division, including short canals around dams. Ten locks, 400 feet long, 70 feet wide, with walls 41 feet high, are proposed in this division; the first three, located in the short canals around dams Nos. 1, 2, and 3, of 10.28 feet lift, and the remaining seven of 10.87 feet lift each, are proposed at the end of the deep cuttings across the spurs, where rock foundations are believed to exist.

From the point where the canal leaves the river to the ravine Quien Sabe, a short distance below the Juanillo branch, twelve cess-pools and thirteen culverts are designed, to receive into the canal or pass under it twenty-five small streams intersecting the line. From Quien Sabe to Greytown the peculiar topography of the country, with the San Juan on one side and the Juanillo on the other, makes unnecessary any work of that kind, a trench at the foot of the embankment being sufficient to drain the canal into the lagoons or either of the rivers on the sides.

DIMENSIONS AND FORM OF THE TRANSVERSE SECTIONS OF THE CANAL.

Three different cross-sections have been adopted for the canal, two for deep cuttings in rock and earth and one for that portion of the line in excavation and embankment combined. The first one, for rock, is 60 feet wide at bottom, and 106 feet at the surface of the water. From the bottom angles the slopes rise with an inclination of 1½ to 1, respectively, of horizontal and vertical distance for the first 10 feet, and thence ½ horizontal to 1 vertical to 10 feet above the water-line, where the prism is 116 feet wide. A recess of 10 feet is here made in each side, and the slopes, with an inclination of 3 inches to the foot, rise to the surface of the rock, where they change to 1½ to 1 to the natural surface of the ground. For deep cutting in earth the proposed width at the bottom is 50 feet, and the slopes rise with an inclination of 1½ to 1. At the surface of the water the trench is 128 feet wide, and 10 feet above this plane 158 feet between the banks. A recess of 15 feet is there made in each side for communication and drains, whence the slopes continue with the same inclination to the surface of the ground. The third cross-section is 72 feet wide at bottom, and with slopes of 1½ to 1 rise to the surface of the ground, and, forming the inner slopes of

the embankment, continue to 5 feet above the water in the canal, where the prism is 165 feet wide. The embankment is 12 feet wide at top, with a descent of one-tenth to the rear, and with the inclination of 2 to 1 falls again to the surface of the ground. (See Plate XVI.)

ROCK.

On the western division the rock at no place approaches the surface of the ground, but on the Lajas line it was visible on the beds and banks of streams from San Pablo to the place where the line leaves the cañon of the Rio Grande, underlying a covering of earth from 4 to 10 feet thick. From the point where the plane of the summit-level prolonged intersects the Pacific slope to Brito the borings made at the site of the locks discovered no rock above the bottom plane of the canal, and none, it is believed, will be encountered in the excavations of this portion of the line. The lock foundations will rest in compact sand and hard clay, except the last three, which it is possible will require bearing-piles to support them. As we proceed north, the rock appears to underlie at greater depth. From the mouth of the Rio del Medio to the summit, at Los Horcones, it was only seen at four or five places, lying in the bottom of the stream at from 15 to 30 feet below the top of the banks, and at no place forming what could be called a continuous and compact mass, but more in the shape of bowlders and dikes. From the summit to the intersection of the lines at Las Serdas none could be discovered in the channels of the streams from 30 to 40 feet deep. It has been assumed in the computations, however, to exist at from 20 to 40 feet below the surface. The rock consists principally of greenstone and graywacke, and a considerable portion of it could be removed without blasting.

At the short canals around the dams at Castillo, Balas, and Machuca the excavations will be in earth at the surface and in rock at the bottom. From the point where the canal is taken from the river to Greytown the general formation of the country is clay loam in the valleys and gravelly clay, with loose stones, on the hills. In the lower valley of the San Juan it is principally coarse sand and sandy loam, with a small portion of clay. Only occasional bowlders and detached stones were visible on the surface of the hills approaching the San Juan River; but in preparing the estimates a large allowance has been made of this material in the excavations for passing these spurs, and the locks, with only two exceptions, (7 and 8,) are supposed to rest on rocky bottom.

SUPPLY OF WATER.

In estimating the amount of water necessary for lockage for both branches of the canal it is assumed that three lockfuls will be required per hour at each lock, or in cubic feet per minute 15,000

The amount lost by leakage, evaporation, and repairs, at the rate of 3 inches per day of the whole surface of the inland canal 8,250

Leakage at two summit-locks 15,000

Total number of cubic feet required per minute 38,250

The lake discharges by the river San Juan, when at its lowest stage, as gauged between Toro and Castillo Rapids, May 2, 1873, by Lieut. J. W. Miller, U. S. N., 747,180 cubic feet per minute, or twenty times the amount here estimated for the canal.

HARBORS.

An artificial harbor is proposed to be made at Brito by means of a breakwater and dredging. The present harbor is formed by a steep and rocky hill, about 250 feet high, projecting in a southerly direction for about 1,200 feet from a sandy beach, lying southeasterly for a distance of two and one-half miles, and ending at another range of hills terminating abruptly on the coast. At the southern extremity of the first hill a small rocky ledge extends into the sea, and ends at 18 feet depth of water at low tide; and from this ledge the breakwater will commence and extend 1,200 feet southeasterly, ending at 30 feet below low tide. A jettee 500 feet long is also proposed, in a southerly direction and nearly perpendicular to the beach, to prevent the shifting of the sand into the harbor, and as a better protection from the swell. The dredging will extend from the break-

water to the tide-lock at the entrance into the canal, and from the jettee to the base of the hill, comprising an area of about sixty-seven acres, which is thought to be sufficient to meet the traffic of the canal, particularly if we take into consideration the proximity to the lake, where vessels can find an ample, safe, and pleasant anchorage; and should an interruption occur in the navigation by the canal, the harbors of Nacascola and San Juan del Sur, from ten to twelve miles to the south, could accommodate a large number of ships with perfect safety. The material to be excavated in the harbor is, so far as could be determined from inspection and borings made at short distance from the line of the coast, compact sand. The Rio Grande, which now empties into the sea at the base of the hill, is proposed to be diverted by means of an artificial channel, and made to discharge some distance to the southeast of the harbor.

The harbor of San Juan del Norte, or Greytown, which until 1850 had a deep channel at its entrance and a deep, spacious, and safe inside basin, has since undergone such changes as to be at present entirely closed, at least at certain times of the year, from all communication with the sea, by the formation of a sand-bar extending across the entrance, and the harbor inside the bar has filled to such an extent that the present depth is at no place over 18 feet. The apparent cause of this change is the shifting of the sand along the beach by the action of the sea striking the coast diagonally in a northeasterly direction. This sand has been brought down by the river San Juan, emptying into the harbor, and is the material forming its delta. The plan proposed by you for the restoration of the harbor to its former condition seems to meet the difficulty and satisfy the desired conditions. It consists in cutting off all communication between the harbor and the river San Juan, by making this stream discharge altogether by its Colorado branch, and to make an artificial harbor by means of a breakwater extending northwest from a point in the mole in front of the harbor, and ending at 35 feet depth of water, and by dredging in sand a channel sufficiently wide and deep to afford an easy entrance, a good anchorage, and thence a safe entrance to the canal.

MATERIALS OF CONSTRUCTION.

From the summit-level in the western division to the harbor of Brito the country is heavily timbered with trees of suitable size and height to furnish timber of the best quality required for the mechanical structures of the canal. Upon both sides of the river San Juan, from Toro Rapids to the Juanillo, the country is also heavily timbered with very durable wood, both above ground and under water. The names of the most suitable woods to be used in the construction of the canal are cedar, madera negra, nispero, guachipilin, tiguilote, mahogany, and genisero.

From the lake to the end of the western summit-level, and in the neighborhood of Brito, stone will be encountered to a great extent, but, as no quarries have been opened, it is difficult to state whether it could be found in masses sufficiently thick to produce dimension-stones. Of these, however, a very limited number will be required, as most of the works are proposed to be of concrete, as the best material adapted for a work of this kind, on account of its simplicity of construction and the monolithic nature of the structure, perfectly suitable to stand shocks and prevent filtration. Basalt and greenstone will be found in the shape of detached stones in sufficient quantities and at convenient places along the line on both sides of the lake, and also at Monkey Point, about forty miles north of Greytown, where high, rocky bluffs project to the edge of the water. On the west side of the lake limestone was found in large quantities, and at several places within three miles from the line of the canal, and at some of the quarries, kilns were in operation producing lime. This lime is extensively used in the country in all wet and dry masonry, and particularly in the construction of indigo-vats, which are generally located by the side of permanent streams, the waters of which are raised, by dams built of the same materials, from 10 to 20 feet high. Some of these we were told had been standing for over one hundred years, and, notwithstanding their exposure to the action of the weather and strong currents and the little or no care taken of them, some of them having been abandoned for many years, they are now in excellent condition. In the town of Masaya we had the opportunity of seeing a water-tank built of common rubble with lime produced from limestones obtained at an extensive quarry near Tipitapa, and, although the dimensions of the walls were not in excess of what would be required if built

with the best hydraulic lime, no leakage could be detected at the outside of the walls, and the mortar had all the hardness that would be required in the work under consideration.

The best clay exists in different parts of the country for the manufacture of bricks, tiles, &c., which, although in a very primitive way, is carried on to a great extent near the large towns. Three brick and tile yards are at present in operation along the Rio del Medio line from the lake to the summit.

ESTIMATE.

In preparing the estimate of the cost of the canal the cubic contents have been computed from the data obtained by the actual survey and from the plans prepared for the different works proposed. The canal has been laid upon the line actually surveyed, except that at a few points changes have been made for short distances where a perfect knowledge of the country on both sides proved that such alterations would not materially affect the final results. And whenever any doubt existed as to the fulfillment of this condition, such allowances have been made as to keep us on the safe side; so that, if the canal should be built upon the line located and the prices accepted as good, the work could be done for the amount given in the estimates, and any alterations introduced on the line proposed by a more detailed survey would necessarily give a difference in favor of the estimated cost of the projected work as herewith given.

It would be difficult to arrive at an exact estimation as to the prices at which the work could be done in the country in which the canal is located, as its sparse population and consequent deficiency of laborers suggest the necessity of relying mainly on the labor of foreigners to perform the work. It is believed, however, that the magnitude and importance of the project, and the favorable conditions of the country as to health, fertility of the soil, abundance and variety of production, and wealth in mines, will enlist the sympathy of all nations, and be an inducement to immigration; and the consequent improvement of the country, as the work progresses, will tend to facilitate the work to such an extent that the increased expense necessary in the preliminary preparations for commencing the work will not increase materially the final cost, as compared with a similar work in this country.

Herewith is appended an estimate of the cost of the proposed canal and of the necessary improvements in the harbors of Brito and Greytown.

Very respectfully, your obedient servant,

A. G. MENOCAL,
Chief Civil Engineer.

Commander E. P. LULL, U. S. N.,
Commanding Nicaraguan Surveying Expedition.

COMPUTATIONS AND ESTIMATES.

Estimate of the cost of constructing a ship-canal from the Atlantic to the Pacific Ocean, across the Isthmus, in the state of Nicaragua, upon the line surveyed by the Nicaraguan Surveying Expedition, as shown on the maps.

The total distance from the harbor of Brito, on the Pacific, to the harbor of Greytown, or San Juan del Norte, upon the Atlantic, is 181.26 statute miles, which may be divided as follows:

INLAND CANAL.

	Miles.
Western division:	
From the mouth of Rio del Medio, at the lake, to the harbor of Brito	16.33
Eastern division:	
Short canal around dam No. 1	0.78
Short canal around dam No. 2	1.57
Short canal around dam No. 3	1.16
From dam No. 4, below San Carlos River, to Greytown	41.90
	61.74

SLACK-WATER NAVIGATION.

	Miles.
From the lake to short canal at Castillo Rapids	37.00
From foot of canal at Castillo to canal at Balas	6.39
From foot of canal at Balas to canal around dam No. 3, at Machuca Rapids	4.06
From foot of canal at Machuca to below San Carlos River	15.57
	63.02
Western and eastern divisions	61.74
Middle division, or lake navigation	56.50
Total miles	181.26

ESTIMATED COST OF WESTERN DIVISION.

From the mouth of Rio del Medio to Brito, 16.33 miles:	
2,915,812 cubic yards excavation in rock, at $1.50	$4,373,718
7,907,812 cubic yards excavation in rock, at $1.25	9,884,765
6,583,788 cubic yards excavation in earth, at 35 cents	2,304,326
2,247,565 cubic yards embankment, at 10 cents	224,757
	16,787,566
Lift-locks.	
24,678 cubic yards excavation in stiff clay, at 40 cents	$9,871
11,030 cubic yards hydraulic concrete in foundations, at $7	77,210
27,543 cubic yards hydraulic concrete in lock-walls, at $8	220,344
213 cubic yards hydraulic concrete in lift-walls, at $8	1,704
70 cubic yards dressed stone in miter-sills, at $18	1,260
358 cubic yards rubble masonry under miter-sills, at $7.50	2,685
1,059 feet 60-inch cast-iron pipe, 456 pounds per foot, at $6	30,402
174 feet 30-inch cast-iron pipe, 150 pounds per foot, at $6	1,566
144 cubic yards hydraulic concrete in man-hole, at $7.50	1,080
761 cubic yards rubble masonry in man-hole, at $9	6,849
Valves and gates, &c	30,000
Laying pipes, $3.20 for 30-inch and $8 for 60-inch, per foot	8,728
	391,699
This plan and estimate may be applied to locks from Nos. 1 to 8 inclusive, as there is no material difference in their locations, and we have for the eight	$3,133,592
Lock No. 9	
22,569 cubic yards excavation in clay, at 40 cents	$9,027
8,921 cubic yards hydraulic concrete in foundations, at $8	71,368
27,543 cubic yards hydraulic concrete in lock-walls, at $8.50	220,184
213 cubic yards hydraulic concrete in lift-walls, at $8.50	1,810
70 cubic yards dressed stone in miter-sills, at $18	1,260
213,600 feet, board-measure, 3-inch plank, at $45 per thousand	9,612
2,600 bearing piles, at $6.50	16,250
Cast-iron pipes	31,968
Man-holes	7,929
Laying iron pipes	8,728
17,000 cubic feet timber in foundations, at 30 cents	5,100
Valves and gates, &c	30,000
	413,236
Lock No. 10.	
2,024 bearing-piles, 25 feet long, at $6.25	$12,650
626,000 feet, board-measure, 3 and 6 inch plank, in foundations and trenches, at $45 per thousand	28,170
15,000 cubic feet timber in foundation, at 30 cents	4,500
3,400 cubic yards hydraulic concrete in foundations, at $10	34,000
24,429 cubic yards hydraulic concrete in lock-walls, at $9	219,861
70 cubic yards dressed stone in miter-sills, at $18	1,260
11,000 cubic yards excavation in sheet-piling trench, at $1.50	17,500
Cast-iron pipes	26,866
Man-holes	7,929
Laying pipes	7,608
Valves and gates, &c	30,000
Pumping, &c	20,000
	410,990

Tide-lock.

2,024 bearing-piles, 35 feet long, at $9	$18,216
640,000 feet, board-measure, 3 and 6 inch plank, at $45 per thousand	28,800
15,000 cubic feet timber in foundation, at 40 cents	6,000
13,600 cubic yards excavation in foundations and trenches, at $1.75	23,800
3,400 cubic yards hydraulic concrete in foundations, at $10	34,000
23,929 cubic yards hydraulic concrete in lock-walls, at $9	215,361
107 cubic yards hydraulic concrete in lift-walls, at $9	963
40 cubic yards dressed stone in meter-sills, at $20	800
Man-holes	9,500
Cast-iron pipes	26,866
Laying pipes	12,000
Gate and valves, &c	20,000
Pumping	25,000
	421,306

Diversion of Rio Grande.

First. At Las Serdas; length of cut 1,520 feet:	
119,457 cubic yards excavation in earth, at 40 cents	$47,783
Second. At lock No. 3; length of channel 3,360 feet:	
261,333 cubic yards excavation in earth, at 40 cents	104,533
Third. At curve 13; length of channel 544 feet:	
35,632 cubic yards excavation in earth, at 30 cents	10,689
Fourth. Below La Flor; length of cut 400 feet:	
21,655 cubic yards excavation in earth, at 30 cents	6,496
Fifth. South of Brito Harbor; length of cut 3,200 feet:	
31,743 cubic yards excavation in earth and sand, at 30 cents	9,523
	179,024

Culvert to pass the Rio Tola.

21,190 cubic yards excavation in earth, at 35 cents	$7,416
365 bearing-piles, at $6	2,190
30,000 feet, board-measure, 3-inch plank, at $45 per thousand	1,350
23,50 cubic feet timber in foundation, at 30 cents	705
9,508 cubic yards hydraulic concrete, at $8	76,064
	87,725

Cess-pool to take the brook Del Medio into the canal.

842 cubic yards excavation in earth, at 35 cents	$337
1,638 cubic yards excavation in rock, at $1.50	2,457
622 cubic yards rubble masonry, at $8	4,976
1,000 cubic feet of timber, at 40 cents	400
	8,170

Cess-pool to take the brook Chocolata into the canal.

5,833 cubic yards excavation in earth, at 40 cents	$2,333
825 cubic yards excavation in rock, at $1.50	1,238
852 cubic yards rubble masonry, at $8	6,816
1,000 cubic feet timber, at 40 cents	400
	10,787

Culverts.

Between locks 1 and 2, 2 and 3, and 5 and 6:	
49,401 cubic yards excavation in earth, at 40 cents	$19,760
3,369 cubic yards rubble masonry, at $9	30,321
3,000 cubic feet timber, at 40 cents	1,200
	51,281

Drain at foot of embankment.

140,800 cubic yards excavation in earth, at 25 cents	$35,200
819 acres grubbing and clearing, at $100	81,900
Three swing-bridges over the canal	60,000
	177,100

Recapitulation of western division.

From the mouth of Rio del Medio to Brito, 16.33 miles:

Excavation and embankment	$16,787,566
Lift-locks	3,957,818
Tide-lock	421,306
New channel for the Rio Grande	179,024
Culverts and cess-pools	157,963
Drain	35,200
Grubbing and clearing	81,900
Swing-bridges	60,000
Total	21,680,777

MIDDLE DIVISION.

Comprising the lake navigation from the mouth of Rio del Medio to Fort San Carlos, 56.50 miles:

West side:	
78,428 cubic yards excavation in gravel under water, at $2	$156,858
10,807 cubic yards excavation in rock under water, at $5	54,035
East side:	
2,523,827 cubic yards dredging in mud, at 20 cents	504,765
	715,658

EASTERN DIVISION.

From San Carlos, at the lake, to Greytown, slack-water navigation 63.02, inland canal 45.41 = 108.43 miles:

Excavation and dredging in the river.

First. From the lake to Castillo, 37 miles:	
2,180,589 cubic yards dredging in mud and gravel, at 40 cents	$872,235
784,010 cubic yards excavation in rock under water, $5	3,920,050
Second. From foot of canal at Castillo to canal around dam No. 2, at Balas, 6.39 miles:	
28,107 cubic yards dredging in mud and gravel, at 40 cents	11,242
12,199 cubic yards excavation in rock under water, at $5	60,995
Third. From foot of canal at Balas to canal around dam No. 3 at Machuca, 4.06 miles:	
44,984 cubic yards dredging in mud and gravel, at 40 cents	17,993
38,703 cubic yards excavation in rock under water, at $5	193,515
	5,076,030
Canal around dam No. 1 at Castillo, 0.78 mile:	
102,845 cubic yards excavation in rock, at $1.25	$128,556
160,329 cubic yards excavation in earth, at 35 cents	56,115
196,602 cubic yards embankment, at 10 cents	19,660
	204,331
Canal around dam No. 2 at Balas, 1.57 miles:	
1,065,226 cubic yards excavation in earth, at 35 cents	$372,829
234,066 cubic yards embankment, at 10 cents	23,407
	396,236
Canal around Machuca, dam No. 3, 1.16 miles:	
620,401 cubic yards excavation in earth, at 35 cents	$217,140
169,239 cubic yards excavation in rock, at $1.25	211,549
276,661 cubic yards embankment, at 10 cents	27,666
	456,355
Canal from dam No. 4, below the San Carlos River, to the harbor of Greytown, 41.90 miles:	
1,445,981 cubic yards excavation in rock, at $1.50	$2,168,971
1,893,788 cubic yards excavation in rock, at $1.25	2,367,235
24,064,053 cubic yards excavation in earth, at 35 cents	8,422,419
4,307,735 cubic yards embankment, at 10 cents	430,773
	13,389,398

Dam No. 1, at Castillo Rapids:

Coffer-dam	$73,802
4,000 cubic yards excavation in rock under water, at $5	20,000
1,143 cubic yards excavation in gravel, at $1	1,143
6,548 cubic yards hydraulic concrete under water, at $12	78,576
2,276 cubic yards coursed masonry, at $15	34,140
3,631 cubic yards hydraulic concrete, at $8	29,048
341 cubic yards dressed-stone masonry, at $20	6,820
481 cubic yards rubble masonry, at $7.50	3,367
13,800 cubic yards stone, gravel, and clay in front of dam, at $1	13,800
	260,696

Dam No. 2, at foot of Balas Rapids:

Coffer-dam	$69,882
4,167 cubic yards excavation in rock under water, at $5	20,385
722 cubic yards excavation in rock, at $1.25	902
8,960 cubic yards excavation in hard clay, at 40 cents	3,584
10,884 cubic yards hydraulic concrete under water, at $12	130,608
3,106 cubic yards coursed masonry, at $15	46,590
4,604 cubic yards hydraulic concrete, at $8	36,832
590 cubic yards dressed-stone masonry, at $20	11,800
382 cubic yards rubble masonry, at $7.50	2,865
19,973 cubic yards stone, gravel, &c., in front of dam, at $1	19,973
	341,871

Dam No. 3, at foot of Machuca Rapids:

Coffer-dam	$60,564
2,680 cubic yards excavation in rock under water, at $5	13,400
3,144 cubic yards excavation in rock, at $1.25	3,930
10,290 cubic yards hydraulic concrete under water, at $12	123,480
3,225 cubic yards coursed masonry, at $15	48,375
6,357 cubic yards hydraulic concrete in hearting, at $8	50,856
488 cubic yards dressed-stone masonry, at $20	9,760
229 cubic yards rubble-masonry, at $7.50	1,717
867 cubic yards dry-stone wall, at $4	3,468
31,582 cubic yards stone, gravel, &c., in front of dam, at $1	31,582
	347,132

Dam No. 4, below San Carlos River:

Coffer-dam	$86,220
13,228 cubic yards excavation in gravel under water, at $2	26,456
7,078 cubic yards excavation in earth, at 40 cents	2,831
21,566 cubic yards hydraulic concrete under water, at $12	258,792
9,723 cubic yards hydraulic concrete in hearting, at $8	77,784
2,668 cubic yards dressed-stone masonry, at $20	53,360
2,598 cubic yards rubble masonry, at $7.50	19,485
1,112 cubic yards dry-stone wall at $4	4,448
606 piles, 30 feet long, at $7.50	4,545
67,000 cubic feet timber in apron, at 30 cents	20,100
18,500 cubic yards stone-filling, under apron, at 50 cents	9,250
30,556 cubic yards stone, gravel, &c., in front of dam, at $1	30,556
	593,827

Lock No. 1, at Castillo Rapids, lift 10.28 feet:

11,258 cubic yards excavation in rock, at $1.50	$16,887
28,037 cubic yards excavation in earth, at 40 cents	11,214
9,993 cubic yards hydraulic concrete, at $8	79,944
70 cubic yards dressed stone, at $18	1,260
140 cubic yards hydraulic concrete in man-holes, at $7.50	1,050
1,761 cubic yards rubble masonry, at $9	15,849
1,233 feet cast-iron pipes, 532,803 pounds, at $6	31,968
Laying pipes	8,728
Valves, gates, &c	30,000
	196,900

Lock No. 2, at Balas Rapids, lift 10.28 feet:	
119,377 cubic yards excavation in earth, at 35 cents	$41,788
8,342 cubic yards hydraulic concrete in foundations, at $7	58,394
22,801 cubic yards hydraulic concrete in lock-walls, at $8	182,408
213 cubic yards hydraulic concrete in lift-walls, at $8	1,704
70 cubic yards dressed stone, at $18	1,260
358 cubic yards rubble masonry, at $7.50	2,685
144 cubic yards concrete in man-hole foundations, at $7.50	1,080
761 cubic yards rubble masonry in man-hole foundations, at $9	6,849
1,233 feet cast-iron pipes, 532,803 pounds, at 6 cents	31,968
Laying pipes	8,728
Valves, gates, &c	30,000
	366,864
Lock No. 3, at Machuca Rapids, lift 10.28 feet:	
24,629 cubic yards excavation in rock, at $1.50	$36,943
47,689 cubic yards excavation in earth, at 35 cents	16,691
8,445 cubic yards hydraulic concrete, at $8	67,560
70 cubic yards dressed stone, at $18	1,260
140 cubic yards concrete in man-holes, at $8	1,120
761 cubic yards rubble masonry, at $9	6,841
1,233 feet cast-iron pipes, 532,803 pounds, at 6 cents	31,968
Laying pipes	8,728
Valves, gates, &c	30,000
	201,111
Lock No. 4, below San Carlos River, lift 10.87 feet:	
40,156 cubic yards excavation in rock, at $1.50	$60,234
197,537 cubic yards excavation in earth, at 35 cents	69,137
8,277 cubic yards hydraulic concrete, at $8	66,216
70 cubic yards dressed stone, at $18	1,260
140 cubic yards concrete in man-holes, at $7.50	1,050
761 cubic yards rubble masonry in man-holes, at $9	6,849
1,233 feet cast-iron pipes, 532,803 pounds, at 6 cents	31,968
Laying pipes	8,728
Valves, gates, &c	30,000
	275,442
Lock No. 5, in curve No. 7, lift 10.87 feet:	
86,322 cubic yards excavation in rock, at $1.50	$129,483
158,050 cubic yards excavation in earth, at 35 cents	55,317
7,426 cubic yards hydraulic concrete, at $8	59,408
70 cubic yards dressed stone, at $18	1,260
140 cubic yards concrete in man-holes, at $7.50	1,050
761 cubic yards rubble masonry, at $9	6,841
1,233 feet cast-iron pipes, 532,803 pounds, at 6 cents	31,968
Laying pipes	8,728
Valves, gates, &c	30,000
	324,055
Lock No. 6, in straight line No. 9, lift 10.87 feet:	
25,472 cubic yards excavation in rock, at $1.50	$38,208
90,722 cubic yards excavation in earth, at 35 cents	31,752
12,378 cubic yards hydraulic concrete, at $8	99,024
70 cubic yards dressed stone, at $18	1,260
140 cubic yards concrete in man-holes, at $7.50	1,050
761 cubic yards rubble masonry, at $9	6,849
1,233 feet cast-iron pipes, 532,803 pounds, at 6 cents	31,968
Laying pipes	8,728
Valves, gates, &c	30,000
	248,839

Lock No. 7, in straight line No. 14, lift 10.87 feet:

226,683 cubic yards excavation in earth, at 40 cents	$90,673
8,921 cubic yards hydraulic concrete in foundations, at $8	71,368
27,543 cubic yards hydraulic concrete in lock-walls, at $8.50	220,184
70 cubic yards dressed stone, at $20	1,400
213 cubic yards hydraulic concrete in lift-walls, at $8.50	1,810
1,233 feet cast-iron pipes, 532,803 pounds, at 6 cents	31,968
Man-holes	7,929
Laying pipes	8,728
Valves, gates, &c	30,000
	464,060

Lock No. 8, in straight line No. 17, lift 10.87 feet:

153,313 cubic yards excavation in earth, at 35 cents	$53,659
10,703 cubic yards hydraulic concrete in foundations, at $8	85,624
27,543 cubic yards hydraulic concrete in lock-walls, at $8.50	234,115
213 cubic yards hydraulic concrete in lift-walls, at $9	1,917
70 cubic yards dressed stone, at $20	1,400
358 cubic yards rubble masonry, at $7.50	2,685
144 cubic yards hydraulic concrete in man-holes, at $8	1,152
761 cubic yards rubble masonry in man-holes, at $9	6,849
1,233 feet cast-iron pipes, 532,803 pounds, at 6 cents	31,968
Laying pipes	11,000
Valves, gates, &c	35,000
	465,369

Locks Nos. 9 and 10, in straight line No. 18, lift of each 10.87 feet:

47,746 cubic yards excavation in rock, at $1.50	$71,619
126,689 cubic yards excavation in earth, at 40 cents	50,675
7,600 cubic yards hydraulic concrete in foundations, at $8	60,800
20,159 cubic yards hydraulic concrete in walls, at $9	181,431
213 cubic yards hydraulic concrete in lift-walls, at $9	1,917
280 cubic yards hydraulic concrete in man-holes, at $8.50	2,380
150 cubic yards dressed stone, at $20	3,000
1,522 cubic yards rubble masonry, at $9	13,698
Cast-iron pipes, 1,083,334 pounds, at 6 cents	65,000
Laying pipes	25,000
Valves, gates, &c	75,000
	550,520

Culverts, cess-pools, and drains.

12 cess-pools	$96,000
13 culverts	195,000
157,600 cubic yards excavation in earth in drains, at 25 cents	49,400
	340,400

Diversion of San Carlos River.

Length of channel, 6,200 feet:

810,222 cubic yards excavation in earth, at 35 cents	$283,578
2,379 acres grubbing and clearing, at $100	$237,900

Recapitulation of eastern division.

Excavation and dredging in the San Juan	$5,076,030
Short canal around Castillo dam, 0.78 miles	204,331
Short canal around Balas dam, 1.57 miles	396,236
Short canal around Machuca dam, 1.16 miles	456,355
Canal from dam No. 4 to Greytown, 41.90 miles	13,389,398
Dams Nos. 1, 2, 3 and 4	1,543,526
Light-locks from 1 to 10 inclusive	3,093,160
Culverts, cess-pools, and drains	340,400
Diversion of San Charles River	283,578
Grubbing and clearing	237,900
Total	25,020,914

Harbors.

Artificial harbor at Brito:	
2,835,185 cubic yards excavation and dredging, at 35 cents	$992,315
287,668 cubic yards stone in breakwaters, at $4	1,150,672
Piers	164,752
Light-house	30,000
Total	2,337,739
Harbor of Greytown:	
2,500 piles in crib-work, at $8	20,000
150,000 cubic feet timber in crib-work, at 30 cents	45,000
30,000 pounds iron bolts in crib-work, at 12 cents	3,600
35,000 cubic yards stone in crib-work, at $4	140,000
210,000 cubic yards stone in breakwater, at $5	1,050,000
4,080,100 cubic yards dredging in sand, at 30 cents	1,224,030
Closing the river San Juan	100,000
Light-house	40,000
Piers at entrance to canal	200,000
Total	2,822,630

Total cost.

Western division	21,680,777
Middle division	715,658
Eastern division	25,020,914
Harbor of Brito	2,337,739
Harbor of Greytown	2,822,630
Total	52,577,718
Add 25 per cent. for contingencies	13,144,429
Grand total	65,722,147

JOURNAL OF PARTY No. 1, LIEUT. E. H. C. LEUTZE, COMMANDING.

Operations in the valleys of the Ochomogo and Gil Gonzalez.

List of the officers and men composing party No. 1:

Officers.—Lieut. E. H. C. Leutze, commanding; Lieut. J. W. Miller; civil engineer, J. F. Crowell.

Petty officers and men.—John Quevedo, Paul Hoffman, Charles Mays, Frank Russell, Harry Thompson, George Britt; two Caribs; eight macheteros; two muleteers.

January 7, 1873.—Left Virgin Bay at 9.30 a. m. and arrived at Paso-Real at 7.45 p. m. At this place one chief machetero, seven muleteers, and one cook reported for duty. Rainy weather.

January 8.—At 9 a. m. left Paso-Real, and established Camp No. 1, near Ramadas; pack-mules with provisions and instruments arrived; discharged six pack and seven saddle mules; the remainder, four pack-mules, and three saddle-mules, and also two muleteers, were kept. Adjusted instruments. Rainy during afternoon and night; no shelter-tents.

January 9.—Sent muleteer to Virgin Bay for tents. Commenced work, taking up the survey of last year at bench-mark No. 2 of line 2, near Paso-Real; ran 2,000 feet; took two cross-sections.

January 10.—Extended line 4,200 feet, and took two cross-sections. Sent to Nandaime for provisions.

January 11.—Extended line 2,514 feet; worked up notes during afternoon; took cross-section and gauged river; found it discharging 1,700 cubic feet per minute. Weather pleasant, with strong northeast winds.

January 12.—No work. Rainy during evening and night.

January 13.—Sent to Nandaime for fresh provisions; ran 3,765 feet; took cross-sections, and gauged river; result, 2,400 cubic feet per minute. Chief Engineer Menocal joined the party.

January 14.—Extended line 2,000 feet; and line No. 1 of last year was made to intersect the main line; the levels were tested at bench 16. Chief Engineer Menocal and Lieutenant Leutze made reconnaissance as far as San Mateo; found the elevation to increase very rapidly, also a great deal of rock. This pass was therefore considered impracticable.

January 15.—Mr. Menocal and Lieutenant Leutze went on a reconnaissance to San Marco; found this pass to be situated near the River Lajas, which crosses the Camino Real to the southward of the Ochomogo, near the headwaters of the Lajas, and within a mile and a half of the Quebrada Güegüe; found the Quebrada San Ignacio, which discharges into the Pacific Ocean. The lowest point on the divide being 225 feet, concluded, in accordance with the instructions of Commander Lull, to abandon the line and move the party to the mouth of the river Gil Gonzales; ran 2,000 feet on the line, and took cross-sections. Mr. Crowell and Lieutenant Miller made a reconnaissance to the northward of the valley of the Ochomogo, ascending a spur of the main ridge to an altitude of 230 feet, situated about two miles from the river.

January 16.—Broke camp at the Ochomogo; Chief Engineer Menocal and Lieutenant Leutze left camp at 3.30 a. m. and proceeded to Guasimala, on the Gil Gonzales, and there took a guide to go to the mouth of the river; but as he lost his way, and after several attempts to refind it failed to do so, they were obliged to return to the place which had been settled upon for the next camp. At 1 p. m. the pack-mules arrived, and shortly after the men in charge of Lieutenant Miller; established camp; Mr. Menocal left the party.

January 17.—Lieutenants Leutze and Miller made a reconnaissance to the mouth of the river. About one mile below Guasimala the water ceased to run, and the river assumed the appearance of an estuary, the banks being very low. Had to leave the river, and shortly afterward, in trying to regain it, crossed some small running brooks, which afterward proved to be branches of the main river. Lost our way in a jungle of piñuela and thick underbrush, and only regained the camp after walking about thirty miles; found the country on north side of river low and marshy. At 2 p. m. Mr. Crowell reported at the camp with the remainder of the party and provisions.

January 18.—As most of party were exhausted from want of sleep, did not work; found a guide to mouth of river. Civil Engineer Crowell went to headquarters with record-levels and transit-book of Ochomogo route.

January 19.—Sunday; no work. Wrote report to commanding officer.

January 20.—Lieutenant Leutze and Engineer Crowell went on a reconnaissance to the mouth of the river; found the river-bed filled up with drift-wood and other matter, and dividing into numerous branches. These all empty into a lagoon, which is divided from the lake by a narrow, wooded sand-bank. The beach could not be reached without a boat, or without making a detour of at least six miles. The Quebrada-la-Carcola, which was followed for some distance, was the old river-mouth; but, as far as could be ascertained, has been dry for some years. The reconnaissance was extended across the divide to the valley of the Chacalapa, but without practical results. During the day cut two offset-lines of 500 feet each.

January 21.—Lieutenant Leutze went to Rivas to consult with Mr. Chamorro on account of trouble with the macheteros; sent to headquarters for provisions; ran 2,200 feet down the river; also cut 2,600 feet into the interior, with the intention of running around the mouth; found the same impracticable and abandoned it; discharged four macheteros and engaged four others.

January 22.—Took up the survey of the river-bank; ran 5,200 feet, and also several offsets; found water-surface slightly higher toward mouth, and on the surface an up-stream current; cutting very difficult and ground muddy. At 3 p. m. had to stop work on account of the pica-pica; received communications and provisions from headquarters; discharged one machetero for insubordinate conduct.

January 23.—Extended the survey 5,400 feet, running around swamp; work very difficult; sent to Obrage for a guide.

January 24.—Frank Russell (machinist) joined the party; ran 1,900 feet toward lagoon, reaching it at that distance; further progress became impossible, party working in water up to the waist; took compass up a tree situated on the line and obtained bearings of the prominent landmarks; estimated lake to be distant about one mile; returned to camp and ran 1,500 feet up river during the afternoon.

January 25.—Surveyed 5,650 feet; plotted week's work and copied books; sent to headquarters for mail.

January 26.—Sunday; no work.

January 27.—Ran 3,400 feet, and made reconnaissance up the river; established station at the Camino-Real; water-surface at that place 81 feet above the lake; took two cross-sections; gauged stream; result 937 cubic feet per minute.

January 28.—Shifted camp to the hacienda Jocomico, preparatory to running the line up the divide.

January 29.—Ran 5,900 feet, and one cross-section of 216 feet, leaving the river at 29,200 feet, to run up the pass of Jocomico; sent to headquarters for bread.

January 30.—Ran up the valley of the Jocomico 4,977 feet, and made one offset of 530 feet; received bread and mail from headquarters.

January 31.—Extended the line up the valley of the Jocomico for 1,000 feet, reaching the elevation of 261 feet above the lake, and finding, on further reconnaissance, that the divide was at least 300 feet higher; abandoned the line; took up the survey at 29,200, and ran up the river a distance of 3,500 feet; sent to headquarters for the doctor, several of the men being sick.

February 1.—Ran 4,500 feet up river, and worked notes up to date. Rainy during entire day.

February 2.—Sunday; no work. Doctor Bransford reported at camp.

February 3.—Doctor left the camp for Virgin Bay; sent a messenger with report and notes; during day ran seven offsets from main line to river; also took seven cross-sections.

February 4.—Ran six offsets and six cross-sections of river.

February 5.—On account of sickness of officers did not work.

February 6.—Ran four offsets to river and extended main line 1,200 feet; discharged chief machetero for bad conduct.

February 7.—Ran 4,000 feet up the Pass San Ramon, and on reaching an elevation of 280 feet

above the lake abandoned it. During the afternoon Lieutenant Leutze and Mr. Crowell made a reconnaissance of about eight miles up the valley of the river; found the water-surface rising continually about 16 feet per mile; also saw much rock. Commander Lull, Master Hawley, Chief Engineer Menocal, and Don Max. Sonnenstern visited the camp. After making the commander acquainted with the facts ascertained he ordered the line to be abandoned. Sent to Rivas for saddle-mules.

February 8.—Discharged macheteros and made preparations to return to headquarters; received seven saddle-mules from Rivas.

February 9.—At 4 a. m. broke camp; at 5.40 left Jocomico; arrived at La Virgen at 9.30 a. m. and reported to commanding officer, who took charge of party. Lieutenant Leutze returned to Rivas to make arrangements for proceeding to Tipitapa.

February 10.—Lieutenant Leutze completed arrangements for trip to Tipitapa and then returned to Virgin Bay.

February 11.—Lieutenants Leutze and Miller, Civil Engineer J. F. Crowell, Captain's Clerk A. L. McCrea, and three men leave Virgin Bay at 12 meridian and proceed as far as Obrage.

February 12.—At 3.45 a. m. left Obrage and proceeded to Granada.

February 13.—At Granada to rest animals.

February 14.—At 4 a. m. left Granada, leaving behind one sick pack-mule; proceeded to Hatio; commenced work at Pasquier and ran 4,500 feet.

February 15.—Moved to Tipitapa and finished work. Total distance to Tipitapa 23,100 feet; difference of level of water-surfaces 22.347 feet; highest point of land 83 feet.

February 16.—Left Tipitapa at 1.30 a. m. and arrived at Managua at 7 a. m.

February 17.—At Managua; called on president of Nicaragua; visited Lake Nejapa, celebrated for its medicinal properties.

February 18.—Left Managua at 4 p. m., leaving Lietuenant Miller in charge of Mr. McCrea, who was sick; went as far as Valle-Gottel.

February 19.—At 4 a. m. left Valle-Gottel and went to Ramadas.

February 20.—At 3 a. m. left Ramadas; reported at headquarters at 11 a. m.

February 21.—Pack-mule arrived. Turned in instruments, &c.

Journal of Party No. 1.—Operations on the San Juan River.

List of officers and men composing Party No. 1, San Juan River: Lieut. E. H. C. Leutze commanding; J. Foster Crowell, civil engineer, transit; * Master J. M. Hawley, level; Master J. B. Briggs, level; Paul Hoffmann, yeoman; Charles Mays, coppersmith; Henry Thompson, cook; George Britt, ordinary seaman; two Caribs, Alex. and Ben.; three soldiers, for macheteros.

March 6.—At Castillo Viejo with party 2; took charge of party 1; established Camp Dump and commenced survey of Castillo Rapids. Rainy weather. Three soldiers join the party.

March 7.—Continued survey; ran 4,800 feet. Weather rainy.

March 8.—Triangulating and continuing line along the bank. Weather rainy.

March 9.—Sunday; no work. Rainy all day.

March 10.—Finished work at Castillo.

March 11.—Broke camp and established Camp Hollenbeck, three miles down river. Rainy.

March 12.—Party engaged in clearing and cleaning camp.

March 13.—Cut a picket 2,500 feet in length to line of party 2, in order to establish communication; commenced to gauge river, and made experiments in order to establish "constant" for the current-meter. Rainy.

March 14.—Finished gauging river; found 1,700,000,000 cubic feet of water pass daily.

March 15.—Regauged river, in order to verify previous results. Commander Lull visited the camp. Rainy.

March 16.—Sunday; no work. Weather rainy.

March 17.—Shifted camp to the mouth of the Bartola River, and named it Camp Runnels. Continued rainy weather.

March 18.—Finished establishing camp. Rainy.

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* Master Hawley was attacked with fever and relieved March 27th. Master Briggs joined the party April 9th.

March 19.—No work. Received six new paddles. Weather improving, but still rainy.

March 20.—Went to Castillo; Master Hawley went on a reconnaissance with Mr. Menocal; Mr. Crowell on line with Party 2. Fine weather.

March 21.—Went to Castillo and reported to Commander Lull; received provisions, viz: 4 barrels bread, 4 kegs bacon, 1 box soup and bouill, 1 box tomato-soup, 1 box coffee. Mr. Crowell working with Party 2.

March 22.—Lieutenant Leutze and Mr. Menocal went on a reconnaissance to a point a mile below Balas Rapids. Commander Lull visited camp. Weather rainy.

March 23.—Sunday; no work. Fine weather.

March 24.—Commenced survey of Mico Rapids, running line on left bank of river; placing prominent points by triangulation; Commander Lull running transit. Rainy weather.

March 25.—Broke camp and established a new one, Don Max, below Balas Rapids. Commander Lull left the party and returned to Castillo. Rainy.

March 26.—On account of sickness no work. Rainy.

March 27.—Ran 5,900 feet, connecting by offset with line of Party 2. Master Hawley, being sick, could not carry the level. Rainy.

March 28.—Carried level over line cut before and made reconnaissance to Machuca Rapids. Weather rainy.

March 29.—Went to Castillo and reported to commanding officer; brought Dr. Bransford back to camp. Lieutenant Hyde turned over to the party Philip McDonald and Frank Victorado, landsmen. Received stores from Paymaster Bemis.

March 30.—Sunday; no work. Rainy.

March 31.—Received stores per steamer Castillo. Fine weather. Master Hawley and Dr. Bransford left.

April 1.—Surveyed Balas Rapids for location of a dam. Received bread. Mail arrived from United States. Commander A. V. Reed and Mr. Hollenbeck visited the camp. Fine weather continuing.

April 2.—Received provisions and three macheteros. Fine weather.

April 3.—Shifted camp to Machuca River; named it Camp Benard. Fine weather continuing.

April 4.—Clearing camp. Dr. Bransford and Paymaster Bemis visited the camp.

April 5.—Party remained in camp. Rain-squalls during day and night.

April 6.—Sunday; no work. Rainy.

April 7.—At 4 a. m. party broke camp, and at 5.30 a. m. started down the river in the flat-boat, Mr. Menocal accompanying party; at 5.45 p. m. stopped at Rancho Capalchi. Heavy rain-squalls all day.

April 8.—At 6 a. m. left Copalchi and proceeded down the river to a point two miles below the junction of the river Serepiqui. Established Camp Hatfield. At 11 p. m. received from steamer Pit Pan one canoe and provisions. Rain-squalls during the night.

April 9.—Commenced survey of the Lower San Juan, by establishing an origin at a point opposite the Serepiqui, the point having been indicated on the diagram; ran 3,700 feet on the line and two offsets, amounting to 863 feet. Master J. B. Briggs reported for duty. Weather clear and pleasant.

April 10.—Continued line for 5,000 feet, but abandoned it on account of the many hills passed over, making it an impracticable route; during the afternoon Chief Engineer Menocal and Lieutenant Leutze went on a reconnaissance down the river and located lines for the next day. Rain during the night.

April 11.—At 3 a. m. received mail from headquarters; commenced work at Station 2, and ran 5,280 feet, keeping closer to river-bank than on previous day; line better; hills for the first 2,500 feet, but not so high; last part of line level ground. At 8.30 p. m. Commander Lull arrived at the camp; canoe capsized in going alongside of steamer; crew all rescued; received stores. Rain-squalls during forenoon; weather pleasant during the afternoon.

April 12.—Ran 4,200 feet through level country; also two offsets of 600 feet each. Rain squalls during forenoon.

April 13.—Easter Sunday; during afternoon Lieutenant Leutze and Mr. Menocal went on a reconnaissance to the Juanillo River. Weather pleasant during the day; rainy during the night.

April 14.—Ran 5,585 feet and offset of 500 feet over favorable ground. Rain-squalls.

April 15.—On account of rainy weather could not move camp, as intended; Commander Lull left the camp; received stores sent from Greytown by Master Hawley.

April 16.—Continued rainy weather; no work.

April 17.—As weather still continued too rainy to move camp, extended the survey 4,854 feet over partially hilly and partially swampy ground; all the party inconvenienced by many mosquitoes and large flies; cut offset of 2,500 feet.

April 18.—Moved camp to the mouth of San Juanillo; named it Camp Rhoades. Rain.

April 19.—Ran 4,328 feet and offset of 1,500 feet; character of ground favorable; Chief Engineer Menocal left the party. Rainy.

April 20.—Sunday; no work. Rainy.

April 21.—Ran 4,400 feet and offset of 68 feet; on account of rainy weather and thunder-squalls had to stop work at 12.30 p. m.; country swampy.

April 22.—Ran 5,312 feet and offset of 145 feet; crossed three small hills; remainder of ground swampy. Rain-squalls; mosquitoes troubling party greatly.

April 23.—Extended survey 5,334 feet and measured offset of 1,300 feet; at distance 42,242 feet, changed course to north 25° east, this being supposed direct course to San Juan del Norte. Weather cloudy, but no rain; at 8.40 felt severe shock of earthquake, lasting about 20 seconds, shaking tents violently and causing several trees in the neighborhood to fall.

April 24.—Ran 5,412 feet, over mostly swampy soil. Mr. Reilly (aid) came up from Greytown with stores; also left stores to be forwarded to Lieutenant Rhoades by first opportunity. Fine weather.

April 25.—The line was extended 5,312 feet; several patches of hard soil between the swamps; walk back to camp very hard and toilsome. Fine weather.

April 26.—Lieutenant Leutze went on a reconnaissance down the Juanillo, but found it impossible to proceed more than three miles, there being little water and the stream full of fallen logs; Mr. Crowell cut an offset of 7,600 feet from head of line to River San Juan, passing over three hills. Weather continuing fine.

April 27.—Sunday; no work. Rainy.

April 28.—Shifted camp to end of offset; named it Camp Miller. Showers.

April 29.—Continued line 5,000 feet, running for the first part through good country, afterward through dangerous swamps; received stores. During the evening pulled to the steamer at the Colorado Forks to see Commander Lull, but found that he had left for Greytown.

April 30.—Walked out to line, two and a half miles; ran 4,300 feet over bad swamp; at 66,800 crossed a river, bearing general appearance of San Juanillo; after crossing same, country became better. Rainy.

May 1.—Lieutenant Leutze and Mr. Crowell went on a reconnaissance; cut a picket perpendicular to line one mile, running over three high and very steep hills, divided by swamp; at distance 4,800 feet struck a small stream running to the west; to the southward a range of high mountains, running toward the river San Juan; from these indications concluded that the stream crossed yesterday was not the San Juanillo; returned to the line and commenced cutting an extension of the same in order to intersect the Juanillo; cut 3,600 feet, and struck a small stream running to northward and eastward; all the party returned to camp very much exhausted, having made ten and a half miles over very rough ground, the swamps on the line having become softer on account of the rain which had been falling all day.

May 2.—Rested, to recuperate strength of party; Commander Lull stopped at the camp over night, on his way up river.

May 3.—Lieutenant Leutze and Mr. Crowell cut a picket of 13,000 feet; first followed stream met with the day before yesterday, then crossed it; and shortly afterward another larger stream, with soft, muddy bottom, running to northward and westward, was crossed with great danger; then the line passed over eight hills, with streams in the valleys between; at 8,000 feet struck a

valley with stream, the general direction of which was east; at 13,000 feet struck a large lagoon, about two and a half miles long and one mile wide; greatest length in northeast and southwest direction; party returned to camp at 6 p. m., having worked thirteen hours, and feeling greatly exhausted. Fine weather.

May 4.—Sunday; received mail from Castillo. Rainy weather.

May 5.—Lieutenant Leutze and Mr. Crowell, (civil engineer,) with three men, left for Greytown, arriving there at 11 a. m.; found the river very dry; made arrangements for proceeding on a reconnaissance the next day; engaged Cæsar Brown for a guide; received provisions from Master Hawley. Fine weather.

May 6.—At 3.30 a. m. left Greytown; went up the San Juanillo to Silico Creek, up the latter and into the lagoon of Silico; found the signal that had been put at the end of the Saturday's line; the object of the reconnaissance being accomplished, returned to Greytown. Fine weather.

May 7.—Left Greytown at 5.30 p. m., and arrived at camp at 2 p. m.; found it hard work. Heavy rains during the forenoon.

May 8.—At 4 a. m. broke camp, and left at 6.30; at 2.30 p. m. arrived at the mouth of the Juanillo; Master Briggs, with four men, went to Greytown for provisions; remainder of party went up the Juanillo about three miles, and camped for the night.

May 9.—At 5.45 a. m. got underway, and proceeded up the lagoon of Silico, arriving at 10 a. m.; at 7 Master Briggs rejoined the party; had hard work hauling flat-boat through the creek; established Camp Moser; received provisions. Fine weather.

May 10.—Lieutenant Leutze and Civil Engineer Crowell went on a reconnaissance, in order to place the line around the hills encountered on last Saturday; were, however, unsuccessful. Fine weather.

May 11.—Sunday; no work. Fine weather.

May 12.—Continued survey, accomplishing 9,342 feet; the first part of line through swamps the latter over hills; followed the picket cut May 3 as nearly as possible. Fine weather.

May 13.—Extended survey to Silico Lagoon, 7,535 feet; triangulated across and took soundings. Breadth of lagoon on the line 7,535 feet; greatest depth of lagoon 13 feet.

May 14.—Ran 7,028 feet; a few hills along the bank of the lagoon after Silico Swamp.

May 15.—Crossed Silico Creek and ran 6,535 feet; all swampy land. Fine weather continuing

May 16.—Shifted camp to Rio San Juanillo; Lieutenant Leutze went to Greytown for provisions; during the night one of the men slightly disturbed by finding a snake in his hammock; named the camp Menocal.

May 17.—Continued the survey; after running 5,800 feet reached Ibo Lagoon; sounded and triangulated across it; distance of line across 2,604 feet; greatest depth 12½ feet. Thunder and rain-squalls during the night.

May 18.—Lieutenant Leutze and Mr. Crowell started for Greytown in order to obtain a guide, but on meeting Commander Lull returned with him to camp; during the day Commander Lull inspected the line and visited Silico Lagoon. Thunder and rain-squalls.

May 19.—Cut a picket into Greytown and moved camp down river; obtained the use of the Company House; had great trouble with the macheteros and sailors, many of whom indulged too freely in liquor. Heavy showers during the day.

May 20.—Finished the survey by running 9,502 feet; line running across Barco and Sheppard's Lagoons; ground in ridges, alternately hard and swampy; Commander Lull came to Greytown; Lieutenant Rhoades and party arrived. Heavy rains during the afternoon.

May 21.—Fine weather.

May 22.—Lieutenant Miller's party arrived; men turned in articles used during the expedition; discharged four macheteros. Fine weather.

May 23.—United States steamship Kansas arrived; sent men on board. Weather clear and pleasant.

May 24.—Lieutenant Leutze went on board Kansas, and received articles for use on board of steam-launch. Weather fine.

Lieutenant Leutze's journal of the trip up the river San Juan for the steam-launch.

May 27.—Took charge of party, consisting of two officers and five men; left Greytown at 7 a. m. in three canoes; arrived at Colorado at 4, 5, and 7 p. m., respectively. Rainy.

May 28.—At 9 a. m. went on board the steamer Pit Pan and at 11 a. m. on board steamer Castillo, and reported to Commander Lull; returned one canoe at Serepiqui. Good weather.

May 29.—Took the remaining canoes over Machuca Rapids; arrived at Castillo at 5 p. m.; at wood-station, near Patricio, found the canoe, which had been taken in Greytown, shifted to steamer Panaloya. Rainy.

May 30.—Returned canoes to the persons from whom they had been hired. Rainy.

May 31.—Left Castillo and proceeded as far as Toro Rapids. Rainy.

June 1.—Arrived at San Carlos at 12 m.; took charge of steam-launch; made slight repairs and proceeded to Zavalo River. Fine weather.

June 2.—At 5 a. m. left Zavalo with Colonel Hanger as pilot; struck on a rock in rapids; worked hard all day, officers and men in the water, trying to haul the boat off, but without success; at 9 a. m. Commander Lull, Dr. Bransford, and Col. Sonnenstern joined the party. Fine weather.

June 3.—At 5 a. m. started work, and after several hours' pulling and hauling got the launch off the rock and into a better position, though still aground; in the afternoon steamer Panaloya came down and stopped to give assistance; Mr. Hollenbeck came on board the launch; took the line to the capstan of steamer and hauled launch up stream about 200 yards, but had to leave her for the night still hard aground. Heavy rain and thunder squalls during the afternoon.

June 4.—At 7 a. m. hauled and lifted the launch into deep water; Mr. Hollenbeck then steered her down the rapids; arrived at Castillo at 11 a. m.; rigged shears, and made all preparations for hoisting out boiler; hauled a flat-boat over the rapids; received assistance from the commandant; put all the property belonging to the expedition in the boat. Rainy weather.

June 5.—Hoisted out boiler and placed it on board of flat-boat; received men from commandant for assistance; bought provisions; Lieutenant Leutze, Mr. Browne, and John Quevedo went to Machuca Rapids in steamer Pit Pan to raise shears. Rainy weather.

June 6.—Raised shears, after great trouble, and placed launch's boiler on deck of Castillo. Rainy weather.

June 7.—Returned to Castillo Viejo during afternoon and reported to Commander Lull. Rainy weather.

June 8.—Attempted to take steam-launch over Castillo Rapids, Anselmo being pilot, Commander Lull and Mr. Hollenbeck on board; grounded at the upper end of the rapids in comparatively deep water, launch drawing 2′ 9″ aft; had to give up the idea of bringing her over, Mr. Hollenbeck promising to send her down the river as soon as there should be sufficient rise to get her over the rapids. Rainy weather.

June 9.—Waiting for steamer to return to Greytown. Rainy.

June 10.—Left Castillo at 12 m.; below Machuca Rapids placed the boiler again into flat-boat; unrigged shears. Heavy rain-storms.

June 11.—Left Machuca at 2 a. m.; at 12 m. arrived at the Colorado; took the flat-boat containing the boiler to below the Boca Taura; arrived at Greytown at 7 p. m. Rainy during the evening.

Very respectfully, &c.,

E. H. C. LEUTZE,
Lieutenant Commanding Party.

Commander E. P. LULL, U. S. N.,
Commanding Nicaragua Surveying Expedition.

JOURNAL OF PARTY No. 2.—LIEUT. W. W. RHOADES COMMANDING.

Operations on the Rio Medio route.

VIRGIN BAY, NICARAGUA, C. A., *January* 7, 1873.

Weather fine and pleasant, with fresh breezes from the north and east. At 10 a. m. started for the mouth of the Rio del Medio with a party composed of four officers, six seamen, and twelve natives; party detailed as follows, viz: Lieut. W. W. Rhoades, U. S. N., commanding; Lieut. J. F. Moser,

U. S. N., level; First Assistant Engineer G. M. Greene, U. S. N., transit; J. E. Cropsey, mineralogist; Henry Butts and Wm. Burnside, chain-men; Jos. Bruner, rod-man; John Buck, first pole-man; Jacob Rabb, rear pole-man; Maxwell, men's cook; six macheteros for cutting; one cook for natives; one officers' cook; two muleteers, with eight mules. At 1 p. m. arrived at Rio del Medio, and established a camp in a coffee-plantation on the lake shore, and near the left bank of the river; Chief Civil Engineer A. G. Menocal arrived in camp at 2 p. m.; made a short reconnaissance up the left bank of the river, through a very fine country, and returned to camp. Seven days' rations on hand.

Wednesday, January 8.—Fine pleasant weather and fresh breezes from east. At daylight called all hands, went to breakfast, and started out to commence the line. At 7 a. m. started from and established station and bench-mark (as per level and transit-books) on the left bank of the river. Extended the line about 2,000 feet through a beautiful level valley, with a very gradual rise from the lake-shore, and dotted with cacao, indigo, and coffee plantations.

Thursday, January 9.—Weather still fine, with pleasant breezes from the eastward. Continued the line up the valley of the Medio, intersecting and crossing the river to the right bank about 4,000 feet from the lake; country a little more undulating and rising gradually from the lake-shore. At night reached the hacienda Castillo. Commander Lull visited the line.

Friday, January 10.—Pleasant weather and fresh breezes. Went back on yesterday's line about 200 feet, and commenced the line running a little more to the westward, through an open country, with occasional patches of woods and heavy undergrowth, making the cutting very hard and slow. Commenced taking cross-sections on the line every 500 feet, running 500 feet on either side. Shifted camp from the cafetal to the hacienda Castillo. Made a reconnaissance with Civil Engineer Menocal along the line as far as Las Serdas, on the Rio Grande, following the Medio to its junction with a small ravine near the hacienda of Jesus Maria, then following this ravine to its source near the summit, crossing the summit to another small ravine, and running down the western slope to the brook Chocolata, and this stream to the Rio Grande at Las Serdas.

Saturday, January 11.—Fine weather and fresh breezes. Extended the line through a rolling country in a southwesterly direction about 2,000 feet. Noticed very little rock along the line so far, but a short distance from it, in a cut about 12 feet in depth, saw considerable trap-rock cropping out, very soft and decomposed on the top.

Sunday, January 12.—Weather pleasant and cloudy, with occasional light showers of rain and light breezes from the north and east. All hands in camp reading and writing home, giving startling accounts of hair-breadth escapes from snakes, lizards, spiders, and various other reptiles too numerous to mention.

Monday, January 13.—Started on the line at 6 a. m. and commenced extending the line through a valley running about south 66° east to cut off a large bend in the river, but, finding we could not connect the line again with the river-valley without going over very high ground, went back a few hundred feet and commenced running the line more to the west, keeping nearer the river. At 4 p. m. stopped work and returned to camp. George W. Reed taken sick with dysentery and fever; sent him to headquarters for treatment. Fresh breezes from north and east and cloudy weather.

Tuesday, January 14.—Fresh breezes from east and north, with fine clear weather. Commenced work on the line, running about south 65° west, and nearly parallel to the Medio, 200 feet distant from the right bank. Saw some good-looking rock at this point suitable for building purposes, showing itself generally about 6 or 8 feet below the surface. Country rolling, with alternate patches of woods and brush, with occasional clearings. Worked through the hacienda Las Mercedes and reached the dam at San Felix. At 4 p. m. stopped work and returned to camp.

Wednesday, January 15.—Pleasant weather, with fair northeasterly winds. Packed up and shifted camp to the hacienda San Vicente. Started work on the line at 8.30 a. m. First Assistant Engineer Greene sick, Mr. Cropsey taking his place with the transit. Extended the line about 2,000 feet through a rolling country, covered with woods and dense undergrowth, filled with the pica-pica, a plant which, when disturbed, fills the air with a very fine dust, causing a most intense burning and itching when brought in contact with the skin, and giving us a good deal of trouble, as our line at times ran through immense tracts of it, making the cutting very slow and difficult.

Thursday, January 16.—Fine weather with light breezes. Went back on yesterday's line about 198 feet to change direction, and ran a cross-section at station 3,244. Mr. Greene taken sick and

obliged to return to camp. Continued the line along the river-valley, first running south 79° 10′ west and then changing to 72° 10′, through a rolling country, with occasional high hills on either side of the line. Extended the line about 3,000 feet and returned to camp.

Friday, January 17.—Commenced the line at the junction of the Medio Brook with the Camino de los Marinos to Rivas. The river along here is crooked and intersected by the line in several places. Extended the line about 2,600 feet.

Saturday, January 18.—Went back on the line 348 feet, to change direction to the left. Cut about 300 feet, when I encountered a dense growth of pica-pica, driving my macheteros nearly mad, finding it impossible to cut through. Went back, changing direction 20 feet more to the left to find better cutting, running through a level plain, about 400 feet wide, intersecting the river in several places with the line, and passing the hacienda San Vicente. At 4 p. m. stopped work and returned to camp. Commander Lull visited the picket to-day.

Sunday, January 19.—Strong breezes from north and east, with fine pleasant weather. Discharged Pablo Ortega, (mule-man,) and received another man in his place. Assistant Surgeon Bransford arrived in camp from La Virgen.

Monday, January 20.—At 7 a. m. commenced work on the line. First Assistant Engineer G. M. Greene returned to La Virgen with the doctor, having a severe attack of fever. Extended the line along a level valley, through which the Medio runs; the country on both sides of the line level for a distance of five or six hundred feet, and covered with woods and dry brush. At 4.30 p. m. stopped work in the narrowest part of the valley, about one mile from the hacienda of Jesus Maria, where a spur from the mountain to the north comes down to the river-bank, running in a north and south direction, meeting the range running east and west, and forming the south side of the valley. Extended the line about 2,500 feet.

Tuesday, January 21.—Fine weather continues. After breakfast shifted to camp Ella, on the hacienda Jesus Maria. Commenced work on the line at 8 a. m. Extended the line about 2,400 feet along the river valley, intersecting the river in several places. Very high hills to the south of the line, sometimes reaching the river-bank and then receding to a distance of from one to two hundred feet from it to the northward. To the north the ground rises on the bank of the river from 15 to 20 feet, and extends in a nearly level plain back some five or six hundred feet to the foot of a range of hills running to the north and east. At 2 p. m. reached the junction of the Medio with a small ravine called the Presa Nueva and nearly dry, where the line leaves the former river and follows the ravine to its source on the summit-level; cutting very hard, and plenty of "pica-pica." At 4 p. m. stopped work and returned to camp. Saw plenty of soft rock cropping out along in the vicinity of the picket.

Wednesday, January 22.—Light breezes and pleasant weather. Ran the line along the valley of the Nueva, the banks averaging about 10 feet down to the water, and covered with a dense growth of brush and woods. This stream is about 15 feet in width, and at the present time is nearly dry, only a small stream of water, about a foot in width and two or three inches in depth, running along its bed. The land rises on the right bank to 20 or 30 feet, and, extending back about 500 feet, comes to the foot of a range of high hills running toward the lake from the summit. On the left bank the country is rolling and extends back some 200 feet, where it meets the range of mountains running parallel to the lake-shore. At night received provisions and stores from La Virgen. Mr. McCrea reported for duty.

Thursday, January 23.—Commenced work on the line, extending it along the valley of the ravine. At station 191+54 obliged to make an offset of 103 feet to clear a patch of pica-pica that it was impossible to cut through, the ground in all directions being level for a distance of five or six hundred feet. From station 190 found the bed of the ravine perfectly dry. Examined a well at this point, and found decomposed trap-rock from 5 inches of the surface down to 4 feet, the depth of the well. At station 195 + 24 offset back to the line and 103 feet to the left, running through a level valley on the summit level. A few hundred feet beyond the latter station the ravine crosses a road leading to the right to Rivas and to the left to the Rio Grande. At 2 p. m. worked out of the brush on to a clear level plateau on the summit-level, about 500 feet in width and from twelve to thirteen hundred feet in length, on the left reaching the foot of the range of high hills running toward the lake, and on the right another range running at right angles to the line. Crossed the

divide, calling the depression, by direction of Commander Lull, Hatfield's Pass, and at 4 p. m. stopped work, after extending the line about 2 800 feet.

Friday, January 24.—Broke camp in the morning after breakfast and shifted to the hacienda Los Horcones, on the west side of the divide; commenced work on the line, extending it along a deep ravine running into the brook Chocolata, which empties into the Grande near Las Serdas; banks of the ravine from 20 to 30 feet in height; saw very little rock except detached pieces lying at the bottom of the ravine; width of ravine about 12 feet at the bottom, sloping back to about 50 feet at the top; ground nearly level for several hundred feet on either side of the line. At station 227 the ravine, after receiving another small run, passes through a gap in the hills to the right. At 4 p. m. stopped work, having extended the line about 2,700 feet.

Saturday, January 25.—Fine weather continued; commenced the line at station 247+93, where the picket passes behind a small knoll, about 30 feet high and 50 feet in diameter, and meets the river again, running nearly parallel to the left bank; ground on either side rolling, with detached hills from 30 to 50 or 60 feet high; noticed large quantities of rock in the river-bed and up the banks to within 3 feet of the surface, covered with a layer of sandy loam, with about one foot of vegetable mold on the surface; extended the line about 2,600 feet and returned to camp.

Sunday, January 26.—Fine, pleasant weather; after breakfast rode to La Virgen for money and stores with Mr. Cropsey; remained at La Virgen, waiting for the lake steamer to arrive, until 5 p. m., when she hove in sight and shortly after came alongside the wharf, but brought no mail. Mr. Cropsey suspended from duty by order of Lieutenant Commander Schulze. Overtaken by dark on the way back to camp and obliged to put back to Rivas for the night.

Monday, January 27.—At 7 a. m. started for camp, arriving at 8.15; started out with the party on the line, running the transit myself, Mr. Cropsey being under suspension and Mr. Greene sick at La Virgen; extended the line 3,500 feet along the valley of the Chocolata, and stopped work a few hundred feet from the casa of Las Serdas and near the Rio Grande, where the Chocolata empties into it. At 4 p. m. returned to camp, where I found Mr. Greene returned from La Virgen fully recovered from the fever.

Tuesday, January 28.—After breakfast started on the line; went ahead to make a reconnaissance and look for a transit-station and bench-mark of last year's line to connect our line with. At 11 a. m. found the transit-station and a bench near the junction of the Chocolata and Rio Grande; went back, changed direction, and connected the two lines, as described in the transit-book; went back, turned the line to the right, and commenced running down the valley of the Rio Grande, taking cross-sections every 500 feet and extending them 500 feet either side of main line; shifted camp to Las Serdas; fine weather through the day.

Wednesday, January 29.—Sent a muleteer to La Virgen for stores. Jos. Bruner, our rod-man, taken down with fever; took the rod myself with Mr. McCrea, to break him in for rod-man. At 4 p. m. returned to camp, when we received our mail up to January 9 from the United States.

Thursday, January 30.—Light rain early in the morning, clearing up by 8.30 a. m.; started macheteros and transit-party out for the line; waiting in camp for carrier to take mail to Brito for the tide-party under Mr. Niles; started one down, but he returned after getting lost, unable to find his way; started out with the level-party and finished the last of the 2,500 feet of cross-section below Las Serdas; continued the line along the river valley, taking its general direction. At noon the doctor arrived from La Virgen, and left at night for Brito with the mail.

Friday, January 31.—Moderate breezes and cloudy weather, with very heavy squalls of wind at intervals; started on the line at 7 a. m. and commenced running the line through a dense undergrowth of brush and pica-pica, and after a hard day's work succeeded in making about 1,000 feet.

Saturday, February 1.—Started on the line at 7 a. m.; weather cloudy, with fresh squalls of wind from north and west; Bruner getting worse with fever; sent to Brito for surgeon; extended the line along the river through a level country, well covered with heavy undergrowth of brush and vines.

Sunday, February 2.—Sent a message to La Virgen with letters and report of progress to commander; Mr. McCrea also went to La Virgen and returned, bringing some stores and a file of papers from Mr. Runnels.

Monday, February 3.—Strong breezes during the night, with very heavy squalls of wind and rain; after breakfast broke camp, packed up, and started for Las Juntas to repair some hut

to live in; started with party for the line, but some got lost, so that it took the rest of the day to find them and get into our new camp. No work on the line to-day.

Tuesday, February 4.—After breakfast started a courier for La Virgen with the level and transit books and with a requisition for stores; extended the line about 2,800 feet along the left bank of the river. At 4 p. m. stopped work and returned to camp.

Wednesday, February 5.—Started on the line after breakfast and extended the line along the river-valley, intersecting the river in several places; struck the picket of last year at station 173; changed direction and followed old line to station 183, near the junction of the Grande and Tola Rivers; country mostly level on either side of line for a distance of 500 feet. At night received stores from La Virgen.

Thursday, February 6.—Started early on the line; sent to Brito for the mail of the tide-party, also to Rivas for sugar and fruits; extended the line about 2,800 feet, through a level country, thickly wooded. At 4 p. m. stopped work and returned to camp; received a letter from La Virgen restoring Mr. Cropsey to duty; sent to La Virgen for stores.

Friday, February 7.—Extended the line through a level country, well wooded, as far as La Flor, when we stopped work and returned to camp.

Saturday, February 8.—Fine weather; after breakfast broke camp and moved to La Flor, arriving there at 11 a. m. with first load, where I found Commander Lull, Mr. Menocal, Don Max, and Mr. Hawley on their way to La Virgen from Granada; repaired the huts and built two tents. At 5 a. m. the mules arrived from Las Juntas with remainder of stores and people; transit-party running a traverse of the Rio Grande from Los Juntas to La Flor.

Sunday, February 9.—Fine weather; sent muleteer to Brito with letters and stores for tide-party, also to Tola for provisions and plantains.

Monday, February 10.—Started party on the line after breakfast, unable to go myself owing to an attack of sickness; at noon Charles Mays arrived in camp from La Virgen with orders to send Mr. McCrea to headquarters at once; sent Mays to the line to run the rod and ordered Mr. McCrea to La Virgen; extended the line about 3,500 feet and returned to camp.

Tuesday, February 11.—Sent to La Virgen for bread and bacon; Bruner still sick with fever and no prospects of getting better; sent him to headquarters for treatment; extended the line through a level plain, thickly wooded with dense undergrowth.

Wednesday, February 12.—Fine weather with fresh breezes. At 7 a. m. commenced work on the line, running through a level country for several hundred feet on either side of the line and covered with a dense growth of brush and vines, making the cutting very difficult at times; extended the line about 5,000 feet, and connected with last year's line about two miles from the port of Brito; at this point the country becomes very hilly and continues so to near the tide-station.

Thursday, February 13.—After breakfast started the transit-party out to complete running a traverse of the river between La Flor and Las Juntas, and proceeded with the other party to connect the levels with the tide-gauge at Brito, which we succeeded in doing, and returned to camp at 5 p. m., where I found the transit-party already returned, having finished the traverse of the river. Master J. M. Hawley arrived in camp, with boring-apparatus, men, and mules, to make some borings along the line between Las Serdas and Brito; received stores from La Virgen.

Friday, February 14.—Fine weather, with light breezes. After breakfast boring party started out and commenced work near La Flor; sent stores to Mr. Niles at Brito, he having run short; all hands in camp washing. At 2 p. m. Commander Lull arrived in camp with the assistant surgeon, and orders to run a few cross-sections on the line where it intersects the river Grande, and also to locate a few points with the transit at Brito.

Saturday, February 15.—Fine weather and fresh breezes. Sent transit-party to Brito, also boring party, and started out with compass and level to run cross-sections at station B, 216, old line; finished the work and returned to camp at 2 p. m. At night transit-party returned from Brito, having finished their work there, the boring party remaining to complete their work in that vicinity.

Sunday, February 16.—Mr. Hawley returned from Brito with boring party; muleteer returned from Virgin with stores; discharged Francis Quiros, machetero, with orders to Mr. Chamorro for payment.

Monday, February 17.—After breakfast broke camp and started with working party to sketch

a plan of the junction of the rivers Tola and Rio Grande and determine the elevation and inclinations of their beds. Finished cross-section at station 177, old line, and established camp at Las Juntas.

Tuesday, February 18.—After breakfast started out with party to run cross sections at station 170, old line; the station was found and the work completed by noon, when we returned to camp. Francisco Quiros returned to camp. At 5 p. m. courier arrived from Commander Lull, with mail and orders to proceed with my party to near the hacienda Castillo, in order to improve the line in that vicinity in several places, as per map and instructions.

Wednesday, February 19.—Broke camp at daylight and shifted to the hacienda San Felix, on the left bank of the Medio. Heavy rain-squalls in the forenoon and clear in the afternoon; all hands in new camp by 4 p. m.

Thursday, February 20.—Started out early for station 10, and commenced running a new line toward the lake to connect with previous line at station 8; extended the line 4,400 feet through a rolling country, covered with dry brush and pica-pica, and returned to camp; discharged our muleteer, Paulino, or rather he discharged himself and got into jail.

Friday, February 21.—Extended the line 17,400 feet, completing the work contained in my orders from Commander Lull; returned to camp and discharged all the macheteros, retaining the muleteers and obtaining eight more animals to move my party to Virgin Bay.

Saturday, February 22.—Packed up in the early morning and sent the men and stores to Virgin to report to headquarters. Went to Rivas with the officers, where we met the commander, took breakfast, and returned to Virgin, and turned our stores and party to Lieutenant Commander Schulze. Remained at Virgin until the 28th instant, waiting for the lake steamer, Commodore Adams, to transport us across the lake.

Operations in the valley of the San Juan.

Tuesday, March 4.—Arrived at San Carlos, proceeded down the river, and at 4 p. m. landed and established Camp Grant, on the Zavalo River, near its confluence with the Rio San Juan.

Wednesday, March 5.—At 5 p. m. left Camp Grant with party and proceeded down the river in the steamer Castillo to Castillo, where we arrived about 6 p. m., and remained on board the steamer during the night. Weather warm and pleasant.

Thursday, March 6.—At daylight landed with the party opposite Castillo and established Camp Dump, occupying some old huts near the bank of the river. At 9 a. m. several soldiers were sent over to us to act as macheteros. At 11 a. m. Commander Lull visited the camp. At 12 m. started a level and transit-line from the left bank of the San Juan River, about 2,000 feet below Castillo, and extended the line 1,700 feet to the northeast, over a broken country. Weather fine and clear.

Friday, March 7.—Started at 6.30 a. m. and extended the line through a very rough and swampy country, covered with a dense growth of brush and vines, for a distance of 3,500 feet. At 4.30 stopped work and returned to camp. Weather fine, with occasional squalls of rain.

Saturday, March 8.—Weather rainy and squally; went out with the party and extended the line 3,100; country broken and swampy, with very thick brush and vines, making the cutting very hard; at 4 p. m. returned to camp.

Sunday, March 9.—All hands in and about camp; weather rainy and squally.

Monday, March 10.—Cloudy weather and rain-squalls; extended the line 2,100 feet; crossed the stream Juan running into the San Juan; owing to the heaviness of the wood on hand had some difficulty in building a raft to cross the party over.

Tuesday, March 11.—Started party out on the line; shifted camp to about two miles below Castillo, on the left bank of river; camp named Hollenbeck; extended the line 1,199 feet, and struck a range of hills averaging 100 feet in elevation. At 2 p. m. stopped work and started for the new camp, making at the same time a reconnaissance between the line and the river, when it was ascertained that the range of hills extended to the river-bank.

Wednesday, March 12.—Weather fine and pleasant, with occasional rain-squalls; extended the line about 4,100 feet over a very rough and hilly country; rock was seen in the bed of ravines and cropping out on the hill-sides.

Thursday, March 13.—Worked on the line all day, with fine, pleasant weather; extended the line 3,100 feet over a rough and hilly country; received stores from headquarters.

Friday, March 14.—Dark, gloomy weather, with heavy rain, until 1 p. m., when it cleared up. At 7.30 a. m. started for the end of the line with the party in the flat-boat, and after a march of three hours and getting lost in the woods with the whole party we found our picket and resumed the line, diverting it to the right to avoid running over some high hills; made a reconnaissance about a mile ahead of the line, through a level country, thickly wooded with dense undergrowth; sent a courier to the commander this morning; also sent Perry back to headquarters, he having a lame foot and unable to work on the line; shot a wild hog on the picket, cleaned him, and took him to camp; stopped work and returned to camp, having extended the line about 2,000 feet; cutting very hard and difficult; cut an offset to the river.

Saturday, March 15.—Started out with party in the canoe and landed at yesterday's offset to the river; commenced work on the line, running through a slightly rolling country, thickly wooded; at noon crossed a large estuary about a mile above the Bartolo River; weather rainy, with light breezes from the east; at 4 p. m. returned to camp in the canoe; wet, rainy weather throughout the day; all hands in camp; at night a flock of wild turkeys flew overhead, and we succeeded in persuading a couple of them to remain and dine with us on Monday.

Monday, March 17.—Heavy rain all day; shifted camp to the junction of the Bartolo and Rio San Juan, establishing Camp Runnels; killed several snakes during the day.

Tuesday, March 18.—Raining hard all the forenoon, and, much to our disgust, we found that some of our shelter-tents leaked badly. However, we managed to keep a little of the wet off by crawling under our rubber-blankets, where we sat and laughed and growled alternately until the rain abated, when we started for the line, and succeeded in running about 1,600 feet between the showers. At 4 p. m. returned to camp.

Wednesday, March 19.—Heavy rain-squalls through the day; party started on the line and ran about 2,500 feet; made a reconnaissance with Mr. Menocal from the Bartolo to see if we could cut off the bend in the river, and came out below the Balas Rapids; line was found impracticable on account of high hills; cut an offset to the river from the end of our reconnaissance, coming out near the wood-shed at the foot of Balas, where we met the river-steamer Castillo on her way up the river; went on board and returned to camp.

Thursday, March 20.—Went on the line, and worked 2,600 feet through a very rough and broken country, covered with a heavy growth of woods, brush, and vines, making the cutting very difficult; at 4.30 returned to camp; weather fine during the day.

Friday, March 21.—Fine, pleasant weather during the day; Lieutenant Leutze and Mr. Menocal started for Castillo in the canoe, landing the level-party on their way up the river near the last bench-mark; started out with the transit and macheteros and extended the line about 2,500 feet, crossing the Bartolo River.

Saturday, March 22.—Weather dark and rainy; heavy rain through the night; started out early and made reconnaissance to left of the line, looking for a valley, but finding nothing but a range of mountains returned to the line, and continued it south 4° east about 400 feet; changed direction to south 60° east, running through a ravine and to the top of another hill, when we changed direction again to south 25° east to fall into a valley a few thousand feet off; country very broken and hilly; extended the line about 3,000 feet and returned to camp; found a wild cow a short distance from camp, shot her, and refreshed ourselves with beef for two days.

Sunday, March 23.—Fine, pleasant weather; pulled up the Bartolo River for about two miles, when I found two sets of rapids of about 2 feet fall in 50 feet; shot some very fine fish at the foot of the rapids, and on the way back to camp captured a fine fat turkey and a marsh-hen.

Monday, March 24.—Opens with dark, gloomy weather; started on the line, running through a narrow valley about south 25° east; extended the line about 2,800 feet and returned to camp; hard rain from 10 to 11 a. m.

Tuesday, March 25.—Fine, clear weather, with moderate breezes, through the day; after breakfast started the level-party out on the line and with the rest of the men shifted camp to the lower part of Balas Rapids, where camp Don Max was established; Commander Lull left camp this morning in a canoe for Castillo; level-party returned, having worked up to the end of the line.

Wednesday, March 26.—Started on the line after breakfast and commenced running about south 70° east; after running a few hundred feet changed direction to south 17° east, to get into the river-

valley, as our farther progress in this line is blocked (as it always has been so far whenever we attempt to leave the river) by a range of mountains; heavy rain through the night, some of our tents leaking badly already, causing a great deal of discomfort to those unfortunate enough to be under them; extended the line 4,700 feet.

Thursday, March 27.—Weather cloudy and cool; started out with Mr. Menocal and three men to make a reconnaissance to ascertain the practicability of cutting off the bend from Balas to lower part of Machuca; and, after a hard tramp of about two and a half miles, through a broken and hilly country, found it impracticable to leave the bank of the river and returned to camp. Heavy rain during the night.

Friday, March 28.—Weather pleasant, with occasional rain-squalls; extended the line 2,500 feet, but struck hills again and were obliged to go back and keep still nearer to the river. At 4.30 returned to camp and made a reconnaissance down the river in a canoe as far as head of Machuca; light showers during the night.

Saturday, March 29.—Dark, gloomy weather and raining hard until 9 a. m.; started out with the party and extended the line about 4,000 feet on the left bank of the river; at 10 commenced raining again and continued nearly all day; at 2.30 p. m. the steamer Castillo passed up the river with Paymaster George W. Bemis on board and several men and stores for the expedition; sent a canoe alongside and got bread and sugar; Mr. Leutze went to Castillo for stores this morning; discharged one of my macheteros, a useless and mischievous individual; Mr. Leutze returned at night with two men for his party and the doctor, Assistant Surgeon Bransford, U. S. N.; mail arrived in camp to-night by a canoe hired at Castillo by the officers.

Sunday, March 30.—Weather cloudy, with light rain during the morning; at 11 a. m. the Castillo passed down the river; several parties out looking for game, but returned unsuccessful; shot two turkeys in camp toward evening.

Monday, March 31.—Weather pleasant and cloudy throughout the day; party employed running a new line between stations 338 and 413; remained myself, feeling indisposed; at 1.45 the Castillo came up the river with stores for the party; at 2.30 the party returned to camp, having run the new proposed line between the above-mentioned stations.

Tuesday, April 1.—No rain during the night, and clear, pleasant weather throughout the day, for the first time since commencing work on the San Juan River; started on the line after breakfast, and extended it about 3,700 feet, over a very rough, broken country; the line running near the left bank of the river; received our mail from Castillo by a canoe hired at our request by the medico; Commander Reed, of the Kansas, visited our camp during the afternoon.

Wednesday, April 2.—All hands in camp waiting to shift down the river, but, as our flat-boat is in use by the company on the river, we must wait until they return her to us. At daylight sent canoe up to the wood-station, and on her return received stores and six macheteros, to be divided between the parties; Butts also returned from headquarters, relieving the man acting as rear chainman; sent Quevedo to headquarters; at night the Castillo returned our flat-boat.

Thursday, April 3.—At daylight broke camp, packed up everything in the flat-boat and canoes and started down the river, and after passing safely over the Machuca Rapids landed and established Camp Benard; during the afternoon heard the report of the torpedo toward the rapids; weather fine and pleasant.

Friday, April 4.—Started for the line at 6 a. m. and after a very hard and fatiguing tramp of two hours arrived at the end of the line and commenced work; extended the line about 5,400 feet through a rolling country, thickly wooded, with heavy undergrowth; at 3.30 stopped work and returned to camp; at night Paymaster Bemis, of the Kansas, visited camp and disbursed money to the officers and men.

Saturday, April 5.—Fine, pleasant weather, with a few showers during the first part of the night; started on the line after breakfast; shot a turkey on our way, and sent him to camp for dinner; extended the line about 3,000 feet, making offsets to the river at intervals and triangulating the Machuca Rapids; country very rough and broken, the high hills to the left in some places coming to the water's edge; at 4 p. m. stopped work and started for camp; saw large quantities of mountain-hens; shot one and took him in for our Sunday dinner.

Sunday, April 6.—Considerable rain during the night, clearing up toward morning with fine, pleasant weather; party No. 1 packed up and got ready for an early start in the morning for the Serepiqui River; winds, with squally weather and light rain.

Monday, April 7.—At daylight party No. 1, accompanied by Mr. Menocal, started in the flat-boat for the Serepiqui River; weather cloudy and threatening; at 6 a. m. started for the line, extending it about 800 feet; cut an offset to the river and continued the triangulation of the rapids; at 11 a. m. resumed the line, extending it 3,200 feet; country level, but thickly wooded for about 600 feet from the river, where the ground suddenly becomes broken and hilly; frequent showers during the day.

Tuesday, April 8.—Weather cloudy and threatening; commenced work on the line through a rolling country; at 10 a. m. reached and crossed the Machuca River; extended the line about 3,400 feet, and returned to camp.

Wednesday, April 9.—Fine weather through the day; extended the line about 4,000 feet, through a very rough and broken country, and returned to camp. Received from the Pit Pan five kegs of bacon and five boxes of bread.

Thursday, April 10.—Packed up at daylight and shifted camp about two and a half miles down the river, where we landed and established Camp Bemis; during the day shot two wild hogs, three turkeys, and three mountain-hens close to our new camp; weather cloudy, with rain toward night; received our mail via Granada by a canoe bound down the river.

Friday, April 11.—Weather cloudy and rainy; employed clearing up and finishing our camp; at 10 a. m., weather clearing up, took the canoe and started for the line, where we arrived and commenced work at 11 a. m., running through a low swampy country, covered with a dense growth of the coyol palm; at 4 p. m. returned to camp. Saw large quantities of wild hogs along the line. Commander Lull passed down the river in the Pit Pan.

Saturday, April 12.—Weather cloudy and rainy; at 8 a. m. commenced work on the line, extending it about 5,200 feet through a level country on and close to the left bank of the river; game of all description in great abundance, especially the mountain-hen.

Sunday, April 13.—Weather cloudy and rainy; took a walk with my shot-gun before breakfast, and shot a turkey for dinner.

Monday, April 14.—Fine weather during the night and morning; at 6 p. m. started out with the party and commenced extending the line along the bank of the river, through a level country; at 10 a. m. struck a spur of hills coming to the bank of the river and passed over the side within 30 feet of the river; extended the line about 5,000 feet.

Tuesday, April 15.—Dark, rainy weather; succeeded in extending the line about 3,400 feet through a rolling country covered with woods and dense undergrowth, making the cutting very hard; shot a turkey.

Wednesday, April 16.—Heavy rain through the night; at 7 a. m., clearing up a little, started for the line; shot a turkey soon after leaving camp; spoke the Pit Pan, with Commander Lull on board, who ordered us to bench off and return to camp, preparatory to starting for the San Carlos River to resume our line at that place; went to the line and established permanent stations and bench-mark, and returned to camp; end of line at transit-station 90,304; bench-mark on left side of picket on tree 90,304 feet from origin at Castillo; on our return shot a mountain-hen near our camp. Commander Lull in camp.

Thursday, April 17.—Rainy weather in the first part of the morning; by 8 a. m. weather cleared a little; loaded up the canoes and started to find a new camp, and after a tiresome pull of four hours landed about 3,000 feet below the San Carlos River, on the left bank of the San Juan, where Camp Chamorro was established; left three men in charge of stores and started back for camp, where we arrived at 8.30 p. m., tired and hungry.

Friday, April 18.—Fine weather, with only one or two light showers in the morning; after breakfast packed up and started with rest of party to the new camp, leaving Commander Lull with two men behind to come down in the steamer.

Saturday, April 19.—Fine, clear weather; after breakfast started in the canoe for a point about one mile above the San Carlos River, at the commencement of the bend running south 70° west. A

permanent station and bench-mark were established, and commenced running south 86° east; after going 2,500 feet over a rough and hilly country struck the river again opposite the mouth of the San Carlos; extended the line about 3,600 feet.

Sunday, April 20.—Heavy rain all night; at 6 a. m the Castillo came up the river and landed Mr. Menocal, who had come up from the Juanillo, where party No. 1 is now located.

Monday, April 21.—Opened with calm, fine weather; at 7.20 a. m. commenced work on the line, running through a very rough country, covered with dense woods; at noon cut an offset to the river, coming out near our camp; took lunch and started on the line again, but at 2 p. m. it commenced to rain in torrents, obliging us to stop work and run for camp, where we arrived drenched to the skin; extended the line 3,500 feet.

Tuesday, April 22.—Raining hard all night; at 7 a. m., clearing up a little, started for the line and ran about 1,000 feet, where we met a range of mountains, and were obliged to go back 1,100 feet; cut an offset to the river and continued the line near the river-bank for a distance of 1,600 feet, when we were again driven in by the rain; on arriving in camp found the Commander had sent the two men down in a canoe and gone himself to Castillo to visit the hydrographic party coming down the river.

Wednesday, April 23.—Weather overcast and cloudy, but no rain; commenced work on the line at 7.45 a. m., running through a level country near the bank of the river; extended the line about 5,000 feet; cut an offset to the river.

Thursday, April 24.—Fine weather and no rain; grub getting very scarce; looking anxiously for a canoe from headquarters with supplies. Extended the line 5,700 feet through a rough, broken ocuntry, with an occasional hill from 40 to 60feet in height, and the farther you recede from the river the higher the hills get.

Friday, April 25.—Fine, dry weather, with every prospect of keeping so for the day at least, so I made up my mind to shift camp, and, after breakfast, pulled up stakes, loaded the canoe, and started down the river, leaving one man to look after the stores until the canoe would return for them; established the new camp about six miles below San Carlos, on a sandy point on the left bank of the river—a beautiful location for a camp, having the full benefit of any breeze blowing up the river, plenty of sun during the day to dry hammocks and clothes, good bathing facilities, and, above all, a fine promenade on which to take our evening walk and smoke our cigars before turning in at night. At sundown a family of six persons landed to spend the night with us on their way to Costa Rica.

Saturday, April 26.—Turned out at daylight, walked down the beach with my shot-gun, and shot a number of snipe and plover for breakfast. Went on the line and worked until 12 m., making about 2,000 feet through a level country, but covered with a dense growth of brush and vines. On the way back to camp landed at a deserted house, with a plantain patch, and got a fine lot of plantains and bananas and also a lot of delicious limes, all of which were very acceptable.

Sunday, April 27.—Fine, pleasant weather during the day. After breakfast took the canoe and, with Mr. Menocal, started down the river in search of provisions, and after a very tedious pull of three hours reached the first house, about two miles above the Serepiqui, where we landed, and succeeded in obtaining a few eggs and some fruits; proceeded to the junction of the Serepiqui, where we obtained some more fruit, eggs, and sugar, and at 1.30 started back for camp; but after working hard until midnight made fast to the bank to let the men rest and get a nap.

Monday, April 28.—At 5 a. m. got under way, and at 8 a. m. arrived in camp, completely fagged out. I concluded not to go out on the line, but give the men a day's rest. Fine, pleasant weather during the day.

Tuesday, April 29.—Weather cloudy and rainy. At 6.30 started for the line, arriving there at 8 a. m.; extended the line about 3,800 feet, through a rough, broken country. At 11 a. m. the Castillo stopped abreast the end of the line and hailed for a boat; boarded her, and found Commander Lull with provisions and a small canoe for the party. At 4 p. m. returned to camp. Raining hard.

Wednesday, April 30.—Fine weather and light breezes. At 6.30 started for the end of the line and commenced work at 7.30 a. m. Extended the line about 4,000 feet, through a very broken

country, the hills extending to the water's edge, and some of them from 80 to 100 feet high. Heavy rain during the afternoon. Killed a large snake. At 4 p. m. started for camp, and on the way scared up a flock of turkeys. Shot two.

Thursday, May 1.—A beautiful bright May morning, making us all wish we were at home. At 6 a. m. started out and commenced work, running through the same rough country as yesterday until noon, when we fell into a beautiful level plain, with high undergrowth. Extended the line 7,300 feet and returned to camp.

Friday, May 2.—Fine weather during the day. Extended the line 5,400 feet, mostly through a level country. At 4 p. m. stopped work about a mile below the camp.

Saturday, May 3.—Fine weather and pleasant breezes. Remained in camp myself on account of indisposition. At 6 a. m. party started out in charge of Lieutenant Moser, and continued the line, over a very rough country, a distance of 4,700 feet.

Sunday, May 4.—Fine weather. At 8 a. m. Commander Lull arrived in camp from Greytown with a canoe-load of provisions for the party, and remained in camp waiting for one of the river-steamers to go up to Lieutenant Miller's party at Castillo. Daniel also came up with the commander, and reported for duty as cook.

Monday, May 5.—Light showers of rain up to 5 a. m., when it commenced clearing up. Started out and extended the line through a very rough and swampy country a distance of 7,000 feet, where we cut an offset to the river and started for camp in the canoe. Shortly after the Pit Pan came up the river with Mr. Hollenbeck on board, who very kindly took us to camp. Commander Lull left camp and went up the river in the steamer.

Tuesday, May 6.—Fine pleasant weather. Continued the line over a swampy country 5,000 feet. At 4 p. m. stopped work and started for camp, where we arrived at 8 p. m.

Wednesday, May 7.—Broke camp in the morning, and in two canoes and a balsa went down the river with party and established Camp Reed, on the right bank of the river, about a mile above the river Remolinito. Weather fine and pleasant.

Thursday, May 8.—Fine weather and light breezes. Macheteros refused to go to work this morning; stopped their breakfast, and promised them that they should have it as soon as they were ready to work, and in fifteen minutes they had all changed their mind and were anxious to go to work again. Went on the line and extended it 5,300 feet through swampy ground. At 3 p. m. cut an offset of 3,000 feet to the river and returned to camp, arriving there at 5 p. m.

Friday, May 9.—Left camp at 6.15. Mr. Menocal sick in camp; continued the line for a distance of 5,600 feet; cut an offset to the river of 1,000 feet and returned to camp. Weather fine.

Saturday, May 10.—Weather clear and warm. Ran 8,800 feet on the line through an undulating country, the last transit-point reaching the river San Francisco near its junction with the San Juan.

Sunday, May 11.—Fine weather during the day. Shot an armadillo near the camp, and caught a fine mess of fish near the opposite bank of the river.

Monday, May 12.—Fine pleasant weather all day. Started on the line at 6.30, running through a level swampy country, thickly wooded, with a dense mass of dry brush and undergrowth, making the cutting very hard and tedious. Prolonged the line 7,700 feet. Cut an offset to the river and returned to camp. During the day Commander Lull visited the camp on his way down the river to go to Monkey Point in the Kansas. Assistant Surgeon Bransford reported for duty in camp.

Tuesday, May 13.—Weather fine and clear. Unable to leave camp myself to-day on account of a severe attack of cholera morbus during the night, leaving me very low and weak. Party started out and extended the line about 4,700 feet, through about the same kind of ground as described yesterday. Mr. Menocal, with two men, made a reconnaissance to the northeast, to discover a lagoon reported to be in that direction; he returned, however, after traveling about five miles, having only found a clear and swampy space, nearly dry.

Wednesday, May 14.—Fine clear weather throughout the day. At daylight started with the party in the canoes and balsa, and after three hours' pulling down stream landed on a sand-bank on the left side of the river, and established Camp "Farewell" about two miles above the Serepiqui.

Thursday, May 15.—Fine weather with light breezes. At 6.30 party started for the line in the canoe. At 3 p. m. the hydrographic party under Lieutenant Miller arrived opposite our camp, with their work, and camped with us for the night. At 5 p. m. party returned to camp, having extended the line 7,500 feet and having passed one hill 120 feet high.

Friday, May 16.—At 6.30 both parties started for their work. Weather continues fine. At 4 p. m. party No. 2 returned to camp, having extended the line 6,000 feet through a rolling country of swamp and woodland. At 4 p. m. the Castillo passed up the river; boarded her and got our mails and provisions.

Saturday, May 17.—Arrived at the end of the line at 7.30 a. m. Weather cloudy, with occasional rain, clearing up by noon. Continued the line about 8,000 feet through a swamp, and returned to camp by 4 p. m. Shot a fine turkey on the way home. Hard rain during the night.

Sunday, May 18.—Dark, gloomy, warm weather, with light rain, accompanied with thunder and lightning. Chartered a canoe for 30 cents a day, agreeing to send her back from Greytown by the first opportunity and be delivered to Mr. Diezman, at the junction of the Serepiqui on the San Juan.

Monday, May 19.—Party started at 5 a. m., expecting to connect the line with station and bench-mark established by Lieutenant Leutze, opposite the mouth of the Serepiqui. Packed all the stores and left them at Mr. Diezman's to be sent to Greytown by the steamer, as we were unable to carry more than the instruments and our personal baggage in the canoe. At 6 p. m. connected with Lieutenant Leutze's station and bench mark, thus finishing the work. Started back to camp and made preparations to start for Greytown. Heavy rain all night.

Tuesday, May 20.—Weather clearing up. At 7.10 a. m. started with the party in the canoes for San Juan del Norte. At 10 a. m. met Commander Lull, just above the Colorado River, on his way up to our camp. Stopped at Barnes' Station, just below the forks of Colorado and San Juan Rivers. Took lunch, and after transferring some of our baggage from our canoe to that of Commander Lull, proceeded for Greytown, and after a hard pull of eight hours arrived at that place and reported to Commander Lull, who had arrived some time ahead of us.

Very respectfully, your obedient servant,

W. W. RHOADES,
Lieutenant Commanding Party No. 2.

Commander E. P. LULL, U. S. N.,
Commanding Nicaragua Surveying Expedition.

JOURNAL OF HYDROGRAPHIC PARTY, SAN JUAN RIVER, LIEUT. J. W. MILLER, *Commanding.*

CAMP LULL, INDIAN ISLAND, TORO RAPIDS, SAN JUAN RIVER.

April 3.—The following is a correct list of the officers and men composing hydrographic party: Lieut. J. W. Miller, U. S. N., commanding, triangulation-levels and topographical notes; Master K. Niles, sounding-boat; Ensign J. H. Bull, level-book; Hamilton Browne, apothecary; John Quevedo, machinist; Frank Russell, machinist; John McSherry, seaman-extra; John Myers, seaman-extra; Timothy Sheehan, ordinary seaman-extra; William Clark, ordinary seaman; W. H. Latimore, carpenter's mate; William Perry, ordinary seaman; Walter Young, cook; one native machetero.

Lieutenant Miller arrived from Castillo with stores. Engaged in making a tripod for *gradienter.* Procured a launch from Colonel Hanger for use of party. Walter Young taken sick with *calentura.* Sent a party up Zavalo River for wild hogs and turkeys. Quantities of wild pigeons about camp.

April 4.—Engaged in fitting up boats for river work. Succeeded, after many attempts, in finishing tripod. Clear. Light easterly breeze, with squalls about 12 meridian.

April 5.—Finished fitting up boats, and stowing provisions and instruments. Unfortunately no place left for sleeping. Took the launch and boats to Hanger's Point, ready for a tow up river from the steamer Panaloya. Clear and warm. Cool at night.

April 6.—Commander Lull arrived in a canoe from Castillo at 9 a. m., reporting the steamer broken down. Obtained a coil of rope and sweeps from Colonel Hanger, to be used in assisting the boats up stream against the current. Clear and warm.

April 7.—Called all hands at 4.15 a. m. Served out coffee, and started up river with fleet of following vessels: Hanger's launch, (the Don Guillermo,) dinghy, balsa, and canoe; launch in tow of dinghy, and balsa in tow of launch; canoe acting as "flying cruiser;" balsa flag-ship. Experiencing heavy currents above Hanger's Point, took line ahead to river-bank, and hauled launch through the rapids and whirlpools. At 9.40 came to, and went to breakfast. At 2 p. m. fresh breeze springing up from northward and eastward. Made sail to dinghy's awning on launch, and hoisted dinghy's mainsail; canoe under foresail of rubber-blanket. At 6 anchored in middle of stream. Called "all hands repel boarders" and rigged mosquito-bars. Launch leaking badly. Walter Young (cook) left behind, sick, in charge of Hamilton Browne, apothecary.

April 8.—Turned out at 2 a. m., and found that the rain and various leaks had filled the launch half full of water. Pleasant, as we were anchored with two fathoms of it beneath us and over us the nettings and a double awning. Stores and clothes wet through. After diligent search fished Commander Lull's knapsack out of the depths of the hold. Resolutions of sorrow to commanding officer for inhospitable treatment on this his first visit. At daylight discovered a large hole in stem of launch; calked it, and nailed over it the bottom of a bread-can. At 7 a. m. started ahead under oars; strong current. At 3.30 p. m., fresh breeze springing up, made sail. Anchored for night at 7 p. m. No leaks and the sleep of the just.

April 9.—Arrived at San Carlos at 3 p. m. At 5.30 ran a line of soundings into the lake on west ½ north course from San Carlos Bluff. Captain Lull and officers paid an official visit to the comandante of the fort. Clear and pleasant.

April 10.—Steamer Adams arrived from Granada at 2.30 a. m. Commenced survey of river at 7 a. m. Adjusted instruments and surveyed about one mile down stream. At 10.30 p. m. steamer Panaloya went up the river. Fresh easterly breeze during the day; calm at night.

April 11.—At 3.30 Panaloya came down from San Carlos, having on board Hamilton Browne, apothecary. Commander Lull left for Castillo. The river here abounds in quantities of fish; caught one hundred and ninety in the *sacate* grass near banks. As the men have time to fish while the officers are taking observations, no danger of running out of provisions.

April 12.—Clear and pleasant. Strong easterly breeze during afternoon. Calm at night, with fog and dew. River-banks very undefined, making progress slow.

April 13.—Sunday; no work. Lieutenant Miller and Ensign Bull went to San Carlos for fresh beef. Full moon and lovely weather.

April 14.—Fitted up new beds from the branches of the palms which line the banks. Surveyed about two miles, the banks being more solid. Clear weather.

April 15.—Rain interfering very much with survey and comfort. At 12 passed the mouth of Rio Melchora. First hill at its mouth. River here full of rocks. Current more rapid; also, movements of Lieutenant Miller, as he tries to avoid a ten-foot alligator at Gradienter Station No. 78. Boat from steamer Adams brings down a barrel of flour for use of party.

April 16.—Surveyed about one and one-half miles. Clear, pleasant weather. Pass the residence of the "last of the Zavalos," this chief being a dignified Indian who tries to make Mr. Niles present him with his bowie-knife for three fish.

April 17.—Making good progress, notwithstanding the light showers.

April 18.—Pass the Medio Queso River; work delayed on account of difficulty in finding any solid banks. Received a mail by steamer Pit-Pan.

April 19.—Surveyed over two miles down stream; sent a mail by the down-river steamer. Commanding officer, with his usual severity, decides that the boats are not intended to be a "floating menagerie." Results: one wounded monkey drowned; one sloth expended; one parrot sent to Castillo; and Luck, the tiger-cat, confined to a locality where she cannot innocently eat mosquito-nets, nor nibble, during the quiet of the night, at our unoffending toes.

April 20.—Sunday; no work. Palm-trees about camp catch on fire; no damage done, as the wind is off shore; woods burning far into the interior as we leave at night.

April 21.—Surveyed about one and three-quarter miles. The Pit-Pan went down the river; sent an official letter to Captain Lull. Heavy showers, with thunder and lightning during afternoon; light rain about midnight. Shot several ducks.

April 22.—Making good progress; banks quite solid. Roast duck on toasted hard-tack is a delectable dish. Clear and pleasant; fresh, easterly breeze.

April 23.—Foggy in the morning. Surveyed about two and one-half miles. Light shower during middle of day; heavy dew at night.

April 24.—Passed the mouth of Rio Chico; extended, grassy flats on left bank retard work very much; saw quantities of alligators. Received one hundred plantains from Commander Lull.

April 25.—Clear and pleasant. End survey for the night at wreck of steamer La Virgen. Gauged the river by means of floats; current becoming quite rapid, and banks higher, with hilly land back.

April 26.—Clear, warm, and pleasant. Reached Hanger's, at mouth of the Zavalo River, about 4.30 p. m. F. Russell, machinist, taken seriously ill with bilious fever.

April 27.—Sunday; no work. Thanksgiving that we are through with the worst part of the work; officers dine with Colonel Hanger; a knife and fork all around, and other luxuries duly appreciated. H. Browne, apothecary, took Frank Russell, machinist, to Castillo in the dinghy, and returned at 7 p. m. Saw a large tapir under lee of Indian Island; got off before we could get a shot at him.

April 28.—Clear and pleasant; gentle easterly breeze. Surveyed through Toro Rapids. At 1 p. m. steamer Panaloya came up, bringing Assistant Surgeon Bransford, with Walter Young, cook. Dinghy nearly swamped in whirlpool off Punta Vaca. The launch, (Don Guillermo,) having left our Luck (the tiger-cat) at Camp Lull, ran on a rock in the strongest part of the rapids, but providentially floated off without receiving material damage. All the party much exhausted with hard day's work.

April 29.—Light drizzling rain between 10 and 11 a. m.; shower at 1 p. m.; cloudy rest of day; high rocky hills and high banks; thick forest of large trees; soil stiff, yellow clay.

April 30.—Cloudy in the morning; fresh easterly breeze; river narrow; making good progress; latter fact, combined with mail by steamer Panaloya, keeps the party in best of spirits. Lieutenant Miller very badly stung with wasps while cutting for a gradienter station.

May 1.—Finished operations on the Upper San Juan, and connected levels with "Bench-mark party No. 2, 1873;" majority of hydrographic party sleeping ashore during the night at Brown's wood-shed; very high hills opposite Santa Cruz River. Gauged the San Juan in three places; excellent timber for building purposes abounds in this region; made ensigns and distinguishing-pennants for all the fleet.

May 2.—Brought all the boats to Castillo, and shot the rapids with launch, canoe, and large balsa; all went over without accident; took provisions, dinghy, and small balsa around by the railroad. Expended one oar, broken in pulling. Clear, pleasant weather; gentle easterly breeze.

May 3.—Engaged in preparing boats and making general repairs for work in lower river; fitted up new bunks for officers and men. Officers writing up the smooth note-books.

May 4.—Sunday; clear and pleasant; breeze from eastward.

May 5.—Surveyed from pole below Castillo Rapids to Camp Runnels; distance six miles; no leveling; launch got aground below Castillo, but was cleared with the assistance of nine soldiers, kindly sent to us by the comandante of the fort. Frank Russel (machinist) rejoined the party.

May 6.—William Clark (ordinary seamen) reported his time of service expired. Surveyed to the head of Mico Rapids, connected with "transit-point, party 1," and started a new survey from transit-point below rapids; brought up for the night at camp Don Max; distance from Castillo by the picket, eight and three-quarter miles. River shoals full of gravel and opaline stones; bottom of Bartola River rock in strata.

May 7.—Surveyed to Machuca Rapids, arriving there at noon. All the boats brought over in safety, though the Don Guillermo ran aground at Point Infernita and lost her anchor, and the small balsa had to be cast adrift, as the launch was for a few moments in great danger in the midst of the whirlpools and counter-currents. Great credit is due Master K. Niles, Ensign J. H. Bull, and H. Browne, apothecary, for the able manner in which they managed their boats. Found the

steamers Castillo and Pit-Pan at the foot of the rapids; reported to Commander Lull; received a large mail and stores; during afternoon connected with "transit-station, party 1," below Machuca, and resumed survey.

May 8.—Very clear; gentle easterly breeze; moonlight at night. Surveyed about four miles, to the commencement of what is known as the Aguamuerta; connected with Rhoades, line and B. M.; resumed leveling; anchored for the night at the mouth of a most beautiful stream; named the waterfall the Cascade Katita.

May 9.—Fog at daybreak. Surveyed about two miles. The course of the river is here very narrow and tortuous, the stream running between steep banks and high hills. The least water in the channel from the foot of Machuca Rapids is about 16 feet, and the depth at places is over 90 feet. Bottom rocky; current very slow.

May 10.—Fog again interfering with our work in the morning; clear the rest of the day; easterly breeze. At 7.30 p. m., two of the officers, of a romantic turn of mind, swing hammocks under the trees for the night; at 10 p. m. howl of a tiger close aboard; at $10^h\ 00^m\ 01^s$ romance goes as quickly as they to the boats; three shots at our striped-skinned visitor, but never a hit.

May 11.—Sunday; no work. Light shower about 1 p. m. Steamer Castillo came down stream about 5 p. m., having on board Commander Lull and Assistant Surgeon Bransford, bound for Greytown. Sent a mail. J. McSherry, ordinary seaman-extra, reported for duty.

May 12.—Clear and pleasant; gentle easterly breeze. Connected levels with B. M. party 2; end of line at night just above San Carlos River. Strong back-current setting up the San Juan for a mile above the mouth of the San Carlos.

May 13.—Surveyed about six miles; river again very broad, and filled with large shoals of black sand brought down from the volcanic mountains of Costa Rica by the San Carlos River. Passed Camp Chamorro.

May 14.—Pushing along very rapidly, the sand-shoals affording great facilities, as there is no cutting to be done; all hands hoping we will not be the last party in, though the last to commence.

May 15.—Passed two high red and yellow clay bluffs on right bank. At 12 m. sighted a canoe on left bank of river; made her out to belong to Mr. Rhoades' party; keep a sharp lookout for party No. 2, and at 1.30 p. m. are hailed from left bank; hoist colors on all the boats, and exchange courtesies with party 2; anchor at night off Mr. Rhoades' camp; cooks join forces and furnish what may be considered, under the circumstances, a swell-dinner.

May 16.—Clear and pleasant. Anchored at night at El Paraiso, two miles below the Serepiqui River; gauged the Serepiqui, also the San Juan, above and below it. The water of Serepiqui is very clear, and apparently holds a solution of lime. Connected with transit-station, party 1.

May 17.—Anchored at night at the San Juanillo outlet. River very broad, containing groups of large, low islands; banks lower, and channel undefined. Heavy shower about 9 p. m. Party very uncomfortable; everything wet and innumerable swarms of mosquitoes about.

May 18.—Sunday; no work. Light rain at night. Quantities of alligators on sand-banks; caught a small one.

May 19.—Surveyed to and gauged the Colorado River. At 5 p. m. Commander Lull, with the governor of San Juan del Norte, arrived from Greytown and remained with the party all night. We were informed by the natives that the river here rises during extreme floods one foot above the banks. The former bank of the San Juan below the Colorado Forks is well marked by the line of large trees.

May 20.—Surveyed about eight miles; experienced great difficulties in getting the boats over the shoals; all the officers and men in the water pushing and dragging the boats. Commander Lull left at daylight for Lieutenant Rhoades' camp. At 2 p. m. party No. 2 passed us on their way to Greytown, having finished their line. Numerous islands and shoals in river-bed.

May 21.—Cloudy but pleasant; northeasterly breeze. Anchored at night at mouth of Barco Lagoon. Party visited by Lieutenant Leutze and Master Briggs.

May 22.—Surveyed to the Caribbean Sea; experienced great difficulty in finding solid land for the gradienter stations; no sand-shoals below the San Juanillo mouth, at which point the water becomes again quite deep—10 to 12 feet. The Don Guillermo sailed for Greytown at 9 a. m., under

command of Lieutenant Leutze, who kindly offered his services to pilot her in. Remainder of fleet arrived at Greytown at 2 p. m., pulling into port in the first order of sailing; exchanged salute and civilities with parties 1 and 2; reported safe arrival to Commander Lull.

May 23 to May 28.—Engaged in writing up books and making out gradienter tables. Weather generally pleasant, with light showers early in the morning and at about 3 p. m.

RÉSUMÉ OF WORK DONE BY HYDROGRAPHIC PARTY.

Distance surveyed, miles	120
Total number of stations	630
Number of working days	33
Average number of stations per diem	19
Average distance per diem, miles	3.7
Average length of sight, miles	.19

Levels taken from Fort San Carlos to Castillo Viejo, and for fifteen miles in the Agua Muerta.

Very respectfully, &c.,

J. W. MILLER,
Lieut. U. S. N., Commanding Hydrographic Party.

Commander EDWARD P. LULL, U. S. N.,
Commanding Nicaragua Surveying Expedition.

REPORT UPON HYDROGRAPHIC OPERATIONS IN LAKE NICARAGUA, BY MIDSHIPMAN JOHN D. KEELER, UNITED STATES NAVY, 1873.

Order of Commander Hatfield to Midshipman Keeler.

VIRGIN BAY, *June* 17, 1872.

SIR: You will remain in charge of that portion of the surveying party that remains in the country, and with them will execute as much hydrographic work as possible, surveying particularly those portions of the lake where it is probable a canal may enter, and running lines of soundings across the lake to San Carlos.

That portion of the lake and coast from Saint George nearly up to the Rio Gil Gonzales should be carefully surveyed, in all cases paying particular attention to the character of the bottom.

In addition to the steam-launch, which I leave you, I will send you a smaller boat from Greytown. After the men of the expedition have acquired sufficient experience, you may discharge such of the Carib boys as can be spared.

You will, when the rivers commence to run, gauge them from time to time, taking frequent measurements of the Lajas. By the mail, which leaves for Greytown about the 1st of October, you will write to me at that place, reporting your wants and the progress of your work. After that you will do the same by each succeeding mail.

Very respectfully,

CHESTER HATFIELD,
Commander.

Midshipman J. D. KEELER,
United States Navy.

LA VIRGEN, NICARAGUA, *January* 3, 1873.

SIR: In obedience to orders received from Commander Chester Hatfield, U. S. N., of which the preceding is a copy, I remained in charge of the small party left here when the expedition of last year returned to the north.

I have the honor to report the following as the work accomplished by the party under my command:

The shore-line of the lake from Limon River to Menco Point has been carefully surveyed, the character of the beach and adjacent land being carefully noted in all cases.

Off-shore soundings have been run out to five fathoms of water, the length of the shore-line, ranges, out and in, averaging each about one-third of a mile. The character of the bottom was carefully observed. The unusually heavy winds interfered materially with the progress of the work, as will be seen from the inclosed summary of journal. That part of the lake between the island of Zapatero and the mainland has been thoroughly sounded, but circumstances rendered it impracticable to make a survey of the shores. A sketch has been made, however, which is sufficiently accurate to show the general outline of the inlet with the soundings.

Gauges of the Lajas and Ochomogo Rivers on this side of the divide, and of the Rio Grande or Brito River on the Pacific side, have been obtained.

On the 1st of July, 1872, I established a rain-gauge, graduated to hundreths of an inch. The total fall of rain to this date has been 47.11 inches. A faithful record has been kept of the height of the lake above an assumed level, as also a record of readings of barometer and thermometer. A careful survey of the harbor of San Carlos has been made, with soundings running out to the Balsillas islands.

The latitudes of La Virgen, San Carlos, and the Solentiname Isles have been determined with sufficient precision for plotting the work; also the differences of longitude between the latter places and La Virgen.

Also the following lines of soundings: first, from buoy located between the islands of Zapatero and Ometepec to San Carlos; second, from San Carlos to La Virgen; third, from five fathoms water off Rio Las Lajas across Moyagalpa Shoal; fourth, from Mayagalpa to point of Zapatero; fifth, from buoy into Menco Point.

To Midshipmen Hughes and Winslow I am indebted for many valuable suggestions and for material aid in carrying on the work. The accompanying books and working-sheets show the data and the corresponding results.

The health of the party has been generally good, although at times sickness has interfered with the progress of the work.

I am, sir, very respectfully, your obedient servant,

JOHN D. KEELER,
Midshipman United States Navy.

Commander E. P. LULL, U. S. N.,
Commanding United States Nicaragua Surveying Expedition.

SUMMARY.

Journal of hydrographic party, rainy season.

Date.	Work.	Officers.	Remarks.
1872.			
July 1	7,323 feet shore-line	Midshipman Keeler	
2	15,840 feet shore-line	Midshipman Winslow	
8-23	Nineteen miles soundings in Ochomogo Inlet; 1,421 casts	Midshipmen Keeler and Winslow.	
11-23	Twelve lines off-shore soundings; located reef at Virgen	Midshipman Hughes	
27	5,280 feet shore-line	do	
Aug. 2, 3	Attempted off-shore soundings; heavy squalls of wind and rain.	Midshipmen Keeler, Hughes, and Winslow.	
6	Launch on sounding trip	Midshipmen Hughes and Winslow.	Midshipman Winslow returned sick; fever.
6-10	One line across Moyagalpa Shoal		
6	Made two attempts at off-shore soundings	Midshipman Keeler	
7	Two lines off-shore soundings	do	
16	Six lines off-shore soundings	Midshipman Winslow	
19	Six lines off-shore soundings	do	
24	10,303 feet shore-line	Midshipman Keeler	
20	Fourteen lines off-shore soundings, reaching Saint George	Midshipman Hughes	
20	38,164 feet shore-line	Midshipman Keeler	
21	Eight lines off-shore soundings	do	
22	28,695 feet shore-line	do	
23	28,308 feet shore-line	do	
28	Attempted gauge of Lajas; river not running	Midshipman Winslow	
29	8,447 feet shore-line	Midshipman Keeler	
29	One line off-shore soundings	Midshipmen Hughes and Winslow.	
Sept. 4	Twenty lines off-shore soundings	Midshipman Keeler	
5	Four lines off-shore soundings	do	Sept. 8. Midshipman Keeler returned to La Virgen sick with fever.
11	Eighteen lines off-shore soundings	Midshipman Hughes	
12	Twenty-two lines off-shore soundings	Midshipman Winslow	
17	Launch left for Moyagalpa	Midshipmen Hughes and Winslow.	
21	Launch returned with leaky tubes	do	
26	Attempted gauge of Lajas; river not running	do	
28	Verifying signals	do	
Oct. 3	Left to gauge Rio Grande	Midshipman Hughes	
5	Gauge of Rio Grande obtained	do	
6	Launch left for Moyagalpa to run lines of soundings to and from San Carlos.	Midshipmen Hughes and Winslow.	
8	Six lines off-shore soundings	Midshipman Keeler	
9	Two lines off-shore soundings	do	

Journal of hydrographic party, rainy season—Continued.

Date.	Work.	Officers.	Remarks.
1872.			
Oct. 15	Launch returned from San Carlos, having completed lines of soundings to and from San Carlos, survey of San Carlos, latitudes of San Carlos and Solentiname Isles, and time-sights at those places.	Midshipmen Hughes and Winslow.	
Nov. 6	Launch left for Moyagalpa to run lines of soundings and survey Ochomogo Inlet.	Midshipmen Keeler and Hughes ..	
11	Attempted to gauge Lajas; not running	Midshipman Winslow	
14	Launch returned, having accomplished as follows: Line-soundings from Moyagalpa to Point of Zapatero; line from buoy to Menco; gauge of Ochomogo River.	Midshipmen Keeler and Hughes ..	Midshipmen Keeler and Hughes and one man sick.
15	Attempted gauge of Lajas; river not running	Midshipman Winslow	
18	.....do	.....do	
19	.....do	.....do	
21	Obtained gauge of Lajas	.....do	
24 to Dec. 30	Very heavy winds; officers arranging and plotting work.....	.....	

REPORT ON HEALTH, CLIMATE, FOOD-PRODUCTIONS, &c., OF NICARAGUA, BY JOHN F. BRANSFORD, M. D., ASSISTANT SURGEON, UNITED STATES NAVY.

MANCHESTER, VA., *November* 5, 1873.

SIR: In obedience to your orders, I have the honor to submit the following report on the climate, food-productions, health, &c., of Nicaragua.

CLIMATE.

In crossing Central America by the route proposed for the canal the region first traversed is the Atlantic slope, composed of undulating land gently rising for about fifty miles to a mountainous region, which is a continuation of the Rocky Mountains of North and the Andes of South America.

For the next fifty miles up the river San Juan the country is hilly, until near the lake the land is again low and marshy.

West of the lake is a lovely rolling country to within a few miles of the Pacific, where another ridge is encountered, a spur from the Costa Rica Mountains having the general direction of the Pacific coast. Sharp and well defined in Southern Nicaragua, it slopes away to the northwest and is lost in the plain of Leon. From this ridge the land falls rapidly to the Pacific.

Owing to the formation of the country, which is comparatively low and narrow, the trade-wind blows entirely across Nicaragua, mitigating the climate and ventilating the country in a most fortunate manner.

The seasons, divided into dry and wet, are of nearly equal duration; the wet season beginning about the 1st of June and ending about the 1st of December. But we have in the dry season occasional rains, and the wet is interspersed with many clear days.

The climate of the Atlantic slope is exceedingly damp; even in the dry season there is hardly a day without rain on the coast at Greytown. The trade-wind, sweeping for hundreds of miles over the Caribbean Sea, becomes loaded with moisture, which is condensed by the land of this Atlantic slope; the wind is discharged of its watery vapor by the rising ground, its supply being pretty well exhausted when it crosses the Cordillera, and we have pleasant weather beyond.

The soil of this region is of unsurpassed fertility, and, with the heat and great dampness, the country is necessarily covered with the densest vegetation. From the tops of the tall trees parasites and creepers of numberless varieties trail and entangle the luxuriant undergrowth into an almost impenetrable mass. There is very little cleared land, the physical obstacles in the way of the agriculturist being almost insurmountable; while the dense vegetation presents, as it were, a living shield to the rays of the sun, protecting from their chemical influence the decaying matter which covers the ground. In this way, and by conducing to the equableness of temperature, the forests are of sanitary value.

The rain-fall diminishes as we ascend the river San Juan, and after passing the mouth of the San Carlos the weather is bright and pleasant in the dry season; vegetation is not so rank; the land is well adapted to agriculture, and, as it is sufficiently damp for the growth of grass, cattle-raising is an easy and lucrative business.

There is almost a continual breeze up the river-valley, and although the heat of the sun is great at mid-day, it is comfortable in the shade, and the nights are delightfully pleasant.

These remarks are applicable in a greater degree to the country between the lake and the Pacific. Here the wind, after sweeping across the lake for about forty miles, fans the country with a breeze which has to be felt to be appreciated. The difference between the temperature in the sun and shade is so great that it is unsafe to remove the hat on entering a house after exposure to the heat of the sun, attacks of neuralgia, &c., frequently following imprudence in this respect. In this section there is very little rain in the dry season, and vegetation is of smaller growth and much less luxuriant.

VEGETABLE FOOD-PRODUCTIONS.

Maize or Indian corn is too well known to require description. This, which has been a prime article of food in Nicaragua since the country was discovered, may be produced in any desirable amount. The soil and climate suit it so well that it is possible to raise three or even four crops on the same land annually. The plant is cut while green and cured as *sacate*, about the only fodder to be met with in the country. The popular bread of the natives, called *tortilla*, is made of maize. It is prepared by the women in the following manner: after soaking the shelled corn in a mixture of wood-ashes and water, (to remove the hull,) and washing frequently, it is crushed on a flat stone with a stone roller, a little cheese is added, and the thin cakes are baked in an earthen pan. It is very palatable, and is used by the natives almost to the exclusion of any other bread. *Tiste* is a pleasant drink, made of parched corn-meal, chocolate, and sweetened water, mixed in a *jicara* and agitated with a molinita, an instrument much like an egg-beater. It is refreshing, and, at the same time, very nourishing.

Bananas and plantains are here surrounded by the conditions most conducive to development and yield. Although it is claimed that these plants had their origin in the eastern hemisphere, it is certain that at the time of the landing of Columbus they formed an article of food of primary importance to the inhabitants of tropical America, and since that event their consequence has been in no wise lessened. They are produced in the most enormous quantities, it having been estimated that an acre of plantains would support fifty persons; and Humboldt's calculation, that the yield of bananas was to wheat as 133 to 1, and to potatoes as 44 to 1, is not considered at all exaggerated. The banana, the fruit of the *Musa sapientium*, and the plantain, the fruit of the *Musa paradisiaca*, are a little different: the banana is sweeter, more delicate, and luscious; the plantain is larger and more nutritious. A portion of the starch of the unripe fruit is converted into mucilage, and sugar in the ripe. The unripe fruit is nearly allied to the potato in composition and nutritive value; the ripe is more closely analogous to rice. The meat of the ripe plantain contains a protein or flesh-forming principle of great nutritive importance. Plantains are usually baked, boiled, or fried, the latter making the most palatable dish. There is absolutely no limit to the quantity of this fruit which may be raised in case of necessity; and there is probably no food which equals it for general use in hot countries.

Rice, which forms the principal article of food of so large a part of the human family, flourishes on the lowlands of Nicaragua. The soil and climate are well adapted to its growth, and it may be raised in any desirable quantity. It comes next after plantains as a food in general use.

The *frijoles* or beans of Central America, which are present at almost every meal, have a peculiar flavor of the most savory character. They are served in various styles, and few of our party will fail to recollect with sensations of pleasure our breakfast-dish of fried *frijoles*. This is an excellent and abundant food.

Yams, which in a great measure substitute potatoes, are coarser than the latter. They contain a large quantity of starch, and are baked, roasted, or made into puddings, &c.

The bread-fruit tree is well suited to this climate, but the natives are so abundantly supplied with other food that they have not given this much attention.

There are numberless other fruits and vegetables found here in wasteful abundance. Among them are cocoa-nuts, oranges, limes, lemons, pine-apples, &c.

Potatoes are raised at Chinandega, and in the highlands of Segovia are said to grow wheat and other productions of the temperate zone; but most of the flour used in the country comes from California.

The sugar-cane is continually ripening, and three crops may be annually taken from the same land. The fields require replanting every ten or fifteen years. The sugar in an unrefined form is much used by the natives, who make it up into *dulces* of infinite varieties, sweet things seeming to be a necessity of their existence. It is said by Squier "that it may be produced for sale at $1.25 per quintal, (101½ pounds English.") He believes this cane to be indigenous, and asserts that it is more tender and juicy than that of the West Indies, which most authorities consider to have come originally from Asia. According to Lindley and Moore, the consumption of sugar has constantly increased in Europe; and this increasing demand must make it a source of great wealth to a country so well adapted to its growth.

Coffee of superior quality flourishes in the country west of the lake. It forms probably the most important export of Nicaragua, and a better system of labor would develop its production into a first-class industry. Coffee is a febrifuge and tonic, and, taken in the early morning, is largely used as a preventive of malarial fever. At the same time that it excites the brain, it seems to have a quieting and soothing influence on the nervous system generally, thus tending to correct one of the injurious effects of heat, while, by diminishing the waste of tissue, it lessens the amount of aliment necessary to sustain life.

The chocolate of Nicaragua is of unsurpassed quality. The plantations require considerable capital in their preparation, but are afterward easily managed with little labor, and are consequently very valuable. The cacao-tree is protected from the wind by mango hedges, and from too great exposure to the sun by the coral-tree or *madre de cacao*. The trees are about 18 feet high, and bear from the age of seven years to about thirty or forty. The seeds of which the chocolate is made are inclosed in an oblong fruit marked with longitudinal ridges, each fruit containing from fifty to a hundred seeds. The capsules turn yellow when ripe and are then gathered. The seeds are removed, and, after being exposed to slight fermentation, are thoroughly dried in the sun.

Cacao butter is obtained from the seed by expression. The chocolate produced in Nicaragua is almost entirely consumed by the people of the country; it is their favorite drink, and, being very nutritious, takes the place of more substantial food. Besides the usual mode of preparation, it is used in making the refreshing *tiste*. Nothing but the unsettled condition of public affairs prevents cacao from becoming an important article of export.

ANIMAL FOOD.

The cattle of Nicaragua are rather smaller than those of the United States, the want of careful management and breeding no doubt accounting for this fact to some extent. The cows are frequently of a dun or mouse color, and beautifully marked with darker lines on the back and shoulders. They are much more graceful in form than the heavy fine stock of the United States. The country is well watered, and cattle thrive well in all parts except on the Atlantic slope, where the insects are intensely annoying. In the hilly region east of the lake, in Chontales and Segovia, where the easterly winds have partially exhausted their supply of moisture, grass grows well and cattle-raising is an important business. West of the lake they are allowed to roam through the woods in search of pasturage. In some cases a cow is marked and turned out, and when she is reclaimed, three or four years afterward, often brings up quite a numerous family, every year of her absence being represented by an offspring. Among the mountains greater caution is required, as the tigers are sometimes very troublesome, killing young cows and grown ones that happen to be caught alone. It is said that the cattle make common cause against the tiger, and usually come off victorious. From the impunity with which cattle roam the forests, day and night, in some portions of the country, I believe that there is not much danger to a cow in good health and strength. The fresh beef of this country is excellent, very juicy, and exceedingly savory; but the jerked beef is an abomination to all foreigners, although the natives eat it with considerable gusto. It is cut and dried in strips, and it sounded rather odd to hear the butcher selling his beef by the yard. Although cows are plentiful not much attention is paid to milk and butter, the people of tropical countries not appreciating such food as highly as do their brethren of colder climates. Cheese is made in considerable quantities.

Hogs are reared without trouble, the wasteful abundance of fruits and vegetables rendering them extremely inexpensive.

Goats are numerous all over the country, but particularly so in Chontales.

Chickens are plentiful. And there is a fine species of wild duck on the rivers. It is very large, of greenish-black color and excellent flesh.

Another wild fowl is the pavon, a variety of curassow, nearly as large as the wild turkey. A male was killed on the San Juan weighing twelve pounds, and measuring 38 inches from the beak to tip of the tail and 49½ inches from tip to tip of the wings. The flesh is very like that of the wild turkey, and is much esteemed.

Mountain-hens and partridges are numerous, and there are numberless pigeons of different varieties.

Venison is very plentiful and largely used, and the droves of peccaries that roam the woods furnish excellent meat when young.

The rivers of Nicaragua abound in fish of every size, from the *zavalo real* to the sunfish. The former is very large. One that jumped into a boat at Castillo weighed sixty-two pounds. The flesh is coarse, but it is eaten by the natives. The *zavalo* proper is much smaller, weighing from three to six pounds. This fish is an industrious scavenger; still it is enjoyed by the natives, and is very good when caught in an unfrequented part of the river and well cooked. The *juapote* is a game fish for sport, about 8 or 10 inches long, a little broader than a chub, and makes a delightful fry. Besides these there are many varieties of perch and sunfish.

The coarse flesh of the tapir and the manatee is eaten by the Indians of the low country.

PLANTS OF COMMERCIAL VALUE.

Indigo is one of the most important exports of Nicaragua. There are large plantations of the plant between the lake and the Pacific. The indigo of commerce is a product of the fermentation of the plant. After drawing off the solution of indigo, the refuse is burned to avoid the unhealthy emanations which it gives off in decomposition. The management of this crop and its subsequent preparation for commerce require great care, and this industry has suffered severely from the uncertainty of labor consequent to the unsettled condition of the country.

Cotton of good quality may be raised here to a large extent. A considerable quantity of it was exported at one time.

The cochineal insect is found on the *opuntios* of the upper country.

The *hule* tree, from which caoutchouc is obtained, is found abundantly in the forests; and rubber has grown to be one of the most important exports of the country, being second, probably, only to coffee. It is obtained from a fine, tall tree with smooth, round stem and large leaves. The rubber-hunters go up the rivers in dug-out canoes, taking provisions of flour, coffee, sugar, &c., for several months. After going as high as possible by water, they establish a camp and separate in search of the rubber-trees, each man armed with the indispensable macheta, and usually a double-barreled gun. While in the woods, their larder is enriched with fish and game in abundance. The hule-man climbs the tree and cuts diagonal gashes around it; these pour the rubber-milk down at one point, where it is caught in tin pans about 18 inches in diameter. The milk then has the infusion of a certain vine (which I was not fortunate enough to see) added to coagulate the rubber. The cakes are about an inch or inch and a half thick and 18 inches across. A good deal of the milk coagulates on the trunk of the tree and in the gashes. This is stripped off and packed in bales. After variable lengths of time—sometimes as long as eight months—the hunters start back. They load their canoes, and when there is more than the boats can carry they string the cakes of rubber on *bejucos* and tow them down to market. The rubber is usually sold to small traders on the river, who have, in a majority of cases, advanced the stores for the trip to the woods. The trader sells to larger merchants, who ship it, principally from Greytown.

Tobacco of good quality is raised in most sections of the country, but especially on the island of Ometepec, the light soil of which seems particularly adapted to its growth. The native cigars, though inferior to Havanas, were much enjoyed by devotees of the weed.

Pita, of fine quality, is manufactured into beautiful hammocks.

The jicara, or calabash-tree, is found in the western part of the country. Calabashes of various

shapes and sizes form an important article in domestic economy, serving as jars, baskets, drinking-cups, &c. There is considerable art displayed in the ornamental carving of some of these.

The long creeping *bejucos*, which trail from the tops of the loftiest trees to the ground, answer the purpose of ropes for the natives, and are used for lashing the frame-work and canes of their huts. The native with his macheta is never at loss for a line, as he may cut the textile *bejuco* of any size, from a small string to a ship's cable. There is one variety which contains a large quantity of water; by cutting off a piece about 2 inches in diameter and a yard in length enough water may be obtained to relieve a thirsty man. Members of our party might frequently be seen, with sticks up to their mouths, draining the *bejuco* of its refreshing contents.

WILD ANIMALS, REPTILES, INSECTS, ETC.

We have in Nicaragua, as might be expected, a multitude of those denizens of the forest which swarm in tropical woodlands.

Chief among these is the tiger, or *jaguar*; an animal inferior in size and ferocity to its cousin of Bengal, but of great strength and sufficiently formidable to make its proximity anything but comfortable. This animal has been known to drag the body of a grown cow for some distance through the thick undergrowth of the Nicaraguan woods, and it is very dangerous when wounded or hungry.

The *puma*, or Mexican lion, is smaller, but is represented by old hunters to be as savage as the tiger.

Many varieties of wild-cats are met with.

Alligators abound in the rivers, and sharks are found in the San Juan and Lake Nicaragua.

Snakes are very numerous and of countless varieties. One of the most conspicuous is the *coral*, a beautiful snake, about three feet long, marked with black and crimson bands. This snake is much dreaded by the natives, who represent its bite as deadly. I killed several that at first attempted to escape but when baffled in that design were very savage, one striking fiercely and then burying its fangs in its own body when pinned down.

The *toboba* is a much larger snake, marked something like the moccasin of the United States. The hule-man and hunter entertain the most inveterate animosity toward this snake, and will spend time and labor to kill one. It has an odor something like that of an alligator, and I have seen a hunter search for half an hour before finding his enemy coiled among the leaves and rubbish around a coyal-palm.

There are several snakes of the boa family, and numerous very small serpents of extremely venomous character.

Snake-bites among the people in the woods and mountains were of frequent occurrence, but our men were fortunate enough to escape. The surveyors always had a party of natives ahead cutting the trail, and these old hands killed a great many snakes. Besides, the men wore thick canvas leggings and were very careful, always on the look-out for the *culebra*.

The myriads of ants that infest the country are very annoying. They sting painfully; the large black ant being fully as severe as the wasp of the United States. Sometimes, thoughtlessly picking up a piece of wood, my hands would suddenly feel as if on fire, and a glance would show the savage little fellows very effectually bringing themselves into notice.

Musquitoes are very troublesome except on the west coast of the lake, where the trade-wind drives them back. They are very small and we had to use thin muslin for bars; these had to be carefully tucked in at the bottom, the smallest aperture affording entrance to the blood-thirsty pests.

Garrapatas, ordinary ticks, were very annoying on the west side, but not at all so on the San Juan.

During the dry season the fleas were almost unbearable in the haciendas. They may be kept out by keeping the tile-floor damp.

The *inigua*, or chigoe, is said to be an insect about the size of a flea, which burrows into the skin of the sole of the foot, and deposits its ova. These become encysted, and after a little time escape by ulceration, sometimes occasioning considerable irritation. We had many cases, but no trouble with any. It was only necessary to remove the eggs and sac, the little wound healing readily. The natives believe that getting the feet wet after the removal of the sac is very dangerous. Our experience in several instances refutes this idea.

On the San Juan, during April and May, several of the officers and men suffered from the presence of a grub under the skin of different parts of the body that had been exposed. These are said to be the larvæ of some fly, which we could never detect in the act of depositing its ova. In some cases the grubs reached the length of half an inch, producing an itching sensation of the most intolerable character, the irritation interfering with necessary rest. Its burrow has an orifice in the skin, and by applying calomel or a moist piece of tobacco for a little while the grub may be easily removed; it seems to relax its hold and is readily squeezed out, to the indescribable relief of the sufferer.

HEALTH, DISEASES, &C.

During the period of our stay in Nicaragua our health was remarkably good, with the exception of malarial fevers. These fevers were of course to be expected in a country where all the conditions favorable to the development of the subtle and mysterious poison are so prominent. We have the tropical heat, extreme moisture, and, consequently, an enormous amount of vegetable matter. Fortunately there are physical conditions which favorably modify the results naturally to be expected from such a combination. First of these in importance is the trade-wind, which sweeps entirely across to the Pacific, ventilating the country, diffusing the malaria, and preventing that accumulation of miasm which makes some localities in the tropics so deadly. We found that camps on the river-bank, where we had the benefit of currents of air which swept up the river almost continually, were decidedly more healthy than those off the river and beyond reach of the wind. The great rain-fall on the Atlantic slope tends to dilute the poison, and, by keeping the marshes generally flooded, prevents the access of air and its chemical effect. Again, this country is densely covered with vegetation, and much of the "intoxication tellurique" is used up in vegetable growth. Malaria has a pretty well determined affinity for trees, and the wind is relieved of its load of poison as it passes over the forest. The shade, too, being almost impenetrable by the sun's rays, protects the humus from their excessive heat and chemical action, thus checking the generation of paludal malaria. These conditions, with the fact that this slope is well drained and of an equable temperature, favorably influence the health of the inhabitants.

Decidedly the most unhealthy place on the route is Greytown, at the mouth of the San Juan River. It is situated on a sand-bank, about a mile and a half from the sea, having the river in front and a lagoon behind it. There are two outlets of the river, and during the dry season a bar forms across the mouth nearer the town, leaving the latter on a *cul de sac* of stagnant, brackish water. At the time that we were there in June this water was so strongly impregnated with decaying animal and vegetable matter as to be unfit for bathing. This would be remedied by opening the harbor and bringing down a larger volume of water from the Upper San Juan, which would insure a constant current.

The inhabitants of Greytown claim that they have never been troubled with yellow fever. During our stay, although cases of intermittent and remittent fevers were very common, they never approached a pernicious character and were easily checked by the simplest treatment. This may, no doubt, to a great degree, be attributed to the strong breeze from the sea and to the fact that excellent water is furnished by the wells.

At Greytown and along the course of the San Juan were found lung diseases of frequent occurrence among the natives. Probably a great proportion of the deaths in this region are due to consumption; although *calentura*, as the natives term the fever, usually gets the credit of all the trouble. On one occasion I was called to see a man whose "fever" had resisted the usual remedies; he was found in the third stage of pneumonia and almost in the grave. Neglect of such cases in so damp a country must necessarily often result in quick decease or lingering consumption.

After passing the mouth of the San Carlos River we enter a much more healthy country. The mountainous region and clearer skies mitigate in a marked degree the ills that the flesh in Greytown is heir to. The prevailing diseases are still the paroxysmal fevers and disorders of the lungs; but they are of much milder nature and less frequent occurrence.

On the west side of the lake we have a country whose beauty is unsurpassed and whose climate is simply delightful. If we may judge by our existence while there in January and February, there is no more healthy country. Our stay in that section was, however, during the dry season, the healthiest time of the year.

This region has the full benefit of the wind which sweeps down the hills of Chontales and across the lake for about forty miles, raising quite a rough sea, which breaks on the west coast. Along this shore of the lake the nights are very cool. The extinct volcanoes Ometepec and Madera, which form an island in the lake, rising to the height of about 5,000 feet, condense the vapor of the higher strata of air, loading the strata below with moisture, which is borne to the west coast and makes the atmosphere at La Virgen cool, and sometimes chilling; rheumatism and neuralgia frequently resulting from exposure. Commander Lull suffered for several days with aural neuralgia; and his case, which baffled treatment, was immediately relieved by stopping a little crack in the wall near the head of his bed, where the raw air whistled in at night. About the same time I was rendered miserable for nearly a week by facial neuralgia, and only obtained relief by putting up my mosquito-bar, which broke the currents of damp air that freely circulated through the room. It may be here mentioned that frequently during the survey we were impressed with the protection afforded by our mosquito-bars from the cold, dew, and malaria.

Our experience induces the belief that the paroxysmal fevers in the lake basin and Pacific slope of Nicaragua are not more severe than they are on an average in the lowlands of the United States. The dry season, as a resting-spell and re-invigorator of the system, is, of course, not equal in its bracing effects to the winter of more temperate countries.

The expedition reached Greytown on December 20, 1872, and left there July 6, 1873. Some of the officers and men were with us only a portion of the time. There were on duty 45 officers and men during the survey; the average roll being 36 for the six and a half months.

The following is a synopsis of our medical journal:

Disease.	Number of cases.	Disease.	Number of cases.
Febris intermittens	18	Pharyngitis	1
Febris remittens	3	Neuralgia	1
Vulnus	3	Odontalgia	1
Catarrhus	2	Furunculus	1
Dysenteria, chronica	1	Abscessus	1
Diarrhœa, acuta	1	Insolatio	1
Cholera morbus	1		
			35

Total number of sick-days	245
Daily average number on sick-list	1.23

There were no deaths. One officer was returned to the United States on account of an attack of sun-stroke; and a man with chronic dysentery, which he had before he joined the expedition, was returned soon after we reached the country.

Of the 45 officers and men, 23 were on the sick-list; some being on several times, sometimes with different diseases; oftener with recurrent intermittent fever. The most troublesome case was a man who was left in the country by the expedition of last year, and who had led a debauched life while here. He was on the list six times; five times with intermittent fever. The next case in obstinacy was a gentleman who had contracted the fever on an expedition to Darien, and who had suffered with it several months before going to Nicaragua.

We stopped at Greytown about a week on our arrival, and no doubt imbibed a good dose of the miasma at that place, as all three of the cases of remittent fever occurred within a month of our arrival; the first at Greytown, and the second before we reached the lake, on our way up the river; the type of fever changing from remittent to intermittent as we ascended from the sea-coast to higher land.

On our sick-list there was only one case of dysentery, and that was chronic, in a man of habits of intoxication, who had suffered with it before joining this expedition.

When we remember that many of these men had had fever on board the Kansas, which was in the Coatzacoalcos River, in 1870-'71, and again in the West Indies last winter, that sailors are notoriously reckless of their health when on shore, the total change in habit from ship-board to camp life, and the expedition ration, principally of canned food and bacon, it must be admitted that this country proved far from the pestilential region described by the survivors of Nelson's party.

There was a marked absence of the bowel complaints for which the tropics are so noted. In

quite an extensive practice among the natives, few cases of diarrhea or dysentery were met with except among the children. When we consider their food of fruits and *dulces*, and their intimate association with pigs and poultry, it is only strange that there should have been so few cases.

The natives generally are remarkably healthy, rarely complaining of any disease except sequelæ of fever, old skin diseases, syphilides, &c. Cases of enlarged spleen are not infrequent, though the liver bears the brunt of the injurious climatic influences, especially in cases of ardent drinkers. We met no cases of tetanus, but were informed that it was not of rare occurrence. A great many foreigners get into the habit of excessive drinking, and fall victims to the nervous diseases, liver complaints, or dysentery.

Among the natives many cases of functional cardiac disorder, associated with dyspepsia, were noticed in persons who had suffered repeated attacks of fever. Improvement followed the use of proper diet and tonics; but the cases were not under supervision a sufficient length of time to determine whether the disturbance would be entirely removed by these remedies.

We saw no cases of the exanthemata, nor diphtheria, nor those low fevers which so often scourge colder climates; and, with the exception of the Atlantic slope and seaboard, lung diseases were rare. The climate of the lake basin and Pacific slope is very favorable for consumptives and persons troubled with different diseases of the kidneys; the latter organs and the lungs being relieved of their labors to some extent by the increased action of the skin and liver.

Among the native population negroes seem by their average physique to enjoy better health than any other people on the Atlantic coast. Some of the men are magnificently formed, and the women have an appearance of health hardly to be mistaken, their figures being larger and better filled out than the Indians of the sea-coast.

In the interior the Indians are decidedly sturdier and more healthy in appearance than are the descendants of their Spanish conquerors; they seem more capable of endurance, more in accordance with the fitness of things in their country.

The women of Nicaragua appear to be better developed than the men. There is not the same difference in size that there is between the sexes in the United States. The women are remarkable for the fine form of their necks, shoulders, and upper extremities; in fact the whole figure is strangely symmetrical and graceful; their unrestrained style of dress doubtless contributing mainly to the excellence of their forms. They are developed early, a girl of fourteen looking fully eighteen, and at thirty they begin to appear old. They frequently bear children at twelve or thirteen.

The population of Nicara gua is said not to increase rapidly, if at-all; but I am sure if a due proportion of the *pickanin nies* were raised this would not be the case. There are a great many illegitimate children, and the want of sanitary precautions, especially conspicuous in their management, is the principal cause of the trouble. Although the masses of the people are cleanly in person, their habitations are disgustingly filthy; pigs, chickens, dogs, and children mixing indiscriminately in the main if not only room of the house, keep the atmosphere loaded with perfumes as different as possible from those usually associated with the tropics. The houses are well ventilated by the spaces between the canes of which they are constructed; and the continual change of air is the salvation of the inhabitants.

The stranger here is impressed with the small number of old people to be seen. One reason of this is the fact that the marriage relation is so rare among the lower classes; the custom of concubinage has been perpetuated since the days of the conquerors, who, leaving their wives in Spain, cohabited with the Indian women. Thus the women when old are thrown aside to die of neglect, and the old men are deprived of the tender care only to be obtained at woman's hand and in the domestic circle.

Foreigners in the hill country generally enjoy good health in proportion as they obey the sanitary requirements of the climate. Essential points are, the use of vegetable diet, fresh animal food, and temperate and cooling drinks; avoiding the fats and oils and intoxicating liquors; frequent bathing and general cleanliness; and avoidance of the mid-day sun. However, one of our healthiest parties worked on the river directly exposed to the sun daily during the months of April and May. And as an instance of the directly beneficent effect of the sun may be mentioned the fact that our health, while at work on the San Juan, was promptly and decidedly improved by changing our camps from the woods to the river sand-banks. In the woods the shade was so

dense that there was frequently no chance to dry damp clothes or bedding. The sand-banks were hard and dry to the depth of three feet, and were as hot as ovens for some hours at mid-day, thoroughly drying everything in camp during the working-hours, while the party was enjoying the benefit of the forest shade.

We think that expeditions to such countries as Nicaragua would find it true economy to carry only such provisions as sugar, tea, coffee, hard-bread, &c.; depending on fruits and vegetables and the fresh animal food of the country for support. The value of strong coffee early in the morning and the importance of abstinence from distilled liquors cannot be to strongly urged. The light wines have a very pleasant effect, taken at dinner. The lungs eliminate less carbonic acid than they do in temperate climates; and oils, fats of every description, and the distilled liquors throw extra duty on the liver, skin, and other excreting organs; and their use, if persisted in, must result in serious injury; while brandy, as an antidote to malarial influence, is not to be compared with coffee.

Those of our party who most nearly adopted the native diet were most healthy.

Very respectfully, &c.,

JOHN F. BRANSFORD,
Assistant Surgeon, United States Navy.

Commander EDWARD P. LULL, U. S. N.,
Commanding Nicaragua Surveying Expedition.

EXTRACT OF PROCEEDINGS OF THE ACADEMY OF NATURAL SCIENCES OF PHILADELPHIA.

DR. BRANSFORD'S COLLECTIONS OF REPTILES AND SHELLS, CLASSIFIED RESPECTIVELY BY PROF. EDWARD D. COPE AND BY GEORGE W. TRYON, JR., ESQ.

Description of some species of reptiles obtained by Dr. John F. Bransford, assistant surgeon United States Navy, while attached to the Nicaraguan surveying expedition in 1873. *By Edward D. Cope, A. M.*

The collection, though not large, embraces a number of interesting new and rare species besides those usually obtained in the region of Nicaragua. The whole number is twenty-eight, distributed as follows: serpents 12, lizards 9, tortoise 1, and Batrachia 6. Several interesting points in geographical distribution are established. I have added descriptions of three new snakes, one from near the same and two from more southern localities.

OPHIDIA.

Pliocercus dimidiatus, Cope.
Ophibolus micropholis, Cope.
Spilotes pullatus, L. var.

Of the typical form; scales in fifteen or sixteen rows, the outer smaller, several median considerably enlarged, the more central only faintly keeled; generally biporous. Only seven superior labials, the eye over the fourth and chiefly the fifth; sixth and seventh much enlarged, and nearly reaching the parietal shield, being only separated by a single narrow temporal each. Orbitals 1–2, the anterior nearly reaching the frontal. Loreal small, longer than high; nasals two, quite elongate. Frontal longer than wide, with broad front and concave sides. Parietals wide, truncate, followed by four scuta, the two outer the larger. Temporals 1–1 or 1–1–1. Inferior labials eight or nine, separated from the anterior gastrosteges by two rows of elongate scales on each side, in continuation of the geneials.

The general form is elongate; head a long oval; muzzle not prominent. Gastrosteges 226; an entire anal: mosteges 118.

General color black; near the middle of the length yellow spots appear at intervals on the belly, and increase in extent and frequency until they occupy most of the space anteriorly. On the upper surface a few yellow spots appear at remote intervals on the anterior half. A yellow band extends across the occiput from angle to angle of the mouth, and one across behind the orbits. There are large yellow spots on the frontal and superciliaries, and the prefrontals and labials are yellow-black, bordered.

Masticophis pulcherrimus, sp. nov.

Scales in quincunx, in seventeen subequal series, all smooth, many of them with two apical pores. Teeth subequal, without noticeable diastemata. Form very slender; tail one-third the total length. Gastrosteges weakly angulated, anal divided. Head flat, rostral low; loreal twice as long as high; prefrontal not reaching frontal, which is quite narrow; occipitals wide oval. Temporals 2–2–1–2 and 2–1–1–2. Superior labials nine—fourth, fifth, and sixth bounding orbit. Geneials slender. Total length, m. .875; tail, .285; gastrosteges, .205; urosteges, .152.

Ground-color clay-white; a black band, occupying two and two half rows of scales, extends on each side from the orbit to the end of the tail. The dorsal interval is one and two half scales in width, and was yellowish or reddish in life, except anteriorily, where it is an emerald-green. This brilliant color extends over the entire top of the head. Lips white.

This species is as slender as, and is partially colored as, some of the tree-snakes of the genus *Ahætulla*. From a small collection made on the "western side of Central America" by Prof.

George Davidson, which also contains *Elaps migrocinctus*, Gir., *Trimorphodon major*, Cope, *Boa eques*, Eyd-Soul.

Oxybelis acuminatus, Wied.
Ahætulla bilineata, Gthr. *Diplotropis bilineatus* Gthr. Ann. Magaz. Hist., 1872, p. 24.
Ahætulla mexicana, D. B.
Leptodira annulata, L. var.
Dipsas cenchoa, L.
Leptognathus atypicus, sp. nov.

Belonging to sec. vi of my monograph of this genus,* that is, with smooth equal scales, and short geneials separated by but one pair of labials from the symphyseals. The body is rather stout, and, unlike most of the genus, nearly cylindric; the neck is not contracted, but the head is wide and flat, and the muzzle short. Scales rather wide; in fifteen rows. Rostral plate subtriangular; a subquadrate loreal; no preocular; postoculars 2; temporals 2×3. Frontals and parietals broad and short, the latter truncate. Superior labials six, eye over third and fourth, fifth and sixth elongate. Inferior labials ten, mostly transverse; four pairs of geneials, all except the first broader than long. Tail short, m. .047 in length, from a total of m. .243.

Color pale, with black transverse spots, which are wide anteriorily (the second covers seven transverse rows of scales) and become gradually narrower, having a width of only two cross-rows on the hinder part of the body. Posteriorly their lateral ends are broken off, and alternate with the dorsal portion. A few small blotches on the ends of the gastrosteges.

This serpent and two fishes were presented to the Academy of Natural Sciences, with the statement that they were derived from some portion of the Peruvian Andes, from an elevation of twelve thousand feet. One of the fishes is *Trichomycterus dispar*, C. V., and the other is described below as *Protistius semotilus*.†

Leptognathus nebulatus, L.
Elaps nigrocinctus, Gird.
Bothrops atrox, L.
Teleuraspis schlegelii, Berth.

Yellow variety with short superciliary horns.

LACERTILIA.

Anolis bransfordii, sp. nov.

Abdominal scales smooth, pavement-like, longer than the dorsal and lateral scales, which are small, subequal, and smooth. Scales of tail subequal, carinate. Muzzle medium, shorter (from eye) than wide at orbits. Auricular meatus large, fully half of eye. Facial rugæ obselete, bounding a

* Proceed. Academy Natural Sciences, Philadelphia 1868, p. 107.

† PROTISTIUS SEMOTILUS, gen. et sp. nov.
Family ? Mugilidæ.

First dorsal fin represented by a single rudimental spine; second originating a little behind the line of the first anal radii. Ventrals present; lateral line rudimental. Mouth bordered above by the premaxillary only, which supports a band of rather large bristle-like teeth, those of the outer series the largest. Dentary bones with strong symphysis, with a band of teeth like those of the premaxillary. Swim-bladder present; alimentary canal short, simple.

Char. Specif.—Snout conical both from the lateral and vertical views. Premaxillary bone viewed from above, wide and angular crescentic; top of head moderately convex in cross-section, its integument not separated by a fold from the premaxillary. Lower jaw horizontal and angulated at the rictus and symphysis as in the genus *Mugil*. Pectoral fin elevated, rather short, the ventral commencing below its apex. Fin radii D. I. I. 10; P. 15; V. 5; A. I. 13; C. forked 2+8—9+2. Scales 4—81—17; lateral line very imperfect; isolated tubes visible at various points between scapula and tail. Head a little more than four times in length minus caudal fin; depth of body 5.5 times in the same; caudal peduncle deep. Eye with round adipose margins, 4.75 times in length of head, and twice in interorbital width. Top of head, opercula, and cheeks entirely scaled, the latter in four rows.

Above olivaceous, below yellow, a broad lead-colored lateral band on the posterior .66 of the length.

Length to opercular border m. .027, to ventral fins .052, to first dorsal .066, to second dorsal .078 to end of caudal fin. .140, all axially measured.

There are three gills and a half, and no pseudobranchus; the first branchial arch is the only one furnished with rakers. Branchiostegal radii six.

In its physiognomy this fish is intermediate between that of the *Mugilidæ* and that of *Cyprinodontidæ*. The form and scaling of the head and mouth, with the small spinous dorsal, are very similar to those of the *Mugils*, while the posterior position of the ventral fins and supporting bones, with the simple stomach and intestine, are characters of the latter family. I was unable to find any *ductus pneumaticus*, and if it exist it must be very slender.

The weight of evidence is in favor of referring this genus to the *Cyprinodontidæ*, and should its only dorsal spine occasionally be wanting, the reference will be less inappropriate than might at first appear.

The rudimental dorsal consists of a short (.002 m.) spine, but little elevated above the dorsal line, on account of the small extent of the membrane which binds it. It is well separated from the second dorsal.

This fish must be regarded as an interesting annectant form between types usually placed in the distinct divisions of *Physostomi* and *Physoclysti*.

distinct cavity, which is covered by smooth scales of the size of those on the remaining portions of the muzzle, in six longitudinal series. Superciliaries wide, separated from each other by one, and from the large occipital by two rows of scales. Twelve supraorbital scuta keeled; six loreal rows; fan little developed. Infralabials equal, small. Limbs slender, the anterior extending to the groin, the posterior to the end of the muzzle; dilatations well developed. Brachial and femoral scales equal ventral. Tail long and slender.

Color above golden-lead color, beneath silvery, the line of separation defined from the orbit to the groin. No cross bands on head or body; front brown speckled; feet blackish.

	M.
Length from end muzzle to eye	.0057
Length from end muzzle to ear	.0105
Length from end muzzle to axilla	.0170
Length from end muzzle to groin	.0350
Length from end muzzle to end of tail	.1190

This species resembles both the *A. longicaudus*, Hallow., and *A. trochilus*, Cope.* From the former it differs in the smooth abdominal scales, large auricular meatus, &c., resembling more the latter. In *A. trochilus*, a fine specimen of which accompanies the collection, the scales of the frontal area are much smaller, forming nine rows; four rows separate the superciliaries from each other and from the occipital. The muzzle is longer, and the head is marked with brown chevrons and cross-bands.

Dedicated to Dr. Bransford, who has been successful in his zoological investigations in connection with the expedition.

Anolis trochilus, Cope.

A female, with a single large egg in each oviduct.

Anolis cupreus, Hallow.
Anolis biporcatus, Wiegm.

The most southern locality recorded for this species.

Anolis pentaprion, Cope.

The most northern locality yet discovered for this *Anolis*.

Chamæleopsis hernandezii, Weig.
Stenodactylus fuscus, Hall.
Sphærodactylus glaucus, Cope.
Amiva eutropia, Cope.

TESTUDINATA.

Kinosternum leucostomum, Dum.

BATRACHIA.

Bufo sternosignatus, Gthr.
Bufo, sp.
Dendrobates auratus, Girard.
Dendrobates ignitus, sp. nov.

First finger shorter than second; end of the tarsus of the extended foot reaching the end of the muzzle. Membranum tympani visible, one-fifth the eye slit in extent; muzzle little prominent, as long as eye measured on the side. Derm of the back rather thick and glandular in fresh specimens; of the belly and limbs smooth. Color, vermilion red, all four limbs black in four specimens. In a fifth, which represents a variety, the red is replaced on the upper surfaces of the body and femur by a pink, which is thickly black-speckled; the faces of all the limbs, which are concealed when the latter are drawn up, are vermilion. Size small.

	M.
Length from end muzzle to axilla	.0095
Length from end muzzle to vent	.0115
Length of fore limb	.0138
Length of hind limb	.0253
Length of hind foot	.0120
Width at tympana	.0060
Width of sacrum	.0040

* Proceedings Academy Sciences, Philadelphia, 1871, p. 215.

Hyla ebraccata, sp. nov.

Of the type of *H. leucohpyllata*, and perhaps to be regarded as a color variety of it. It is a very distinct one and probably geographically circumscribed, and hence, until intermediate forms are discovered, may be considered as a species. Head broad, short, lores nearly vertical. Tympanum one-fifth orbit; skin above perfectly smooth. Fingers palmate to end of first phalange, toes to end of second. Tongue little free behind; vomerine teeth in fasciculi opposite anterior margin of nares. The heel extends to beyond the muzzle, which marks the middle of the forearm. Color above very light golden-brown; a deep brown triangular spot between the eyes, whose apex is produced backwards to a similar large spot on the back. A purplish-brown band from the end of the muzzle to the end of the coccyx, which fades below into the white of the belly. Edges of the upper lip white-marked; a large yellow spot below the eye, and small yellow spots in the lateral band. On the foreleg, the humerus like the forearm is brown above, silver-spotted. On the hind leg, the femur is entirely colorless; tibia is brown with silver bands and spots; bases of all the toes colored. Fingers uncolored except on the metacarpus. Belly yellow. Length of head and body 29 mm., width head 11 mm. Length hind leg 51 mm., to hind foot 22 mm.

Hypsiboas xerophyllum, Dum. Bibr.

Differing slightly from the typical form Surinam; probably a geographical variety.

APPENDIX.

Propus vermiformis, gen. et sp. nov.

Char. Gen.—Family *Chalcididæ*. Scales smooth, in annuli; a lateral longitudinal fold. Limbs one pair, the anterior only, without digits or claws. A few pores at the side of the vent. Head shields above, two internasals, one frontal, a narrow superciliary which descends in front of each eye, and a pair of parietals. Nostrils on the suture between internasal and first labial; a loreal shield. Tail elongate.

This genus is near to the *Ophiognomon** discovered by Prof. Orton, in Ecuador, and is principally distinguished from it by the absence of the posterior limbs.

Char. Specif.—Scales in twenty-six longitudinal rows on the posterior, and twenty rows on the anterior part (with closed lateral folds) of the body, and fifty-one transverse annuli between the nape and the vent. Anteriorly they are imbricate on the dorsal surface; posteriorly they are truncate. The abdominal and thoracic scales are subequal, those of the seventh row from the gular groove excepted, which embrace two between the fore limbs, and are not longer but wider than the others, but not so wide as long.

There are five upper labial plates, of which the third and fourth are of subequal length, and bound the orbit below; the second is the least. A large rhombic temporal separates the fourth and fifth from the parietals, behind which are two others. There are four narrow inferior labials and three infralabials, of which the two anterior are in contact on the middle line with those of the opposite side. They are preceded by a large geneial and small symphyseal. The last infralabials are separated from each other by four narrower scuta and from the temporal on each side by two scales. Two pores on each side of the vent, and three elongated scuta in front of it. Tail subquadrate in section, (perhaps contracted.)

	M.
Length of head and body	.064
Length of head	.006
Width of head	.004
Length of tail, (extremity lost)	.058
Length of fore limb	.0027

Color, a dark reddish-brown; a dorsolateral series of pale spots, one each side, separated by an average width of eight scales.

From Nauta on the Peruvian Amazon; obtained by Professor Orton. Various peculiarities distinguish this little saurian from the *Ophiognomon trisanale*, among which are the more numerous scales and mutual contact of the second pair of infralabials.

* Cope, Proceedings Academy Science, Philadelphia, 1868, p. 100.

Gerrhosteus prosopis, gen. et sp. nov.

Dentition opisthoglyph; cranial scuta normal, except that the prefrontals are united into a continuous shield. A loreal and a preocular; pupil vertical. Anal scutum undivided; subcaudals two-rowed. Scales poreless, smooth, subequal. The neural spines of the vertebræ each supporting a shield-like expansion, giving a T-shaped cross-section which is divided by a median groove.

This genus is the first of the *Ophidia* known to possess the osseous expansions common to some genera of Batrachia, etc., of the western tropical part of the neotropical region, and the miocene salamanders of the genus *Chelotriton*, Pom. The great development of the neural spine is not unlike that seen in frogs of the genus *Dendrobates*, which are characteristic of this region. The series of closely consecutive bony parallelograms forms an elevated rib throughout the length of the animal, which is clearly visible through the skin, which is not involved in it, though thin and closely adherent. The structure would appear to be an additional protection to the spinal cord from blows or falling objects.

Char. Specif.—General appearance that of a Lycodont, while the dental and scutal characters ally it most to *Oyrrhopus*. Head an elongate oval, very distinct from the narrow neck; body moderately stout; tail short, terminating in a corneus spine. Rostal plate small, not prominent, internasals small. Frontal broad as long, straight in front, with two subequal lateral facets for the preocular and the short superciliary. Parietals elongate. Nasal apparently single, large, descending nearly to the edge of the lips. Dorsal small, not longer than high. Preocular large, postoculars two, small. Eye small. Temporals 1–2, narrow. Superior labials seven; eye over the third and fourth, fifth and sixth the longest; geneials rather short, subequal. Scales in seventeen longitudinal series, rather wide; the first not materially larger. Gastrosteges 137; anal 1; urosteges 32. Total length, m. .305, (12.5 inches); of head .011; of tail .046.

Color, light brown, with black triangular spots on each side of the middle line, the apices directed downward and extending half-way to the gastrosteges. The intervals between the apices are about four scales in length, and are centrally darker than immediately round the black spots. The spots are sometimes connected by a black vitta on the median line, giving, when they alternate, the appearance of zigzag band. Top of head dark brown; lower surfaces and lips pale and unspotted.

The neural osseous plate is deeply longitudinally fissured, each half having a tubercularly rugose superior face. The anterior border is notched, while the posterior is a little produced on each side of the groove. Length of plate, m. .0018; width of plate, .0013.

From Nauta on the Peruvian Amazon; two specimens obtained by Prof. James Orton during his last survey of that region.

LIST OF SHELLS COLLECTED IN NICARAGUA BY DR. J. F. BRANSFORD, U. S. N. PREPARED BY GEO. W. TRYON, JR.

1.—*Terrestrial species.*

Ortholicus princeps, Broderip.
Bulimus Petensis, Morelet.
Glandina indusiata, Pfr.

2.—*Fluviatile species from Lake Nicaragua.*

Unio cyrenoides, Phil.
Anodonta Bridgesii, Lea.
Ampullaria pyrum, Phil.

3.—*Marine species from Brito and San Juan del Sur.*

Solen (Mesopleura) subteres, Conrad.
Mactra exoleta, Gray.
Strigilla fucata, Gould.

Donax (Hecuba) dentifera, Hanley.
Donax (Serrula) radiata, Val.
Crassatella undulata, Sowb.
Venus multicostata, Sowb.
Chione fluctifraga, Reeve, *var.* callosa, Sowb.
Chione gnidia, Brod. & Sowb, *var.* amathusia, Phil.
Chione (Cytherea) grata, Say.
Cryptogramma subrugosa, Sowb.
Tivela radiata, Sowb, *var.* Hindsii.
Tivela planulata, Brod. & Sowb.
Amiantis unicolor, Sowb.
Dione alternata, Brod.
Dione lupanaria, Lesson.
Dosinia ponderosa, Gray.
Cardium procerum, Sowb.
Lævicardium elatum, Sowb.
Arca tuberculosa, Sowb.
Noetia reversa, Gray.
Meleagrina margaritifera, Linn.
Pecten ventricosus, Sowb.
Placunanomia macroschisma, Desh.
Murex punceps, Brod.
Cypræa cervinetta, Kiener.
Cypræa arabicula, Lam.
Mitra (Strigatella) tristis, Brod.
Oliva incressata, Solander. (=Molchersii, Menke.)
Purpura biserialis, Blain.
Purpura speciosa, Val.
Purpura intermedia, Kiener.
Purpura patula, Linn.
Purpura carolensis, Reeve.
Purpura melones, Lam.
Monoceros cingulata, Lam.
Monoceros muricata, Brod.
Columbella fuscata, Sowb.
Columbella Boivini, Reeve.
Conus purpurascens, Brod.
Conus pyriformis, Reeve.
Cerithium maculosum, Kiener.
Ranella nana, Sowb.
Trochus pelles-serpentis, Chemn.
Omphalius viridula, Menke.
Littorina zizzag, Chemn.
Turritella goniostoma, Val.
Nerita ornata, Sowb.
Neritina intermedia, Sowb.
Crepidula aculeata, Brod.
Fessurella nigropunctata, Sowb.
Siphonaria gigas, Sowb.

REPORT BY DR. FREDERIC M. ENDLICH, GEOLOGIST OF THE SMITHSONIAN INSTITUTION, UPON LITHOLOGICAL AND GEOGNOSTIC SPECIMENS COLLECTED IN NICARAGUA IN 1872–'73.

The lithological and geognostic specimens from Nicaragua, Central America, submitted for classification by Commander E. P. Lull, U. S. N., have been duly examined, and the following may be stated with reference to them:

Mainly, the specimens consist of sedimentary and volcanic rocks, the former occurring in more or less local outcrops, the latter apparently constituting the larger portion of the surface.

To admit of any deductions relative to the general distribution, however, the amount of material given is too small and the data supplied, regarding locality, &c., are too meager. In order to arrive at any definite conclusions, a geologist must be thoroughly acquainted with the geognostic and topographical features of any section of country that he may wish to report upon.

Besides the rocks a number of fossils have been collected, contained in gray and reddish limestone, with sometimes calcite, but their state of preservation is such as to admit of no specific identification, so that the geological age of the formation in which they are contained can only be surmised. It may perhaps properly be placed in the vicinity of the carboniferous.

Some of the limestones are argillaceous, several to such an extent that the clay predominates, and they form calcareous argillites. One of these latter was found to contain numerous minute crystals of pyrites. A limestone from Soledad, to which attention was directed, was found to be of a light gray color, partly crystalline, not sufficiently so, however, to pass for marble, and upon examination proved to be very pure. Undoubtedly this stone could very well be used for technical purposes, where the application of "burnt lime," &c., is required. From Tipitapa a light brown to yellow limestone was obtained. It is tufaceous; was found to be sufficiently pure to make good mortar, &c. Although it contains a small amount of alumina, this will probably render it all the more durable. Some organic matter found in it will burn out. Darker colors usually prevail among the rest of the limestones submitted, they containing sometimes but very few impurities.

Of considerable interest are the volcanic rocks contained in the collection. Classification of young volcanic rocks, without a comprehensive acquaintance with the geological conditions under which they occur, can rarely be much more than approximate. So much can be said, however, that the rocks under consideration belong to the Tertiary period, probably to the latter half of it, analogous to the volcanic material found in the Rocky Mountains of the United States.

Compact basaltic types appear to be the most numerous, partaking somewhat of the character of the more coarse-grained dolerite. Compact basalt or dolerite—if not too coarse-grained—will always form a valuable stone for building purposes, wherever found in blocks of the requisite size. Where pressure must be endured, fine-grained compact basalt has been found to answer better than the majority of rocks usually employed for building purposes. A specimen from San Carlos indicates a variety that would probably answer well as building material. Basalt yields very gradually only to the destroying action of atmospheric influences, in consequence decomposes very slowly, thus forming a desirable acquisition for building purposes. Prior to the basalt in geological age seem to be the remaining specimens of volcanic rocks. Although lithologically not identical with the analogous rocks farther north, they probably belong to the Andesitic group of eruptives, deriving their name from the wide distribution they were found to have throughout the Andes Mountains.

Several specimens of sand were collected, but as they are merely made up of the *débris* of volcanic rocks, through which the drainage seems mainly to pass, they present but little interest.

Some silver ores from Segovia were also contained in the lot, but arriving only a short time before my departure for the West, the facilities for making examinations were no longer at hand, and therefore no determination of their value was made. The continuation of the mining enterprise, however, at the place of their occurrence, is the best indicator of their value.

Respectfully submitted.

FREDERIC M. ENDLICH.

REPORT OF SIX MONTHS' OBSERVATIONS OF WEATHER, &c., OFF GREYTOWN, NICARAGUA, BY COMMANDER A. V. REED, COMMANDING UNITED STATES STEAMER KANSAS, 1874.

UNITED STATES STEAMER KANSAS, (3D RATE,)
Off San Juan del Norte, (Greytown,) Nicaragua, June 18, 1873.

SIR: In obedience to your orders, I have the honor to submit the following report of observations made here during the past six months, which include all of the dry season. We have not been here continuously, but have made visits as follows: From December 20 to 26, 1872; January 10 to 15, 1873; January 28 to February 8; March 11 to April 6; May 2 to 13; May 17, and May 23 to June 18.

The latitude, as found from the mean of several meridian altitudes of the sun and of fixed stars by sextant and artificial horizon, is 10° 55′ 16.7″ north, and the longitude, brought from Aspinwall by repeated trips, is 83° 40′ 23″ west. The place of observation is in the public plaza south 3° west of the Catholic church spire, 250 feet distant, and the longitude of Aspinwall 79° 53′ 03″ west.

The only regular winds that we have found are the trade-winds, which, however, do not blow home constantly. They vary from east by north to northeast, generally at east-northeast, are not strong, and rarely last all night, being succeeded about 10 p. m. by light and baffling land-breezes, varying between south-southeast and northwest. This place seems to be near the limit of the trades, so they cannot be depended on, though they usually blow every day, but sometimes very light and only for a few hours. Along the coast to the southward still less dependence can be placed on them, while at Monkey Point, forty miles to the northward, they are stronger and more reliable.

This place is not subject to bad gales, and the gulf from here across to Point Manzanilla, near Aspinwall, seems to be very free from strong winds.

The people usually expect a norther at the breaking up of the wet season in January; this we had on the 19th, off Aspinwall, and it is the only stormy wind we have experienced in these waters in the six months we have been here.

The dry season usually lasts till late in May, when the rains set in, and are of daily occurrence during June and July, with considerable thunder and lightning.

In August and September they have very pleasant weather, with less rain and the sea outside usually smooth, but in October and November again they have disagreeable weather and daily rains.

Currents.—There is a well-developed and regular current setting to the southward and eastward, parallel to the coast, varying from three-quarters to one and one-quarter knots per hour; it continues along to the eastward, following the trend of the coast, and to northward and eastward beyond Aspinwall.

There is also a current setting out of the San Juan River, but it does not extend far from shore, and is only important as affecting the bar at the entrance of the harbor.

The original entrance to the harbor at Punta Arenas is entirely closed now by a dry sand-bar from 50 to 300 feet wide, and the river has broken out another passage at Harbor Head, two and one-half miles to the eastward. This bar at Punta Arenas breaks through nearly every year at the time of high water, but closes up again.

The opening at Harbor Head is changing all the time, and consequently the direction of the current and depth of water on the bar are variable. Lately this current has been setting to northward and westward up the coast, and the effect of the sand brought down the river being thrown back on the coast by the heave of the sea has been to make an excellent landing-cove for boats and lighters about two miles to the westward of Harbor Head, and near what was formerly Punta Arenas.

This is changing daily, and may close up at any time; it has lasted about two months now, and has been a great convenience for unloading vessels, and it has enabled us to communicate with the town easily.

The point at Harbor Head materially changed in February by the river's breaking through to the westward and forming an island of about half an acre, and now very little water runs around the point, and it will probably be closed soon by a sand-spit which has made out from the land to southward and eastward of Harbor Head; then the entrance will be on the other side of this island from where it was in January. The bar and land are chan ging all the time, so that a survey, however accurate, would not be reliable the following year with out corrections. There has been from 2½ to 4 feet of water on the bar at Harbor Head since we have been here, and a bad surf much of the time, which has made communication with the town by this way quite uncertain. There is an iron steam-lighter here of a capacity of twelve tons, but it can make only one trip per day loading or unloading vessels outside, and part of the time the bar has been so bad that it was useless here, and it was sent down to the mouth of the Colorado, twelve miles distant, to transfer cargo there. At one time there was no communication with the town here for a week, in consequence of the trade-winds blowing steadily and stronger than usual and bringing in a heavy swell.

Anything like a strong breeze cuts off all communication, except by canoes, which the Caribs* and the Blewfield Indians are very skillful in handling; they will go in and out through the surf in almost any weather.

All the land on the coast here, except two hills below a point three miles south of Punta Gorda, is low and flat, and has probably been formed by alluvial matter brought down by the rivers, or washed down from the highlands back from the present coast-line in a long course of years.

If this is correct, the water all about here must have been quite deep, for we go but a few miles off shore to get into blue water and off soundings. On our last trip from Aspinwall, when twelve miles east-southeast from our present anchorage and seven miles from the land, the water being discolored by the water from the Colorado River, we got a cast of the lead, but found no bottom at 125 fathoms; but on nearing the shore, one and a half miles, we found bottom at 32 fathoms—a sandy blue mud. From this point the soundings gradually decreased as we neared the shore, the character of the bottom remaining the same. I would have liked to go back and run a line of soundings out to the deepest water in the gulf, to determine the character and contour of the bottom, but did not have the time nor means.

There are no dangers in approaching the anchorage, and you can run into five or six fathoms anywhere; the lead is an unfailing guide. There are nine feet just outside the surf, which soon deepens to three fathoms.

The best anchorage at the present time is in six fathoms water, with Dead-Tree Point bearing east to east half north by compass, and the Catholic church spire in Greytown bearing southeast half south, in full view of the town, which is inland.

Vessels frequently anchor in 10 to 12 fathoms, with Harbor Head bearing south, about one and a half miles distant; but they roll much more there, and the other anchorage has several advantages. The holding-ground is good at either place.

There is no good landmark between Round Hill, eighteen miles above Greytown, and Turtle-Bogue Hill, twenty-three miles below, but the latter particularly is excellent; a small, round hill, with nothing but low land around it, and entirely different from anything else along the coast.

Vessels coming to Greytown, particularly under sail, on account of the coast current, would do well to keep to the northward till they strike soundings, then coast along down, which they can do in six fathoms in safety, keeping well in-shore after sighting Dead-Tree Point, which makes well out to eastward. The anchorage is the only bight, with a northerly exposure, between Monkey Point, forty miles above Greytown, and Turtle Bogue, and it may be easily recognized by this. If a vessel falls to the southward of the Point it is difficult to work up against the current, as the

* A tribe of negroes inhabiting the coast to the northward, and supposed to be the descendants of a slave cargo wrecked upon the coast many years ago, and to whom the name Carib has been improperly applied.—E. P. L.

wind is usually light; but from the northward a vessel can float down with the current in a dead calm.

Fresh water can be obtained by sinking shallow wells on the beach, but it is not of first quality. The water of the inner harbor is fresh, though at times in the dry season a little brackish; but if taken at the mouth of the river, where there is considerable current, it is good and sweet, though it must contain considerable vegetable matter, and it is not easy to get it off through the surf. Usually enough rain-water can be caught by the awnings to supply a ship.

Small quantities of provisions, lumber, and other stores can be purchased on shore, but they are all imported, and prices are high.

There are no pilots here and none are necessary.

July 5, 1873.—(Additional.)—On the 16th ultimo a small trench was dug through the sand-bar at Punta Arenas, which by the high water of the river was soon enlarged so as to make a good entrance for boats, and to-day I passed through it in a ship's boat, finding six feet of water, and the entire width of the opening about 80 feet. It is the best entrance they have had to the harbor for three years, and it is expected that it will remain open as long as the high water continues in the river.

The landing cove heretofore referred to has entirely closed up.

Very respectfully, your obedient servant,

ALLEN V. REED,
Commander U. S. N., commanding Kansas.

Commander EDWARD P. LULL, U. S. N.,
Commanding Nicaragua Surveying Expedition.

REPORT ON BLASTING OUT OBSTRUCTIONS IN THE CHANNEL OF THE RIVER SAN JUAN. BY COMMANDER A. V. REED, COMMANDING UNITED STATES STEAMER KANSAS, 1874.

UNITED STATES STEAMER KANSAS, (3D RATE,)
Off Colorado River, Costa Rica, April 7, 1873.

SIR: In obedience to your orders of 4th ultimo, in relation to sending some torpedoes to the Nicaragua Surveying Expedition to clear out obstructions in the San Juan River at Castillo, I have the honor to make the following report:

On the 25th ultimo I sent Lieut. F. G. Hyde, who has had a course of instruction at the torpedo station at Newport, from Greytown up the river, by the way of the Colorado, with three 75-pounder torpedoes, with different devices for discharging them. The electrical machine unfortunately was out of order, and could not be used for this work.*

I went up the following day to superintend the work personally.

We arrived at Machuca the 29th, and, by your direction, commenced work there, as the rapids there are dangerous, and there are some rocks which, if they could be removed, would greatly benefit the river navigation; besides the current does not run as swiftly there as at Castillo, and it would be easier to place the torpedoes properly. The river being at a very low stage these rocks were near the surface of the water, and our first endeavor was to discharge a keg of rifle-powder just above Buoy Rock, to make a bed for one of the large torpedoes to rest in, and so have more water above it. We were not successful in this, though we made a number of attempts, for want of proper means of discharging the torpedoes.

We used principally blasting-fuse of different kinds, which, though made to burn under water, would not withstand the twisting and whipping of this rapid, irregular current, and chafing against the rocks, though we tried several expedients and exhausted all the means at our disposal to protect it. Finally, we placed one of our 75-pounder torpedoes on top of the rock at the upper end, having weighted it with bars of iron to prevent its being moved by the current, and discharged it

*This was a frictional machine, which was formerly furnished as part of the torpedo outfit of ships. It has now given place to the dynamo-electric machine invented by Prof. M. G. Farmer.—E. P. L.

by means of a friction-primer and a long lanyard led down the river. The rock was tough, apparently of a limestone formation, and worn smooth by the action of the water; and there being but 18 inches of water over the torpedo, I was somewhat surprised at the result obtained. Where the upper end of the rock had been there was a hole 4 or 5 feet deep, and that part of the rock had been blown to pieces and thrown off into deep water, so that it would not have interfered with the passage of a river-boat.

The rock was too large, however, to be cleared away by a single torpedo, but I judged, from the effect of this one, that four or five would have cleared it away entirely, and made the passage of Machuca Rapids much safer than it is at present.

The current there runs about five and a half miles per hour, and surges and twists around, making it very difficult to place a torpedo, particularly as we had nothing but a canoe to work in; so having demonstrated the fact that a proper application of powder would clear out the channel so as to render the navigation by the river-boats easy and safe, and not having the proper appliances at our disposal, this work was stopped.

Besides the canoe-men we had the assistance of two Caribs, who had been accustomed to work in and around water all their lives and were very skillful, or we could not have succeeded as well as we did.

I think that a flat-boat, with an anchor and chain, so that it might be dropped down to the rocks from above, and a hollow iron wedge of this ⅄ shape resting on the rock and held with the point up stream, so that the person placing the torpedo could work in comparatively still water, would be everything requisite to doing this work successfully.

As an illustration of the power of the water here, I would say that it was all a man could do to stand when the water was 8 inches above his knees, and to do any work it was necessary to hold on to the boat with one hand while working with the other; deeper than this they could not work at all, except from the canoe; again, the stern-wheel steamer Pit-Pan, carrying 120 pounds pressure and making fifty-five revolutions per minute, could not stem the current and get around this rock.

The difficulties at Castillo Rapids being still greater than those at Machuca, no attempts were made to do anything there.

Several 12½-pound kegs of fine rifle-powder, furnished by Mr. Hollenbeck, the president of the Nicaragua Steam-Navigation Company, were afterward exploded under and around obstructions in the river, caused by trees, &c., with excellent effect, and much improving the temporary channels and facilitating the river navigation.

These were discharged by means of blasting-fuse, but in places where the current was much less than that around Buoy Rock.

Very respectfully, your obedient servant,

ALLEN V. REED,
Commander U. S. N., commanding Kansas.

Commander EDWARD P. LULL, U. S. N.,
Commanding Nicaragua Surveying Expedition.

A BRIEF HISTORICAL MEMOIR OF INTEROCEANIC COMMUNICATION ACROSS THE GREAT ISTHMUS, ESPECIALLY OF THE PLANS FOR A SHIP-CANAL ACROSS NICARAGUA. BY PROFESSOR J. E. NOURSE, U. S. N.*

This problem of interoceanic communication has been justly said to possess "not only practical value, but historic grandeur." It clearly links itself back to the era of the conquest by Cortez, three and a half centuries. And one may rightly say, further, that it links itself to the ages running back beyond even our Christian era. For, among the objects earnestly striven for by men through all the long centuries, there has been one which, in some features at least, has been the same with this problem; the same with that before the mind of Alexander, first opening up by his military expedition Asia to the Greek; the same with that before the old Roman, bringing from that far-off

* Furnished by request of Commander Lull.

land coveted wealth and luxuries to his proud capital; the same before the men of the Middle Ages, pushing on by different routes their intercourse with the East; the same, in part, with that before Columbus and his followers:—the one perpetuated unchanging desire for closer, readier, intercourse with Asia—old Cathay.

It has been reserved for our age to crown the lower motives in these enterprises, often of mere gain and adventure, with those of extending over the East the highest types of civilization and Christian enlightenment, hopefully to be conferred upon it by every means tending toward the closer intercourse and fellowship of men.

Such means are involved largely in the successful issue of this problem; for it is to be remembered in this connection that the historical development of civilization has been westward. "It has followed the sun," says Guizot, "from east to the west." The development of its vigorous type in our day on our own western shores is already undermining the effete systems of Japan—an earnest and token of the increasing power which it must secure by every increase of closer intercourse through all new channels of commerce.

It cannot, therefore, be uninteresting to any mind drawn to this problem to study the enterprises undertaken for its solution, nor will it be possible to escape being drawn into sympathy with this great object and with every faithful explorer in his labors and privations to secure it. Nor, although the plans of one generation for this may have failed, and even those of to-day may seem yet deferred, can this interest and sympathy be withdrawn; for the object remains as worthy, the names associated with it are as worthy, and the final issue will seem, perhaps, as hopeful, despite the obstacles which for this, (as for many other great interests of the world,) by some strange providence, defer the coveted success.

Only a very extended treatise could present even a sketch of the enterprises undertaken for the end proposed by individuals and associations and by the governments occupying the great Isthmus, or those most directly related to it. The brief compend which follows is designed to stimulate interest in the general question in hope of its successful issue.

It will be sufficient here to sketch in brief—

I. The disposition of the Spanish monarchy toward interoceanic communication.
II. The disposition of the States of the Isthmus toward it on their acquiring independence.
III. The plans for the opening up of a route through Nicaragua.

I. RELATION OF THE SPANISH GOVERNMENT TO THE OPENING UP OF INTEROCEANIC COMMUNICATION.

Spain, which acquired through her Columbus a new empire, lying near, as it was supposed, to the riches of Asia, could not be indifferent, from the moment of her discoveries, to the means of crossing these lands to yet richer ones beyond.

India, from the days of Alexander and of the geographers Mela, Strabo, and Ptolemy, was the land of promise, the home of the spices, the inexhaustible fountain of wealth. The old routes of commerce thither had been closed one by one to the Christians; the overland trade had fallen into the hands of the Arabs; and at the fall of Constantinople, 1453, the commerce of the Black Sea and of the Bosphorus, the last of the old routes to the East, finally failed the Christian world. Yet even beyond the fame of the East, which tradition had brought down from Greek and Roman, much more had the crusaders kindled for Cathay and its riches an ardor not easily suppressed in men's minds.

The error of the Spanish admiral in supposing that the eastern shores of Asia extended 240 degrees east of Spain, or to the meridian of the modern San Diego in California—this error, insisted on in his dispatches and adopted and continued by his followers, still further animated the earlier Spanish sovereigns and the men whom they sent into the New World to reach Asia by a short and easy route.

During three successive and marked periods this animation existed; in the first, or so long as the delusion that it was Asia which had been discovered remained, the sensation throughout Europe was at its height; in the second, from the discovery of the South Sea by Balboa, in 1513, the eagerness of the mariner to reach Asia, now known to lie beyond, continued to be known

world wide; in the third period, if we may so say, from the accession of Philip II, "this sacred fire of Spain" (now possessed of all the domain in the New World from which exploration westwardly for such a route could now be made) languished and was at last smothered by her sovereigns.

In the first period the very announcement of Columbus of his discovery stirred Europe by the expectancy of such new and short roads to the East. His announcement, read in various editions in prose and verse for years following, was entitled, "A letter of Christopher Columbus, to whom our age is much indebted respecting the islands of India beyond the Ganges, lately discovered." To his dying day, 1506, as is well known, he believed this true; supposing he had reached "Zipangu," Japan. In 1501 he was exploring the coast of Veragua, in Central America, still looking for the Ganges, and announcing his being informed on this coast of a sea which would bear ships to the mouth of that river; while about the same time the Cabots, under Henry VII, were taking possession of Newfoundland, believing it to be part of the island-coast of China.

Although these were grave blunders in geography and in navigation, the discoveries really made in the rich tropical zone, the acquirement of a new world, and the rich products continually reaching Europe from it, for a time aroused Spain from her old lethargy. The world opened east and west. The new routes poured their spices, silks, and drugs through new channels into all the Teutonic races. The strong purposes of having near access to the East were deepened and perpetuated doubly strong, by the certainties before men's eyes of what had been attained.

In the second period of which one may speak in looking back upon that age, Balboa appears, (1513,) gaining from a height on the Isthmus of Panama the first proof of its separation from Asia; and Magellan enters the South Sea at the southern extremity of the country, now first proven to be thus separate and a continent. Men began then to think that creation was doubled, and that such discovered lands must be separate from India, China, and Japan. And the very successes of the Portuguese, under De Gama, bringing from their eastern course the expectancy of Asia's wealth, intensely excited the Spaniards to renew their western search.

The Portuguese, led around the Cape of Good Hope, had brought home vast treasures from the East, while the Spanish discoverers, as yet, had not reached the countries either of Montezuma or of the Incas. Their success "troubled the sleep of the Spaniards."

Everything, then, of personal ambition and national pride, the thirst of gold, the zeal of religious proselytism, and the cold calculations of state policy, now concurred in the disposition to sacrifice what Spain already had of most value on the American shores in order to seize upon a greater good, the Indies, still supposed to be near at hand. And since it was now certain that the new lands were not themselves Asia, the next aim was to find the secret of the narrow passage across them which must lead thither. The very configuration of the Isthmus strengthened the belief in the existence of such a passage by the number of its openings, which seemed to invite entrance in the expectancy that some one of them must extend across the narrow breadth of land.

For this the Spanish government, in 1514, gave secret orders to D'Avila, governor of Castila del Oro, and to Juan de Solis, the navigator, to determine whether Castila del Oro were an island, and to send to Cuba a chart of the coast, if any strait were possible. For this, de Solis visited Nicaragua and Honduras; and later, led far to the south, perished in the La Plata. For this, Magellan entered the straits which, strangely enough, he affirmed before setting out, that he "would enter," since he "had seen them marked out on the geographer Martin Behaim's globe." For this Cortez sent out his expeditions on both coasts, exposing his own life and treasure, and sending home to the emperor in his second relation a map of the entire Gulf of Mexico.* For this great purpose, and in full expectancy of success in it, the whole coast of the New World on each side, from Newfoundland on the northeast, curving westward on the south around the whole sweep of the Gulf of Mexico, thence to Magellan's Straits, and thence through them up the Pacific to the straits of Behring, was searched and researched with diligence. "Men could not get accustomed," says Humboldt, "to the idea that the continent extended uninterruptedly both so far north and south." Hence all these large, numerous, and persevering expeditions by the European powers.

* See a most singular and instructive dispatch on this matter from Cortez to Charles V, October 15, 1524. See translation of these by Folsom.

Among them, by priority of right and by her energy, was Spain. The great emperor was urgent on the conqueror of Mexico, and on all in subordinate positions in New Spain, to solve the secret of the strait. All Spain was awakened to it. "How majestic and fair was she," says Chevalier; "in the sixteenth century what daring, wh at heroism and perseverance! Never had the world seen such energy, activity, or good fortune. Hers was a will that regarded no obstacles. Neither rivers, deserts, nor mountains, far higher than those in Europe, arrested her people. They built grand cities; they drew their fleets, as in a twinkling of the eye, from the very forests. A handful of men conquered empires. They seemed a race of giants or demi-gods. One would have supposed that all the work necessary to bind together climates and oceans would have been done at the word of the Spaniards as by enchantment, and since nature had not left a passage through the center of America, no matter, so much the better for the glory of the human race; they would make it up by artificial communication. What, indeed, was that for men like them? It were done at a word. Nothing else was left for them to conquer, and the world was becoming too small for them.

"Certainly, had Spain remained what she then was, what had been in vain sought from nature would have been supplied by man. A canal, or several canals, would have been built to take the place of the long-desired strait. Her men of science urged it. In 1551, Gomara, the author of the 'History of the Indies,' proposed the union of the oceans by three of the very same lines toward which, to this hour, the eye turns with hope."

"It is true," said Gomara, "that mountains obstruct these passes, but if there are mountains there are also hands; let but the resolve be made, there will be no want of means; the Indies, to which the passage will be made, will supply them. To a king of Spain, with the wealth of the Indies at his command, when the object to be obtained is the spice trade, what is possible is easy.

"But the sacred fire suddenly burned itself out in Spain. The peninsula had for its ruler a prince who sought his glory in smothering free thought among his own people, and in wasting his immense resources in vain efforts to repress it also outside of his own dominions through all Europe. From that hour Spain became benumbed and estranged from all the advances of science and art, by means of which other nations, and especially England, developed their true greatness.

"Even after France had shown, by her canal of the south, that boats could ascend and pass the mountain-crests, it does not appear that the Spanish government seriously wished to avail itself of a like means of establishing any communication between her Sea of the Antilles and the South Sea. The mystery enveloping the deliberations of the council of the Indies has not always remained so profound that we could not know what was going on in that body. The Spanish government afterwards opened up to Humboldt free access to its archives, and in these he found several memoirs on the possibility of a union between the two oceans; but he says that in no one of them did he find the main point, the height of the elevations on the Isthmus, sufficiently cleared up, and he could not fail to remark that the memoirs were exclusively French or English. Spain herself gave it no thought. Since the glorious age of Balboa among the people, indeed, the project of a canal was in every one's thoughts. In the very wayside talks in the inns of Spain, when a traveler from the New World chanced to pass, after making him tell of the wonders of Lima and Mexico, of the death of the Inca, Atahualpa, and the bloody defeat of the Aztecs, and after asking his opinion of El Dorado, the question was always about the two oceans, and what great thing would happen if they could succeed in joining them."

"The Spanish government alone cared nothing for it. For years there was not one publication upon the subject which the humblest of our civil engineers would not now deem beneath his study. It became a mere idea and legend. The long wars of the Spanish monarchy and its fearful decline almost consigned the very idea to oblivion."

During the whole of the seventeenth and eighteenth centuries Spain had need of the best mode of conveyance for her treasures across the Isthmus. Yet those from Peru came by the miserable route from Panama to the deadliest of climates, Porto Bello, and her European wares for her colonies toiled up the Chagres River; while the roughest of communications farther north connected the Chimalapa and the Guasacoalcos in Mexico, and the trade there was limited sternly to but one port on each side. As late as Humboldt's visit, in 1802, when remarking upon the "unnatural modes of communication" by which, through painful delays, the immense treasures of

the New World passed from Acapulco, Guayaquil, and Lima to Spain, he says "these will soon cease, whenever an active government, willing to protect commerce, shall construct a good road from Panama to Porto Bello. The aristocratic nonchalance of Spain, and her fear to open to strangers the way to the countries explored for her own profit, only kept those countries closed." The court forbade, on pain of death, the use of plans at different times proposed. They wronged their own colonies by representing the coasts as dangerous and the rivers impassable. On the presentation of a memoir for improving the route through Tehuantepec by citizens of Oaxaca, as late as 1775, an order was issued forbidding the subject to be mentioned. The memorialists were censured as intermeddlers; and the viceroy fell under the sovereign's displeasure for having seemed to favor the plans.

The great Isthmus was, however, further explored by the Spanish government for its own purposes; its recesses were traversed, and the lines of communication which we know to-day were then noted.

The plans of these routes furnished by Humboldt in the atlas illustrating his "Personal Narrative of Travels in the New World," show an accuracy of detail which can be attributed only to their being derived from good Spanish maps. In regard to the maps and charts of the New World, however, it is a remarkable fact that, as concerns Nicaragua, those which seem ever to have fallen into the hands of any others than the Spaniards are meager and inaccurate. The collections of Mr. Jefferys, geographer to the King in the middle of the eighteenth century, as well as those published under the sanction of the admiralty, and those of Mr. Arrowsmith—all drawn from charts captured by the English in their wars with Spain—contain detailed charts and plans of Porto Bello, of Chagres, of Panama, of Vera Cruz, and of the neighboring coasts, but nothing of the regions farther north or south.

In addition to the fact that comparatively little was explored north or south of that which early became the main highway, the Panama Isthmus, there is confirmation here of the truth that Spain concealed and even falsified much of her generally accurately made surveys. No stronger proof of this need be asked than that which Alcedo gives in connection with the proposal by Gogueneche, the Biscayan pilot, to open communication by the Atrato and the Napipi. "The Atrato," says the historian, "is navigable for many leagues, but the navigation of it is prohibited under pain of death, without the exception of any person whatever."

The Isthmus of Nicaragua has always invited serious consideration for a ship-canal route by its very marked physical characteristics, among which is chiefly its great depression between two nearly parallel ranges of hills, which depression is the basin of its large lake, a natural and all-sufficient feeder for such a canal.

Any valuable knowledge of its topography is of recent date, though its general features were early known to the Spaniards. Gonzales D'Avila and Hernandez de Cordova traversed the country, when they named it Nicaragua, from the cazique who aided them in its conquest. In 1524 a squadron of discovery sent out by Cortez on the coast of the South Sea, announced the existence of a fresh-water sea at only three leagues from the coast; a sea which, they said, rose and fell alternately, communicating, it was believed, with the Sea of the North. Various reconnoissances were, therefore, made, under the idea that here the easy transit would be established between Spain and the spice lands beyond.

It was even laid down on some of the old maps that this open communication by water existed from sea to sea; while later maps represented a river, under the name of Rio Partido, as giving one of its branches to the Pacific Ocean and the other to Lake Nicaragua. The archives of Madrid contained French and English memoirs on joining the Pacific and the lake, based on these crude ideas—memoirs opened to Humboldt in the end of the eighteenth century. An exploration by the engineer, Bautista Antonelli, under the orders of Philip II, corrected the false idea of an open strait. The Spanish government did not divulge his survey; nor were those previously ordered by the royal decrees of 1524 and 1537 ever executed; the Castilian captains in Nicaragua being fully occupied by their own rivalries in their search for gold. Notwithstanding that in 1546 Melchor de Veidergo demonstrated the navigability of the San Juan River by descending it with four brigs, no efforts were made to improve it, nor inquiry instituted as to the practicability of a

canal from sea to sea. Reports upon this, occasionally made to the council of the Indies, resulted in a single reading and their consignment to the archives.

The strangeness of all this utter neglect is increased when one remembers that the same government expended upon the famous Desague of Huetocha, the open cut made to protect the city of Mexico from inundations, a no smaller sum than $6,000,000; cutting with seeming readiness to the depth of more than 150 feet for a long distance. The city had a great memory of the conquest to perpetuate, and the palace of the viceroy must be safe; but the great routes of trade and intercourse, affecting the interests of the world, were of less moment. This, says Chevalier, "was to falsify her own interests and those of civilization, and yet by the divine law there is a right of confiscation against states which do not improve the talent committed to their trust; a law written often in letters of fire on the pages of history."

In the eighteenth century a new cause arose for jealousy of her neighbors and for keeping her northern part of the Isthmus from their view. In the years 1779 and 1780 the serious purposes of the English government for the occupancy of Nicaragua awakened the solicitudes of the Spanish government for this section. The English Colonels Hodgson and Lee had secretly surveyed the lake and portions of the country, forwarding their plans to London, as the basis of an armed incursion, to renew such as had already been made by the superintendent of the Mosquito Coast forty years before, when, crossing the Isthmus, he took possession of Realejo, on the Pacific, seeking to change its name even to Port Edward. In 1780, Captain, afterward Lord, Nelson, under orders from Admiral Sir Peter Parker, convoyed a force of two thousand men to San Juan de Nicaragua for the conquest of the country.

In his dispatches Nelson said: "In order to give facility to the great object of government, I intend to possess the lake of Nicaragua, which for the present may be looked upon as the inland Gibraltar of Spanish America. As it commands the only water-pass between the oceans, its situation must ever render it a principal post to insure passage to the Southern Ocean, and by our possession of it Spanish America is severed into two."

The passage of San Juan was found to be exceedingly difficult; for the seamen, although assisted by the Indians from Blewtown, scarcely forced their boats up the shoals. Nelson bitterly regretted that the expedition had not arrived in harbor in January, in place of the close of the dry season. It was a disastrous failure, costing the English the lives of one thousand five hundred men, and nearly losing to them their Nelson.

At this period Charles III of Spain sent a commission—Cramer, Ysasi, and Maestre—to explore the country. These commissioners, as well as Don Manuel Galisteo, reported unfavorably as regarded the route, and the idea was abandoned. A favorable report, in fact, would have been opposed to the exclusive policy of Spain. The English government regarded the construction of a canal here as an important step in their severance from the mother country. Spain, also, believing and fearing this, forbade all access to this coast, even falsifying and suppressing its charts and permanently injuring the navigation of the San Juan and the Colorado by obstructions in their beds.

It is, however, a relief here to learn that when Humboldt visited the New World, he could say, "The time is passed when Spain, through a jealous policy, refused to other nations a thoroughfare across the possessions of which they kept the world so long in ignorance. Accurate maps of the coasts, and even minute plans of military positions, are published." It is also true that the Spanish Cortes, in 1814, decreed the opening of a canal; a decree deferred and never executed.

II. EARLY FAVORABLE DISPOSITION OF THE CONFEDERATION.

Turning from the indifference of Spain toward the improvement of the routes through her domain, a more favorable record is presented at the moment almost of the independence secured by her colonies in the first quarter of the present century. And in no point does this appear in favor of these States more pleasantly than in Nicaragua.*

The desires of the Central American States were expressed to the United States by a proposal of Minister Cañaz to Mr. Clay, Secretary of State, in the year 1825, asking co-operation in constructing a canal. Mr. Clay instructed our representative, Mr. Williams, February 10, 1826, to ascertain if

* See treaty of Nicaragua with United States, 1867.

surveys had been made, if confidence could be placed in their accuracy, and what facilities of construction were offered. No detailed report appears to have been made, in consequence, doubtless, of the unsettled state of the country. No survey was offered.

The scheme offered to the "Confederation of the Center" was from the American house of Messrs. Palmer & Co., of New York, and was announced as under the patronage of the President of the United States, De Witt Clinton, and other eminent men of New York.

Under the direction of President Adams, Mr. Clay gave instructions like those given Mr. Williams to the commissions of the United States sent to Panama.

In 1828 the King of the Netherlands proposed to undertake the work, if a survey should show its practicability. The Dutch General Verveer came over with instructions to undertake the canal. He found Central America in the midst of one of her incessant revolutions; the matter was deferred; the liberal offers of the Dutch government were not finally closed; and the revolutions in their own country (1830) put an end to their plans.

III. PLANS FOR OPENING UP A ROUTE THROUGH NICARAGUA.

Bailey's survey.—The favorable disposition of General Morazan, President of Central America, in 1836, toward a canal, induced him to employ on a survey Mr. John Bailey, R. M., long a resident in the country. His exploration was chiefly confined to the Pacific side, with some observations also on the San Juan River. His work was brought to a close by the dissolution of the federal government. Discovering at Guatemala the plans of the engineer of the Spanish government, Galisteo, he adopted them but partially, distrusting their accuracy. He took up another line on the west, from San Juan del Sur, on the Pacific, to the lake. His survey was made "with great care for four months, but with a theodolite only," taking neither lines of levels nor barometrical observations.

He reported for the lake: Length, ninety miles; breadth, forty to thirty miles; depth near the shore, that is to say about 100 yards from the beach, 2 fathoms; intermediate soundings, 5 to 15 fathoms. For the elevation of the lake, from a series of 351 levels taken in 1838, at different stations between the port of San Juan and the mouth of the Rio Lajas, in the lake, he made the surface of the lake 128 feet 3 inches above the level of the Pacific at low water. This has been found inaccurate.

From observations made during the rainy and the dry seasons respectively, in 1839, the difference between the usual minimum elevation in the dry and the maximum elevation in the wet season was estimated by Mr. Bailey to be 6 feet 6 inches.

In regard to the San Juan River, Mr. Bailey reported that from measurements made in the two seasons it would appear that at least 28,178 cubic yards per minute in the dry season and 85,840 in the wet are drawn off from the San Juan, a quantity, Mr. Bailey remarks, sufficient to fill in seven hours a canal 28,000 yards long and 600 broad. The Colorado, therefore, he said, "should be dammed across." His survey being made before the ruin of Greytown Harbor, he did not report upon it; his whole work having been left incomplete (and wholly unrecompensed) by the dissolution of the government known as the "Confederation of the Center." A survey of the harbor, by Master G. Peacock, of His Majesty's ship Hyacinthe, in 1832, shows on its chart that the bar would then admit large ships, and the roadstead afford it good shelter.

The surveys by Bailey revived the plans of Galisteo and popularized the idea of a canal in Nicaragua. In 1844 Señor Castellon was sent by Guatemala, San Salvador, and Honduras to solicit the protection of France and offer commercial advantages. M. Guizot had just given in charge to Garella an examination of the Panama route, which had been so favorably represented, and where no conflict with British interests was involved. Castellon visited Louis Napoleon in the fortress of Ham and enlisted him in the undertaking. A decree of the Central American government in 1846 assigned to it the name "Canale Napoleone de Nicaragua." The scheme was earnestly advocated before the Institution of Civil Engineers in London, and will be found at length in Les Œuvres de Napoleon, vol. 2. It was based on the idea of crossing not the narrowest tongue of land, but through the section of country the most populous, fertile, healthy, and productive. The western terminus was to be Realejo. The plan was founded, however, on no survey; and, according to Mr. F. Belly, (afterward connected with plans for a canal and for French influence in

Nicaragua,) to Napoleon's vision it was to be a revival of old dreams in the making of a new capital in the west, since the eastern vision of Constantinople and the Indies had been destroyed by the guns of Sir Sidney Smith at St. Jean d'Acre.

Political and commercial events of higher moment transpired in 1849. The gold-fields of California, by creating necessities for transportation of the multitudes of emigrants, induced new propositions to the government of Nicaragua for concessions. Meanwhile England bent anew her whole policy to securing permanent control on the Isthmus. In January, 1848, she seized the port of San Juan, naming it Greytown, designing to establish a protectorate, in order to "obtain control of so desirable a spot in the commercial world and free it from the competition of the adventurous North Americans."

Under the representations against these movements, made to the President of the United States by the authorities of Nicaragua, Mr. Hise and Mr. Squier were sent out on special missions, and under their influence a liberal concession was made to the American, Atlantic and Pacific Ship-Canal Company.

Survey by O. W. Childs.—Under appointment from the company named above this distinguished engineer of Philadelphia began a survey on the Pacific side, in August, 1850. After reconnaissances of several other lines, including that from the lake to Realejo—the route afterward so fully advocated by Napoleon III, and favored by decree of the congress of Central America in 1846—Colonel Childs chose the line which terminated in Brito Harbor; giving very strong reasons against the route through Lake Managua, which have been confirmed by each subsequent survey to this date.

He commenced his survey at a point in Lake Nicaragua 17 feet below the elevation at which that elevation is to be maintained to which surface all comparisons refer, a point 25 chains from the shore, and directly opposite the entrance of the Lajas. The length of the line between these points was 18.90 miles. The whole fall, from the surface of ordinary high lake to the Pacific at surface of highest tide observed, is 102.92, and to lowest tide 111.47 feet. This latter descent was to be made by 14 locks, mostly of 8-feet lift.

A harbor at Brito was to be formed by the construction of a jetty, by excavations, and by a wharf surmounted by a stone wall. The two wings of the jetties were to be respectively 10–50 feet northwest, and north, and 217 feet south, leaving between them an entrance of 400 feet in width and an area of 28.80 acres at high tide. The harbor was designed for sea-going vessels only, the state commerce being able to be accommodated at Nacascola, San Juan del Sur, Fonseca, or Realejo.

On the river San Juan the line of levels was commenced at the surface of low lake at San Carlos and carried down to Greytown. The whole distance from the outlet of the lake to 17 feet depth at Greytown was 119.31 miles. The whole fall from high lake to surface of the highest tide observed in the harbor was made 107.41 feet; to the lowest tide, 108.73 feet. The first 90.80 miles of the river was to be made navigable by excavation in its bed and by dams to be passed by locks and short canals; the remaining 28.57 miles of canal were to be independent of the river.

At the time of Colonel Childs' survey the harbor of Greytown was connected with the sea by a channel 24 feet in depth and 1,300 feet in width. On the outer side, and about 800 feet below the termination of the natural route, a sand-bar, with a top width of 350 feet, rose to within 5 to 8 feet of the sea surface, being changeable in position because of subjection to the waves and currents. The largest steamer then (1851) plying between Europe and the United States and Chagres could pass through. He proposed here a breakwater of two arms, the one from the termination of the natural mole 330 feet, the other at right angles from the main-land 1,188 feet toward the channel, leaving an entrance of 1,584 feet in width. He believed this to be sufficient for safe navigation.

At the request of the Atlantic and Pacific Canal Company, this survey being referred by Mr. Conrad, Secretary of War, to Col. J. J. Abert and Maj. W. Turnbull, United States Topographical Engineers, these officers reported: "We think the plan practicable, there being an abundant supply of water in the lake summit-level alone, apart from other supplies below it. * * * We are not of the opinion that any other route is as adequately supplied with water. We think the work can be done at the amount stated by Colonel Childs; it could be

done for much less in this country. Also, that two jetties at San Juan Harbor, and probably those at Brito, can be dispensed with. We recommend that additional surveys be made from the Casa de Felipe by the valley of the Juan Mills River, to determine if a more correct line cannot be found."

The American minister in England having requested, through Earl Malmesbury, the opinion of English engineers, Edward Aldrich, Royal Engineers, and James Walker, civil engineer, were designated. They examined Colonel Childs' plan and estimates through close inspection and personal questioning of Colonel Childs who was then in England, and reported favorably on his plans and estimates, suggesting, however, a canal of greater dimensions and objecting to the form and size of Brito as a harbor for ship navigation.

Until the more recent surveys of Michler, Trautwine, Hughes, and those of the late Government expeditions, the remark of Squier remained true, that Colonel Childs' survey was the only one conforming to the requirements of modern engineering. His own belief to the day of his death, and the belief of his assistants, among whom is Mr. S. H. Sweet, now superintendent of the State canal-works of New York, has been unchanged, that this route can be made available for the fullest wants of commerce; and that it would have been laid hold of at the time of the survey for a canal but for the lucrativeness of the route in its use as a mere transit. For as the required capital for the greater work was not readily secured, the company referred to above were permitted to have their powers for a ship-canal reserved and separated, and a new "Accessory Transit Company" formed under its franchise. Their profits of travel and traffic continued to be large, notwithstanding the rivalry of the Panama Railroad, until the transfer of interest by the projectors of the Nicaragua route to the Panama line, and until the miserable invasion of Walker, which almost destroyed both the resources of the transit and all good feeling toward Americans. The transit company, however, stated, as late as 1867, that "more than 150,000 passengers had been conveyed across since their establishment in 1851; that their works at Greytown were extensive, all their river-steamers being built and repaired there; and that of these they owned two on the lake of 400 tons burden each, and seven river-steamers, capable of conveying 500 passengers each. A gain in transit was secured by the western terminus, San Juan del Sur being 680 miles nearer to San Francisco than Panama.

The strongest reason for regret that the survey of Childs was not embraced at the time and applied to the construction of a larger work than he proposed, is found in the fearful injury to the harbor at Greytown, which might at that day have been permanently saved by the engineering which would have been called out. Perhaps the history of our coast-line has no sadder points than in this injury at the outlet of a stream connecting with such an inland reservoir as Lake Nicaragua, near the opposite coast. Spain might have saved and ennobled the harbor. The acceptance of any of the sincere offers made by Nicaragua at the different dates of her propositions to foreign governments and capitalists might have saved it. But the feebleness of a state immediately at the time of securing her own independence, and the increased difficulties brought on by the unfortunately perpetuated dissensions of Central America, forbade Nicaragua herself to construct the canal. It is not pleasant to find, further, that political causes, as the revolutions in Belgium and France, the grasping policy of England, and, nearer to our own doors, the invasion of Walker and bombardment of Greytown, have delayed the works projected, which might have saved the harbor in which so late as the time of that bombardment more than twelve men-of-war safely lay at anchor. The harbor, thus once available, and which by the means at the command of the engineer might have been at some era protected from the inroads of the sea, has been almost lost, according to the report of Captain West, of the Coast Survey, and that of the commission of the National Academy of Sciences, and this from the following causes:

1. The deposits made by the San Juan, (draining so large a surface of country,) particularly below the divergence of the Colorado, which steals a large volume from the San Juan.

2. The oscillation of the Caribbean Sea, caused by the northeast trades backing the sea directly into the bight at Greytown, with a force far greater than the feeble tide of a few inches rise and fall.

It is for the engineer to determine how far and by what means this harbor can be restored, or

what new neighboring one may possibly be created. There seems this large relief in the case, as well as in regard to a harbor on the Pacific terminus, that on this Nicaragua line a harbor of great size is less necessary, since the great lake above affords ample refuge and anchorage in which vessels can telegraph their arrival and await their orders. If such termini can be secured as will meet the wants of commerce, the great natural sure water-supply of this route, its comparative salubrity, the productivenesss of the country, and the reduction of distances to the western coasts of America and of the East, may command for it the required investment either from the capitalists of our own country or from abroad. The latest concession by Nicaragua—that granted to M. Chevalier in 1869—proposes international guarantees of the three great powers, like those in the Clayton-Bulwer treaty of 1850, and an international association to execute the work. Capital, however, for any one of these routes, can doubtless be secured by our own citizens, on the showing of the practicability of the route at what would be called even in our own day a moderate cost. It seems clear that the productiveness of the countries lying within these routes*—countries, until the existence of misrule, so populous—and the very rapidly growing demands of our Pacific slope for the transportation to eastern markets of her agricultural resources now exceeding her mineral wealth; these, if considered by themselves, and leaving out of view the immeasurable advantages to be conferred by improved intercommunication upon the countries passed through and upon the same semi-civilization beyond, will compel a favorable issue of this great problem.

PROJECTED ROUTES ACROSS NICARAGUA.

1. Rio San Juan de Nicaragua, Lake Nicaragua; Rio San Carlos, Gulf de Nicoya; Rio Nino, Tempisque, Gulf de Nicoya; Rio Sapoa, Bay Salinas; Rio San Juan del Sur; Brito.
2. Rio San Juan, Lake Nicaragua, and Lake Managua; Rio Tamarinda; Port Realejo; Bay of Fonseca. The branch lines named above have been at one time or another advocated as routes for a canal.

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Report by Committee of National Academy of Sciences, consisting of General Humphreys, Admiral Davis, Henry Mitchell, and others, made at the request of the Nicaraguan minister, and forwarded by Prof. Henry to the Secretary of State September 20, 1866. Senate Miscellaneous Document No. 44, Fortieth Congress, first session.
Report on Interoceanic Railroads and Canals, to Senate of United States, by Rear-Admiral C. H. Davis, U. S. N. 1867.

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* Valuable information in regard to the climate, productiveness, area, and population of Nicaragua has been recently given to the public in a pamphlet by Hon. Mr. Bernard, minister resident from that country.

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Plate No. 1.
MAP OF NICARAGUA
Showing Explorations and Surveys
DITIONS OF 1872 & 1873
The
he proposed line
FOR AN
INTEROCEANIC SHIP CANAL.
Scale
Soundings in Feet
PACIFIC
OCEAN
ATLANTIC
OCEAN
LAKE MANAGUA
LAKE NICARAGUA
UNEXPLORED
COSTA RICA
Rio Grande

U.S. NICARAGUA SURVEYING EXPEDITION
COM^DR CHESTER HATFIELD, U.S.N. COMMANDING 1872
COMMANDER E.P. LULL, U.S.N. COMMANDING 1873
A.G. MENOCAL, CHIEF CIVIL ENGINEER.
WESTERN DIVISION
SURVEYED BY PARTY No. 2.
Lieut. W.W. Rhoades, U.S.N. Commanding.
Lieut. J.E. Moser, U.S.N.
First Assist. Engineer, G.M. Greene, U.S.N.
Lieut. J.M. Bowles, U.S.N.
Master Kossuth Niles, U.S.N.
Ensign E.M. Hughes, U.S.N.
LAKE NICARAGUA
PACIFIC OCEAN

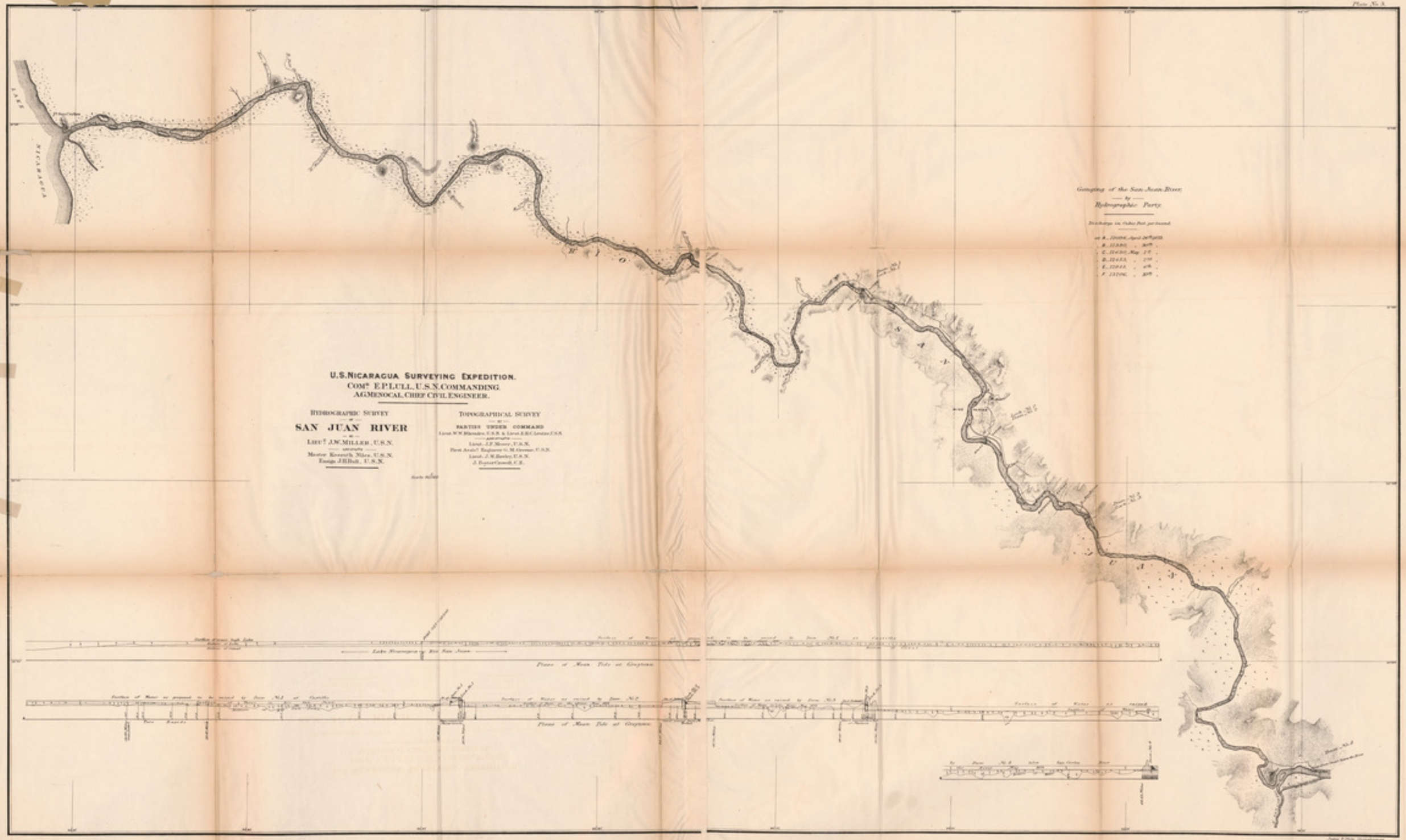
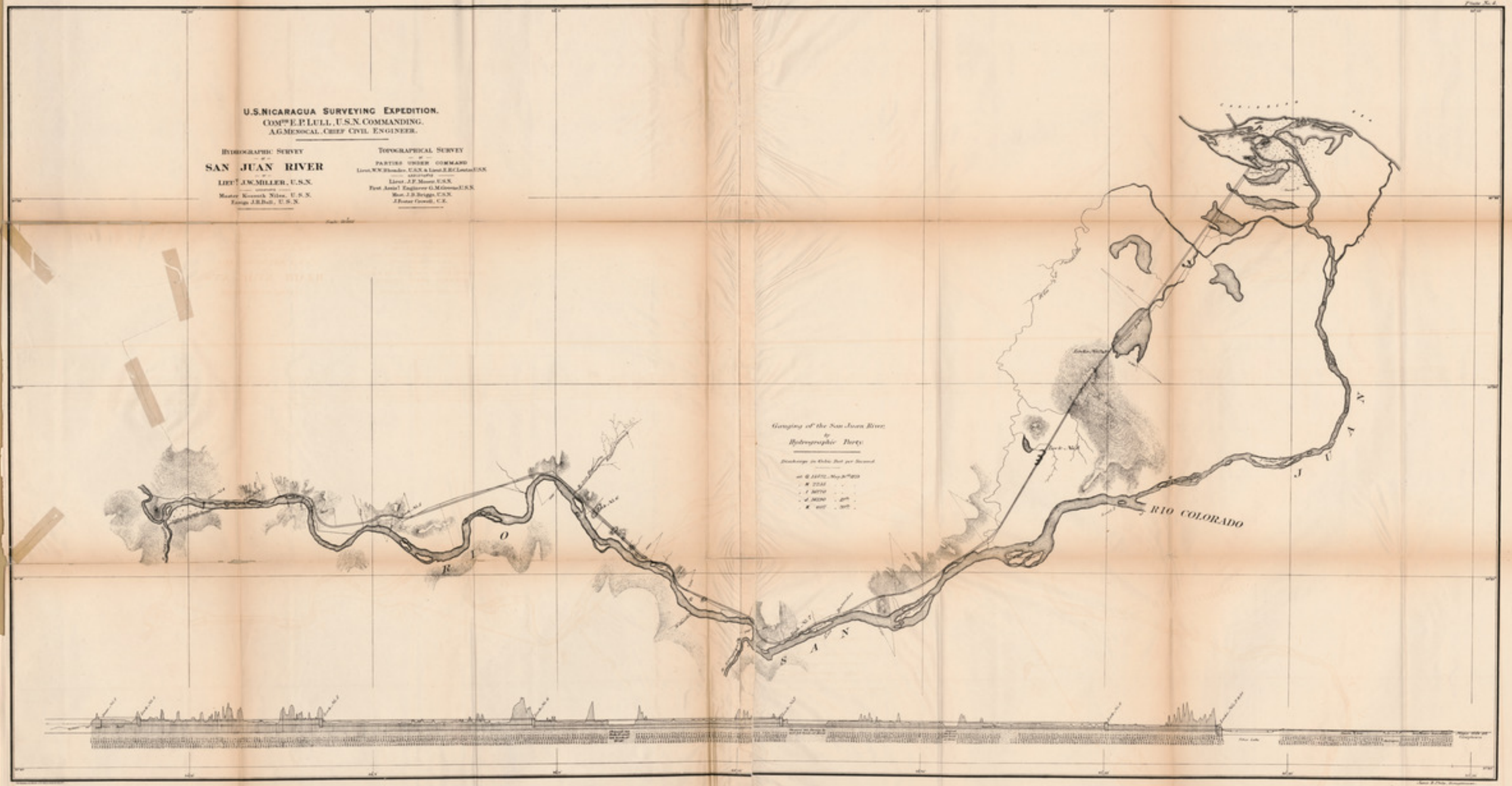


Plate No. 3.
LAKE NICARAGUA
RIO SAN JUAN
U.S. NICARAGUA SURVEYING EXPEDITION.
COMR. E.P. LULL, U.S.N. COMMANDING.
A.G. MENOCAL, CHIEF CIVIL ENGINEER.
HYDROGRAPHIC SURVEY
SAN JUAN RIVER
LIEUT. J.W. MILLER, U.S.N.
Master Kenneth Niles, U.S.N.
Ensign J.H. Ball, U.S.N.
TOPOGRAPHICAL SURVEY
PARTIES UNDER COMMAND
Lieut. J.F. Moore, U.S.N.
Lieut. J.M. Hawley, U.S.N.
J. Foster Crowell, C.E.
Gauging of the San Juan River
by
Hydrographic Party
Discharge in Cubic Feet per second
Plane of Mean Tide at Greytown
Plane of Mean Tide at Greytown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First Assist. Engineer G.M. Greene U.S.N.
Mast. J.B. Briggs, U.S.N.
J. Foster Crowell, C.E.
Gauging of the San Juan River
by
Hydrographic Party
RIO COLORADO
RIO SAN JUAN

HARBOR OF SAN JUAN DEL NORTE

— GREYTOWN —

Surveyed by

LIEUT. JAS. M. MILLER, U.S.N.

ASSISTED BY MASTER J.B. BRIGGS, U.S.N.

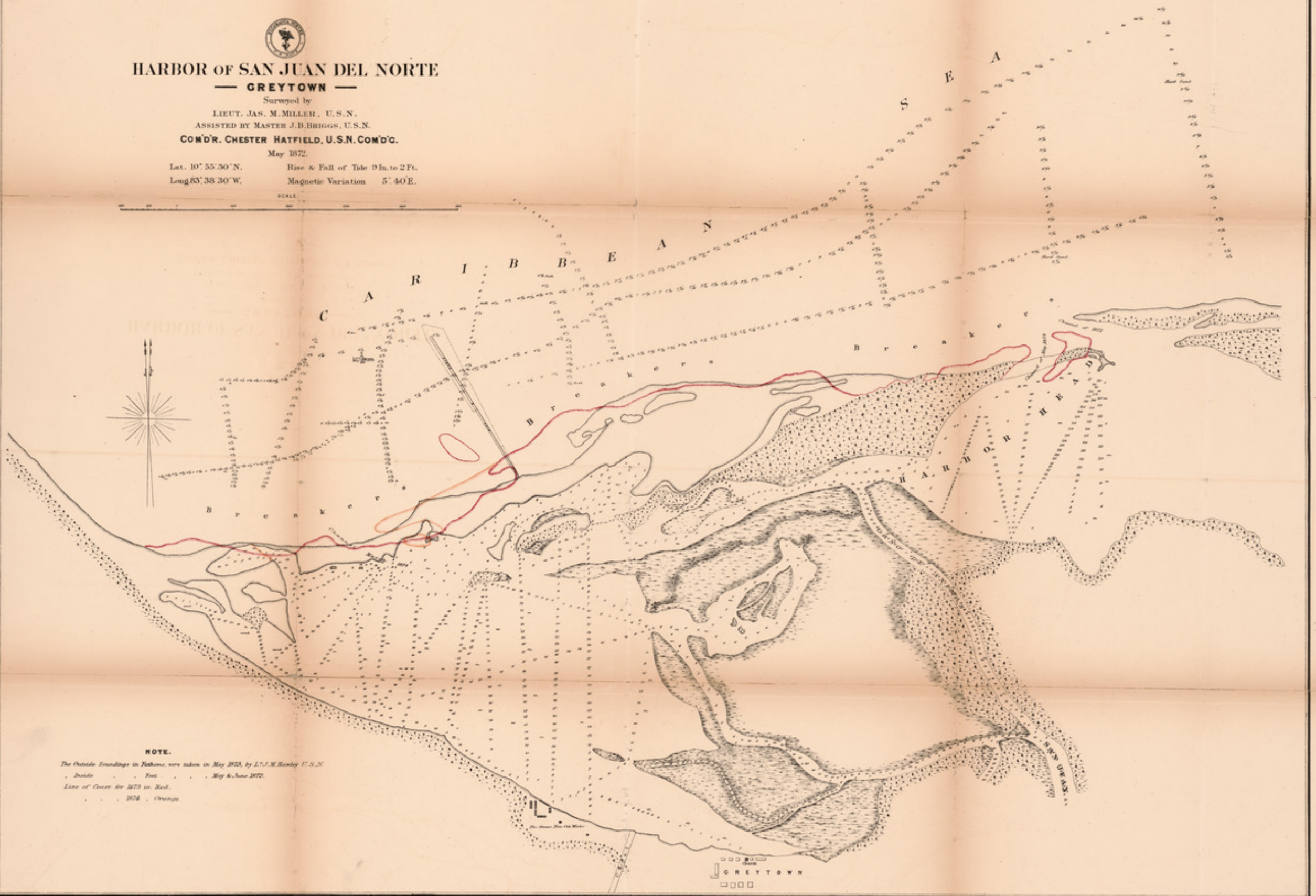
COM'D'R. CHESTER HATFIELD, U.S.N. COM'D'G.

May 1872.

Lat. 10° 55' 30" N. Rise & Fall of Tide 9 In. to 2 Ft.

Long. 83° 38' 30" W. Magnetic Variation 5° 40' E.

SCALE.



NOTE.

The Outside Soundings in Fathoms, were taken in May 1873, by L.T.J.M. Hawley U.S.N.

" Inside " " Feet. " " " May & June 1872.

Line of Coast for 1873 in Red.

" " " 1874 " Orange.

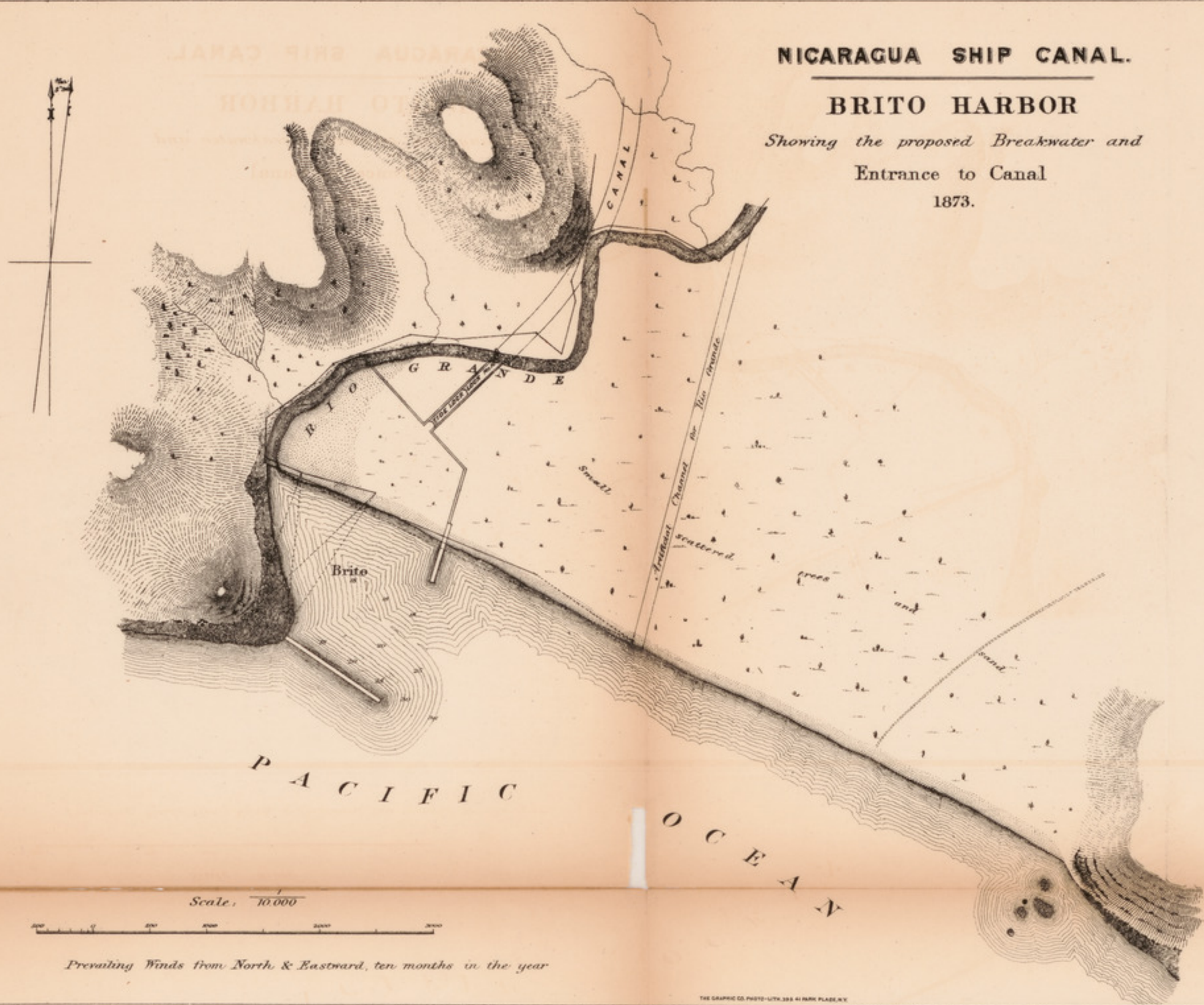
NICARAGUA SHIP CANAL.

BRITO HARBOR

Showing the proposed Breakwater and

Entrance to Canal

1873.



THE GRAPHIC CO. PHOTO-LITH. 335 & 337 PARK PLACE, N.Y.

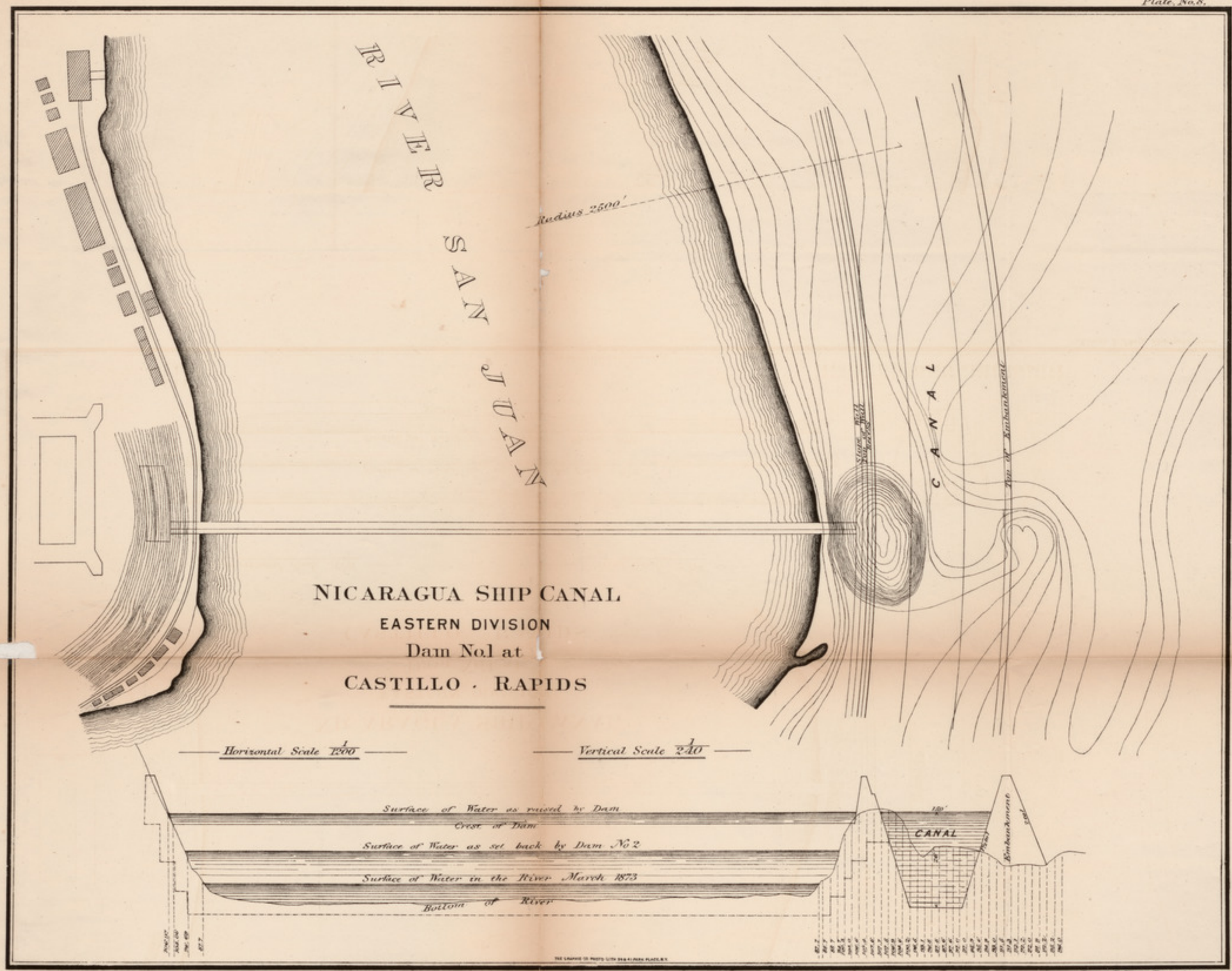
James B. Philp, Draughtsman.

U.S. Nicaraguan Surveying Expedition.

CASTILLO RAPIDS.

Showing Proposed Location of Canal.
and
Dam across Rapids.

Scale $\frac{1}{4000}$



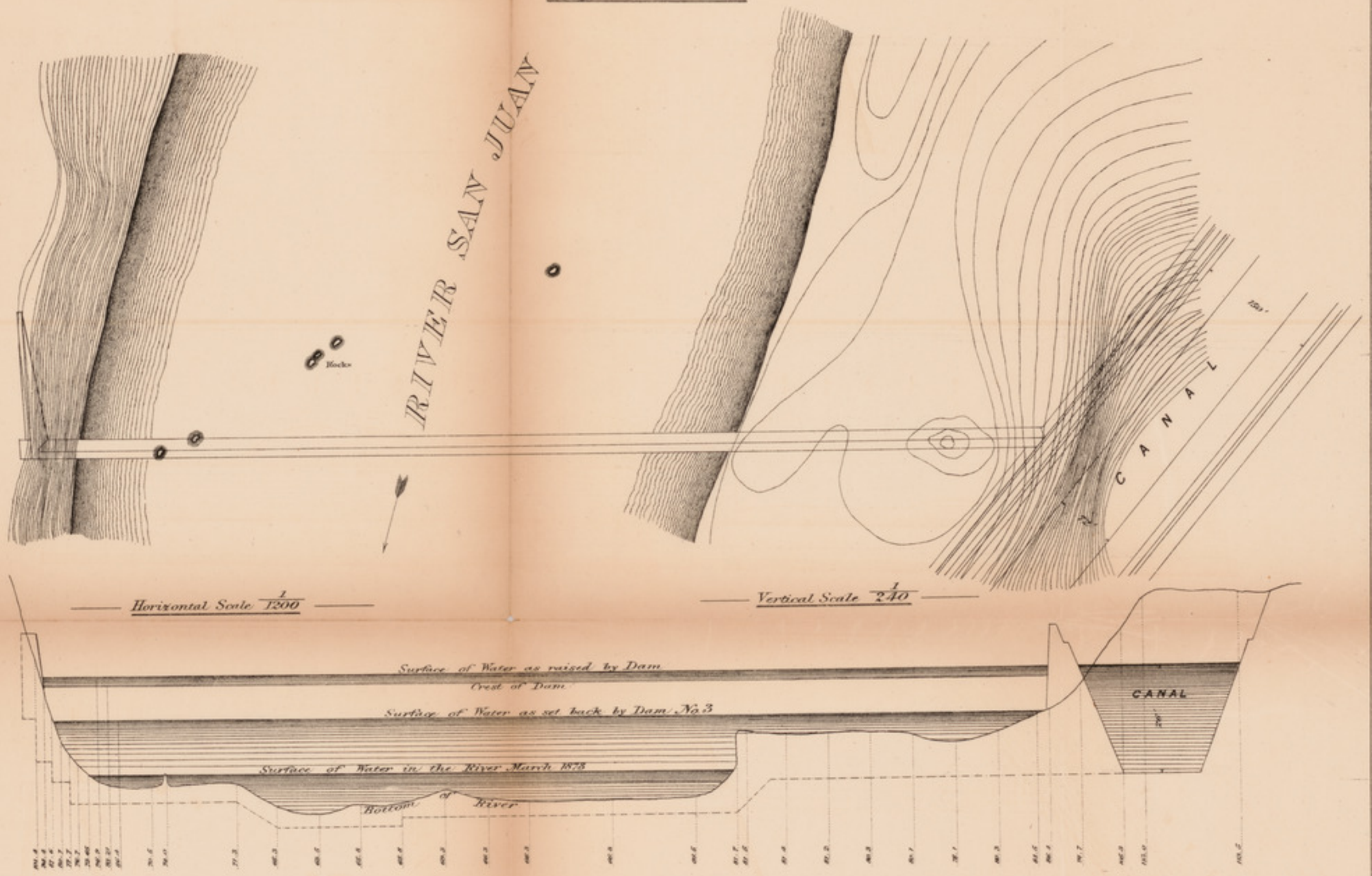
James B. Philp, Draughtsman

NICARAGUA SHIP CANAL

EASTERN DIVISION

Dam No. 2 at

BALAS RAPIDS

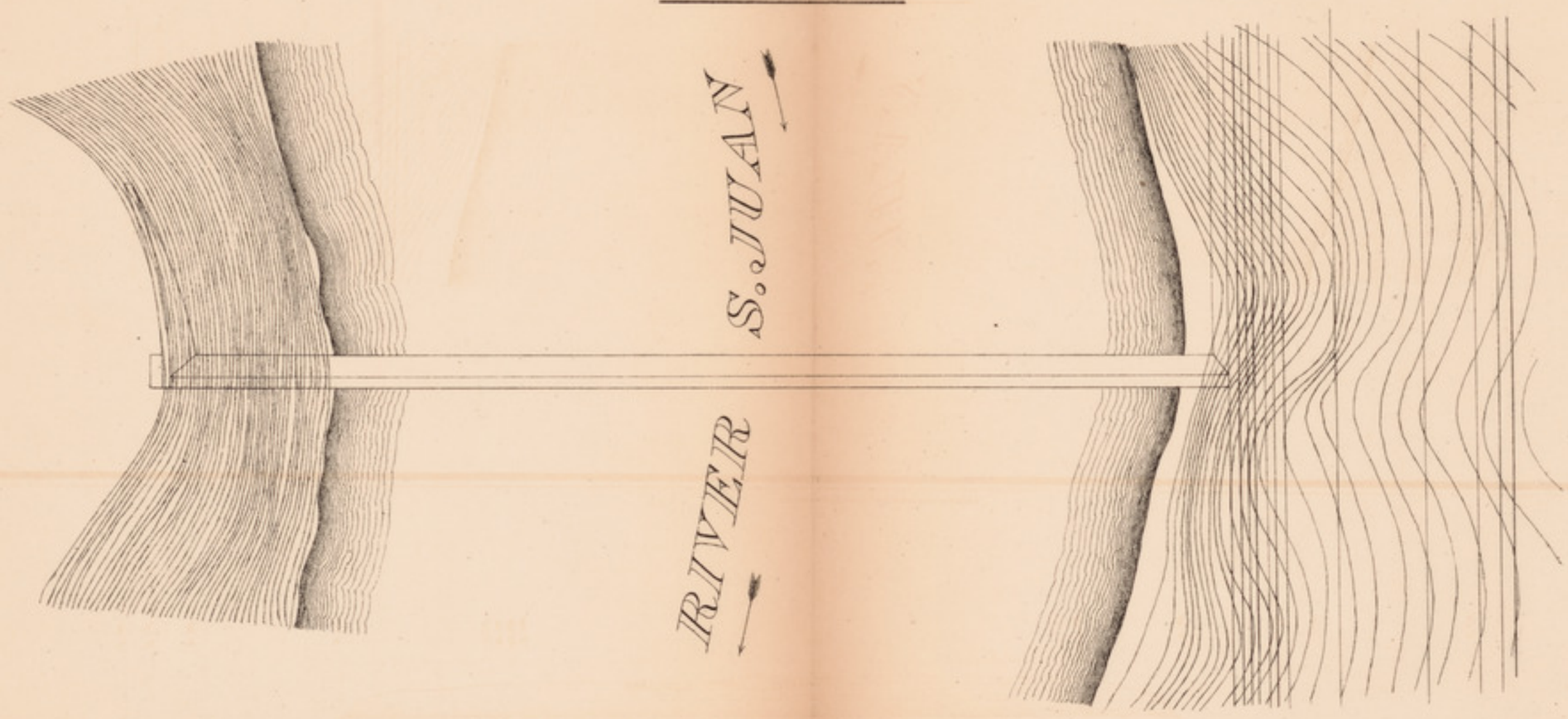


NICARAGUA SHIP CANAL

EASTERN DIVISION

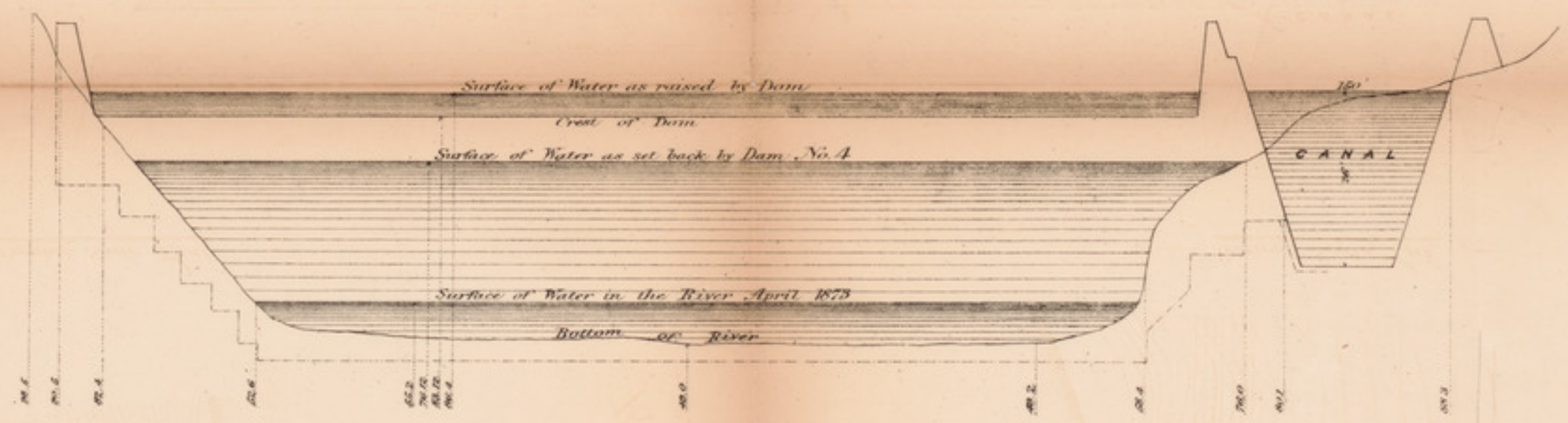
Dam No. 3 at foot of

MACHUCA RAPIDS



Horizontal Scale $\frac{1}{1200}$

Vertical Scale $\frac{1}{240}$



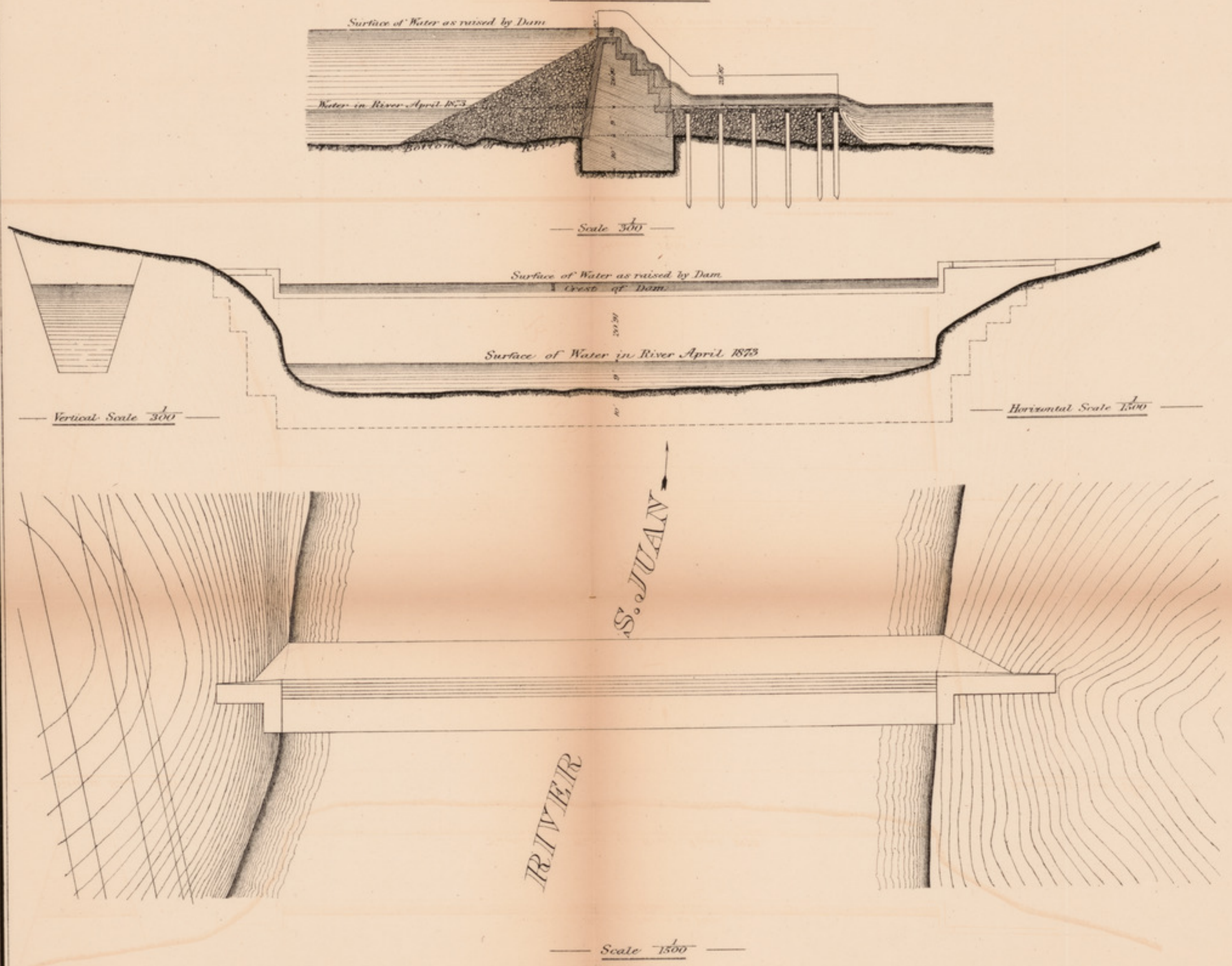
THE LITHOG. CO. PHOTO-LITH. 39 & 41 PARK PLACE, N.Y.

NICARAGUA SHIP CANAL

EASTERN DIVISION

Dam No. 4 below the

RIVER SAN CARLOS

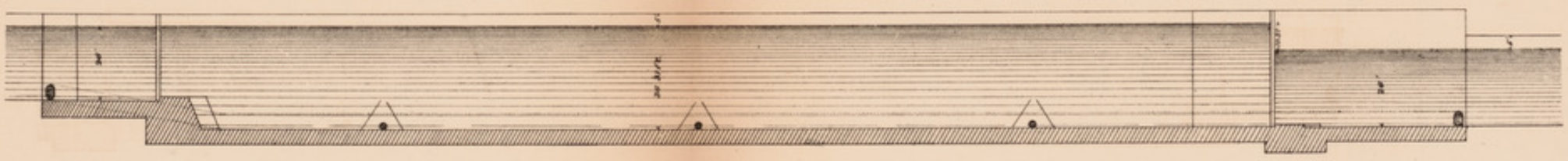


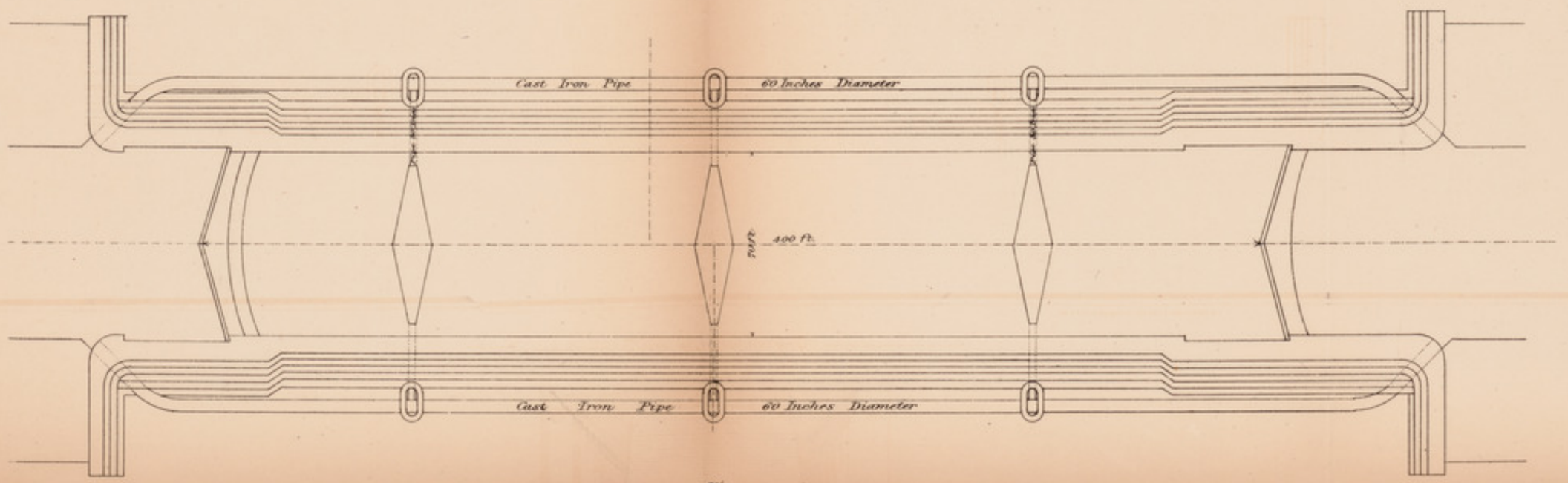
THE GRAPHIC CO. PHOTO-LITH. 366 & 368 PARK PLACE, N.Y.

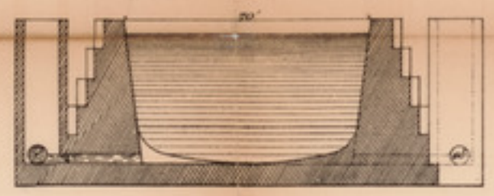
GENERAL PLAN OF LOCK,

As proposed for the

NICARAGUA SHIP CANAL.

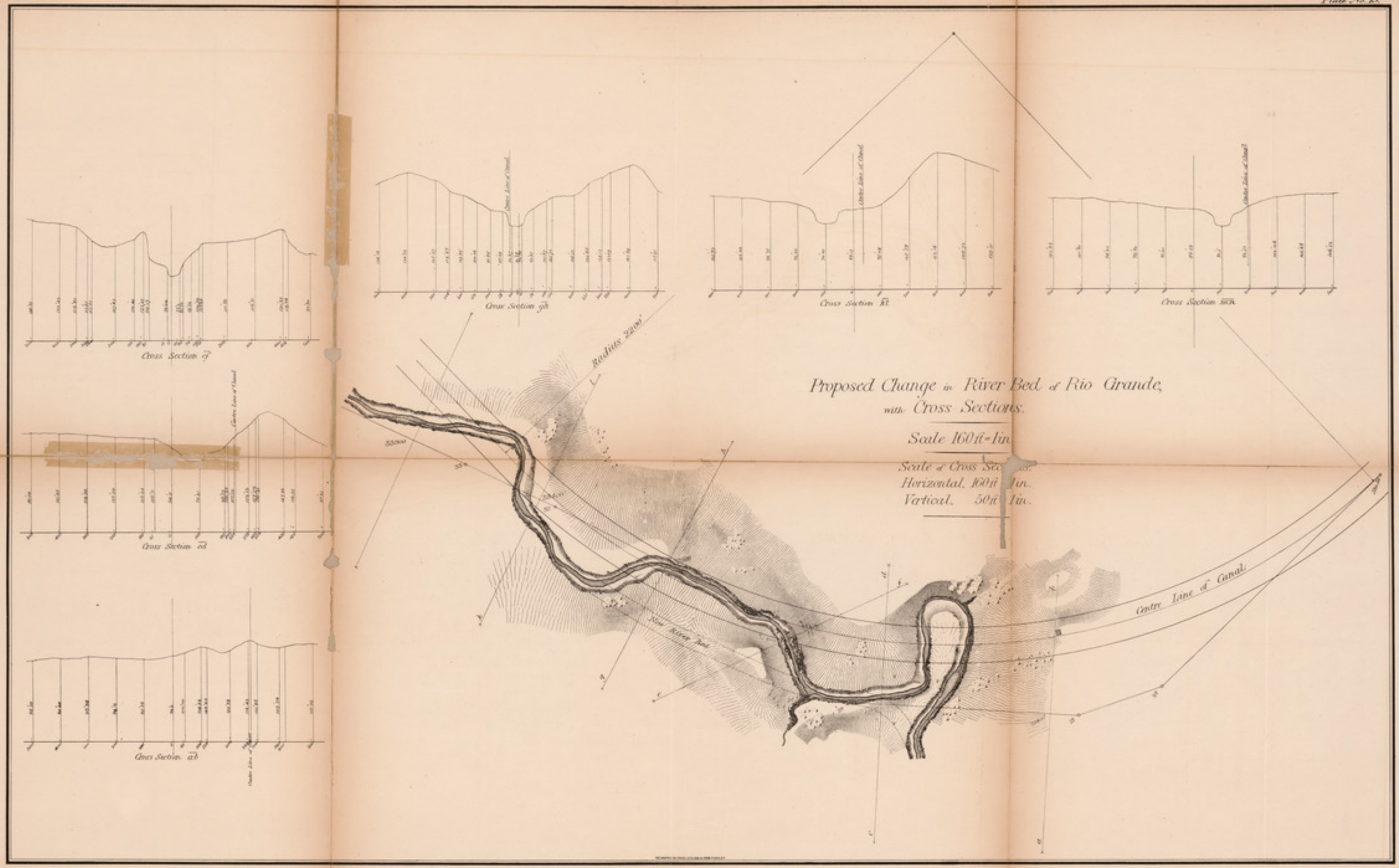






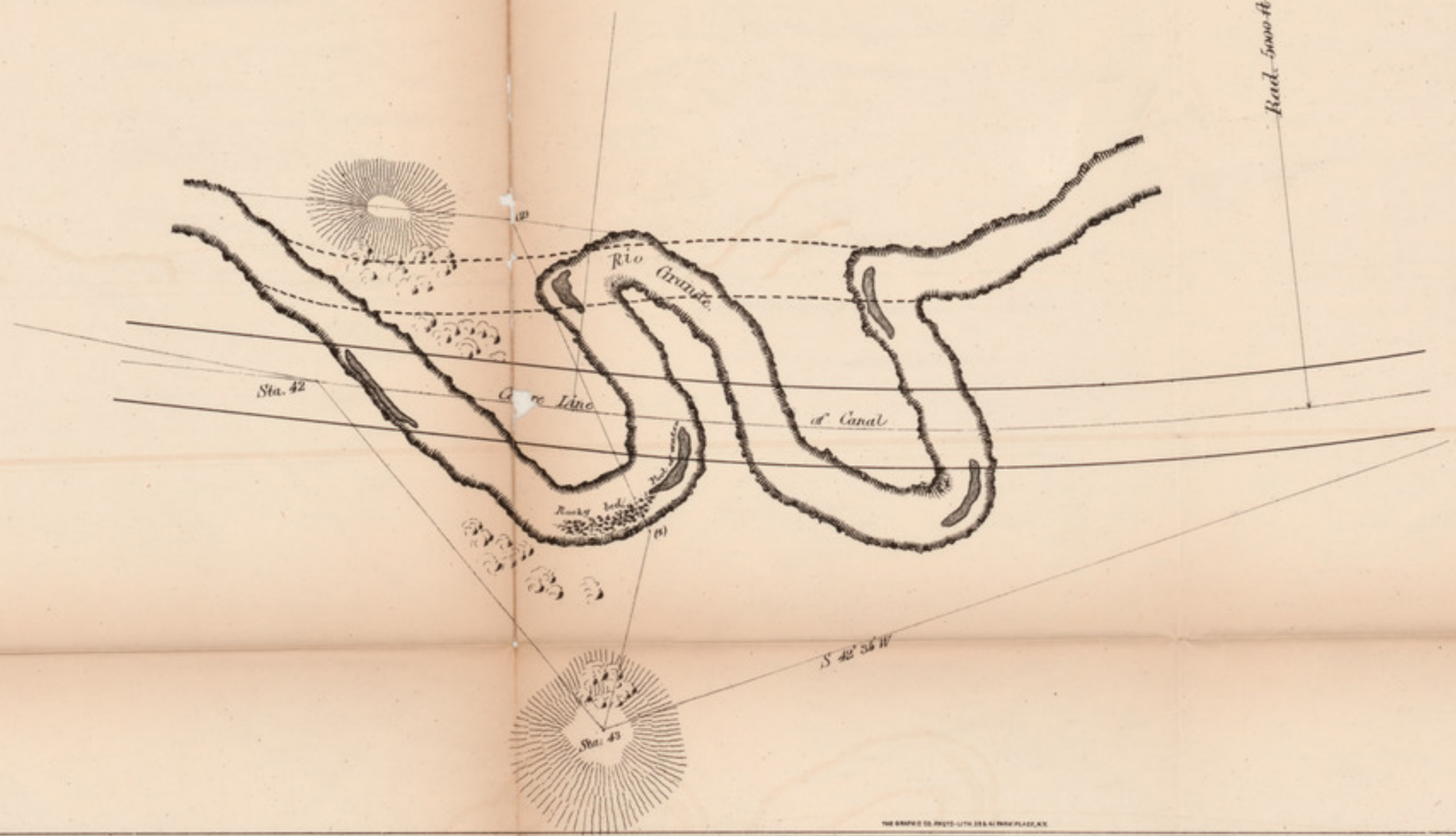
Scale 40 ft. to an Inch.

THE GRAPHIC CO. PHOTO-LITH. 39 & 41 PARK PLACE, N.Y.


Proposed Change in River Bed of Rio Grande,
with Cross Sections.
Scale 160 ft = 1 in.
Scale of Cross Sections.
Horizontal. 160 ft = 1 in.
Vertical. 50 ft = 1 in.
Cross Section cf
Cross Section gh
Cross Section kl
Cross Section mn
Cross Section cd
Cross Section ab
Radius 2200'
Centre Line of Canal
New River Bed

Proposed Change in Bed of River to Accommodate the Line of Canal.

Scale, 160 ft = 1 in.



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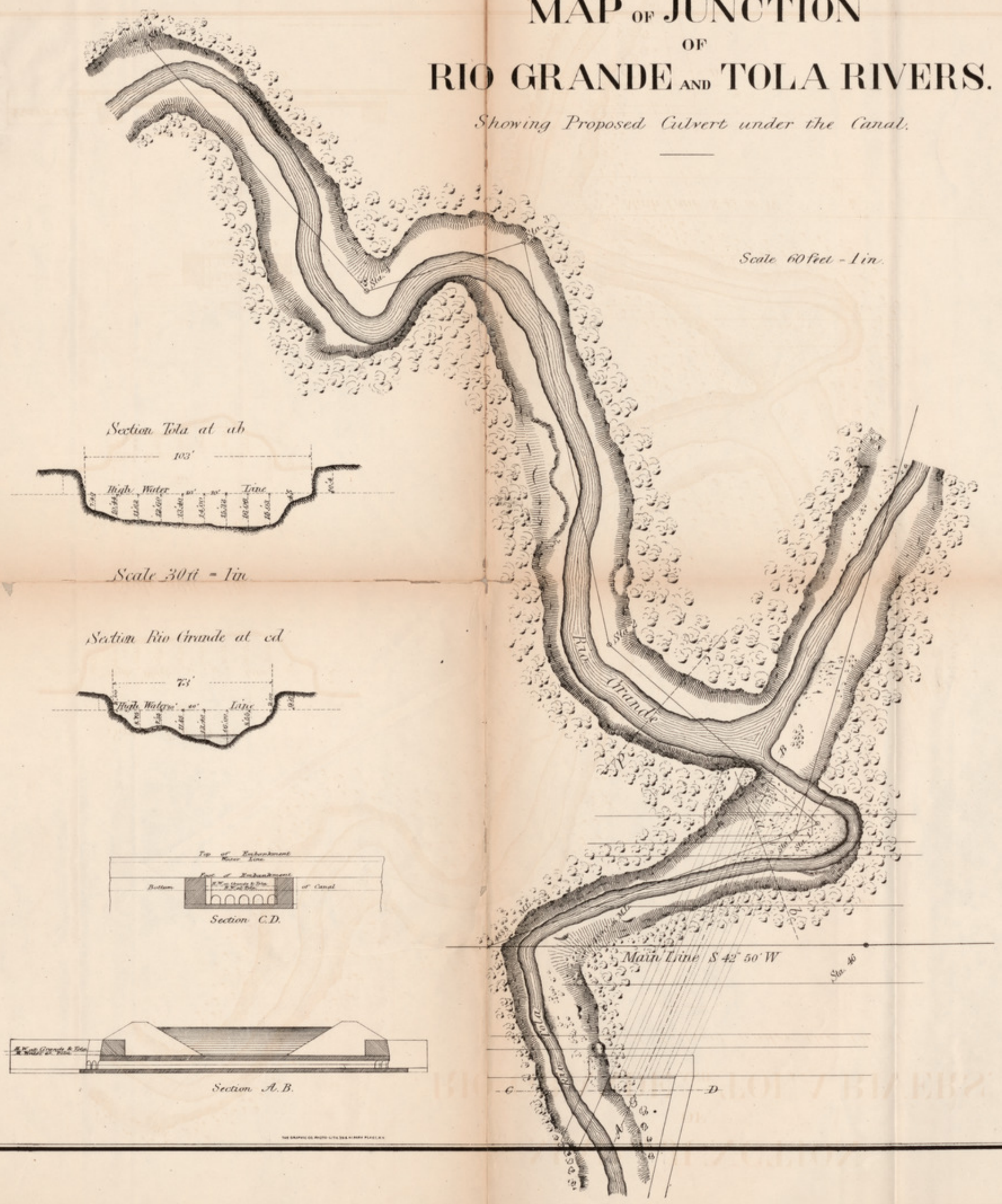
MAP OF JUNCTION OF RIO GRANDE AND TOLA RIVERS.

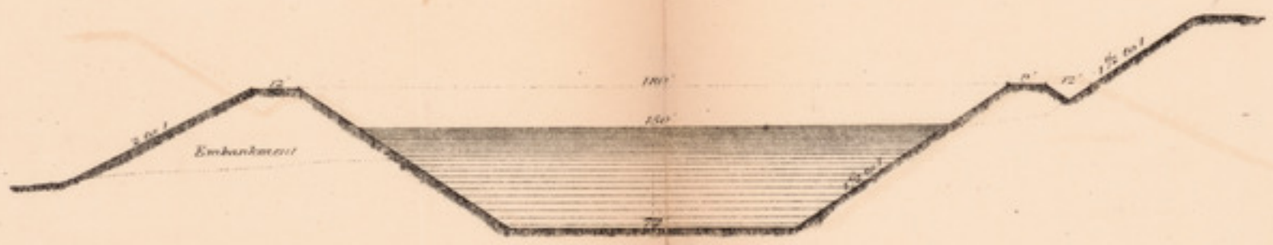
Showing Proposed Culvert under the Canal.



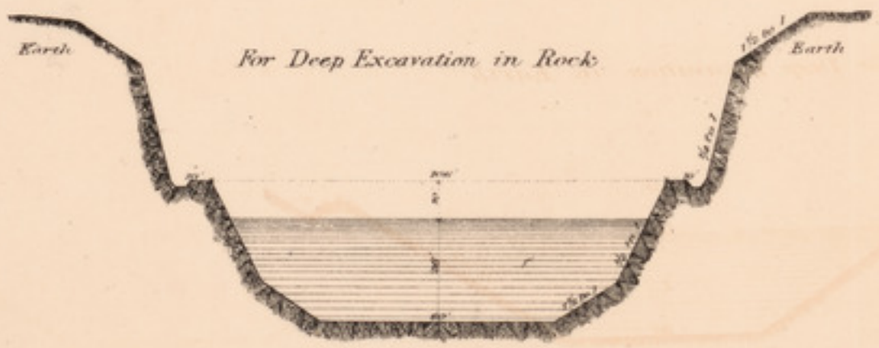
NICARAGUA SHIP CANAL.

Proposed Transverse Section.

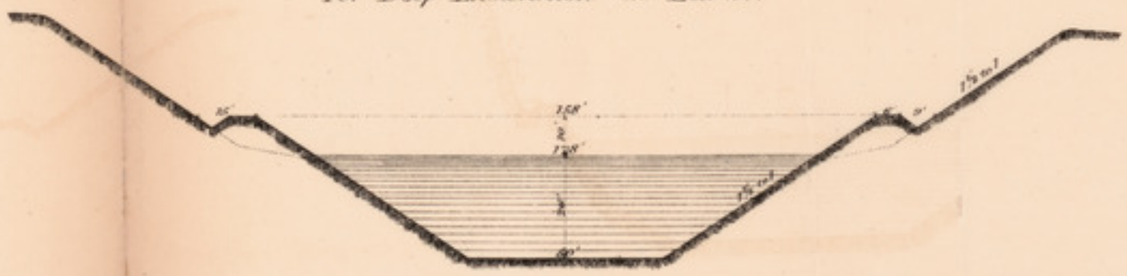
For Excavation in Earth and Embankment



For Deep Excavation in Rock



For Deep Excavation in Earth.



Scale $\frac{1}{480}$ *or 40 feet = One Inch.*

THE GRAPHIC CO. PHOTO-LITH. 39 & 41 PARK PLACE, N.Y.

James B. Philp, Draughtsman.

U.S. NICARAGUA SURVEYING EXPEDITION

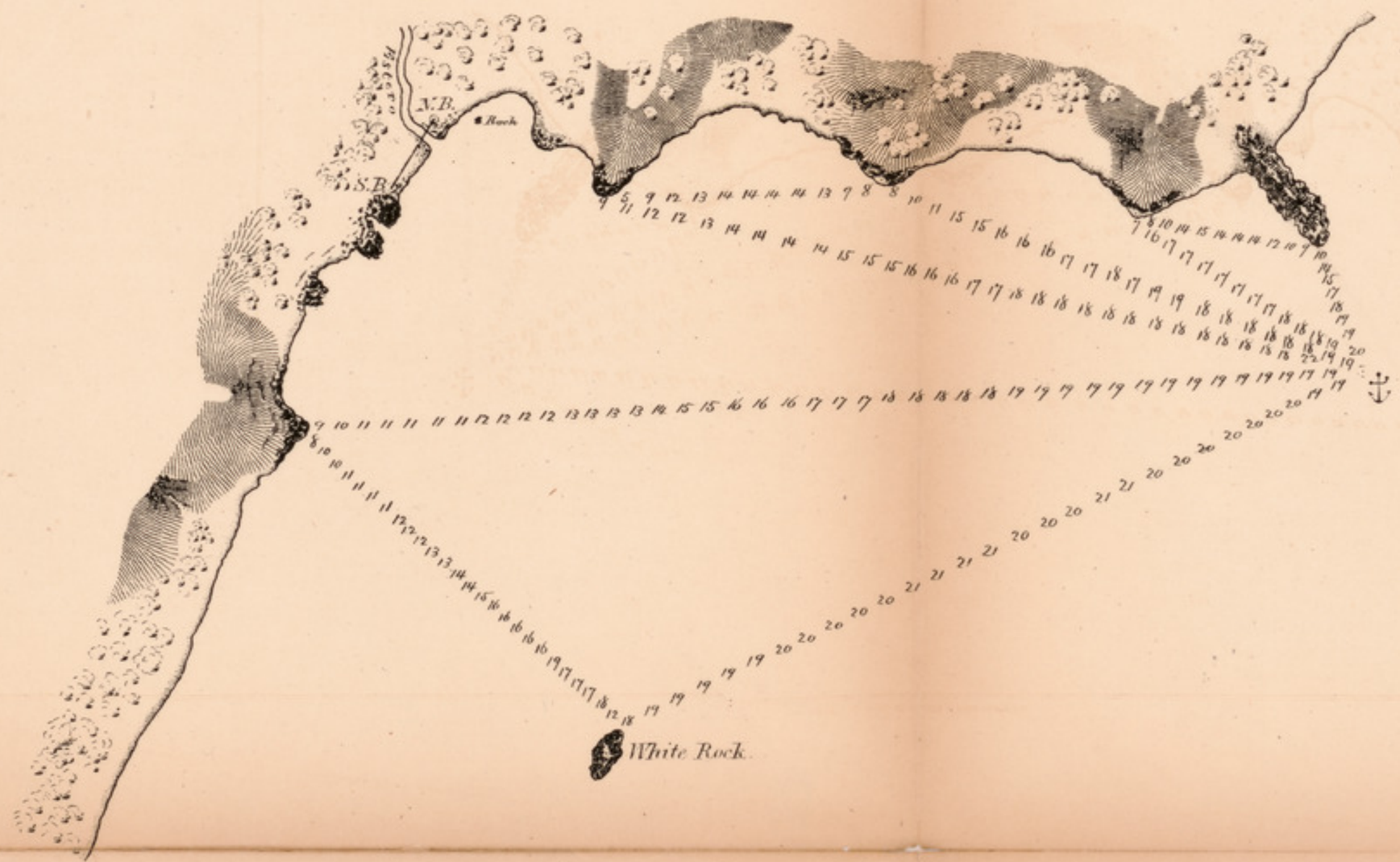
GORDA BAY — NICARAGUA.

Surveyed 1873, by Com.r E.P. Lull, U.S.N.

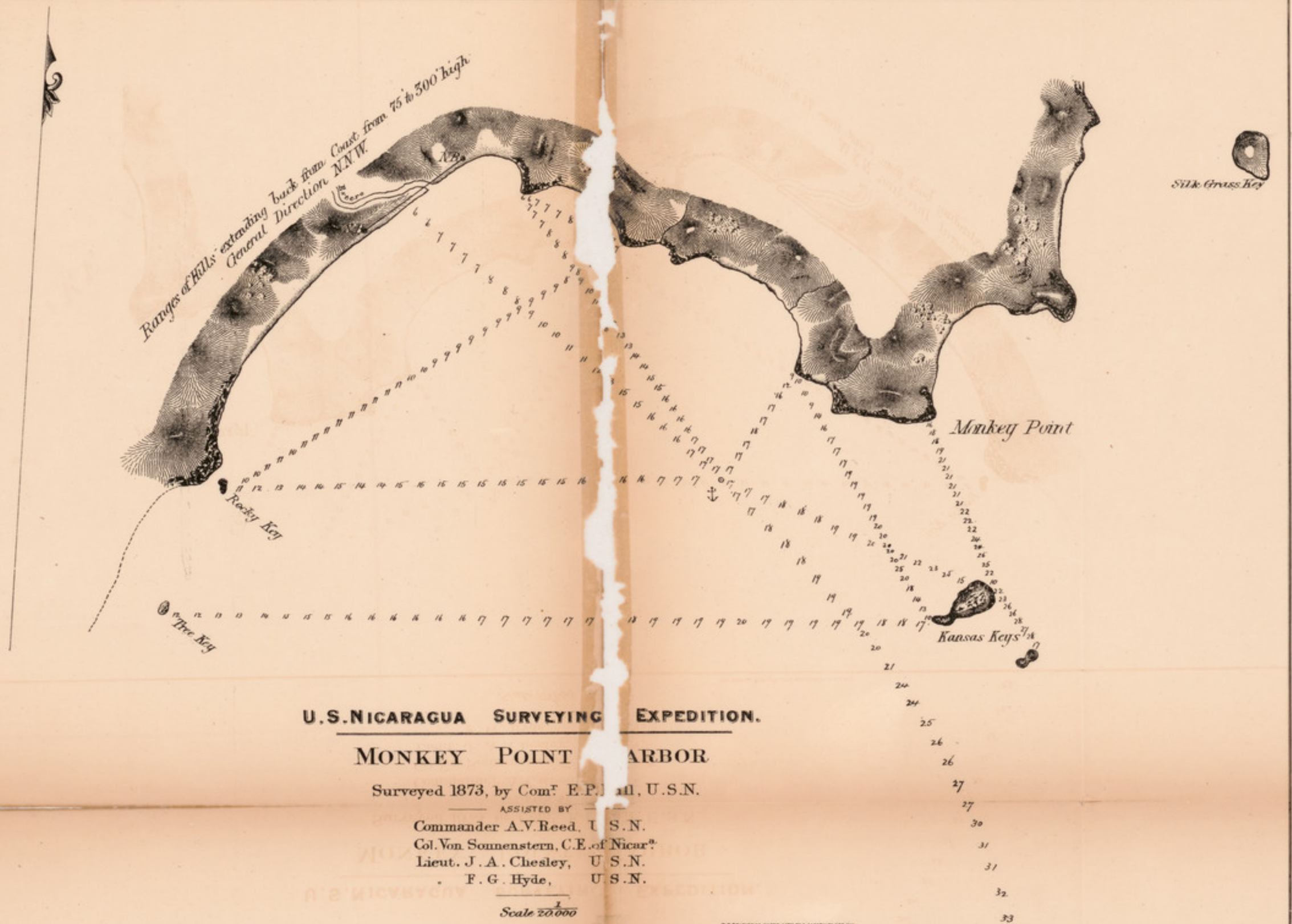
ASSISTED BY

Commander A.V. Reed, U.S.N.
Col. Von Sommerstern, C.E. of Nicar.a
Lieut. J.A. Chesley, U.S.N.
" F.G. Hyde, U.S.N.

Scale $\frac{1}{20000}$



THE GRAPHIC CO. PHOTO-LITH. 39 & 41 PARK PLACE, N.Y.



U.S. NICARAGUA SURVEYING EXPEDITION.

MONKEY POINT HARBOR

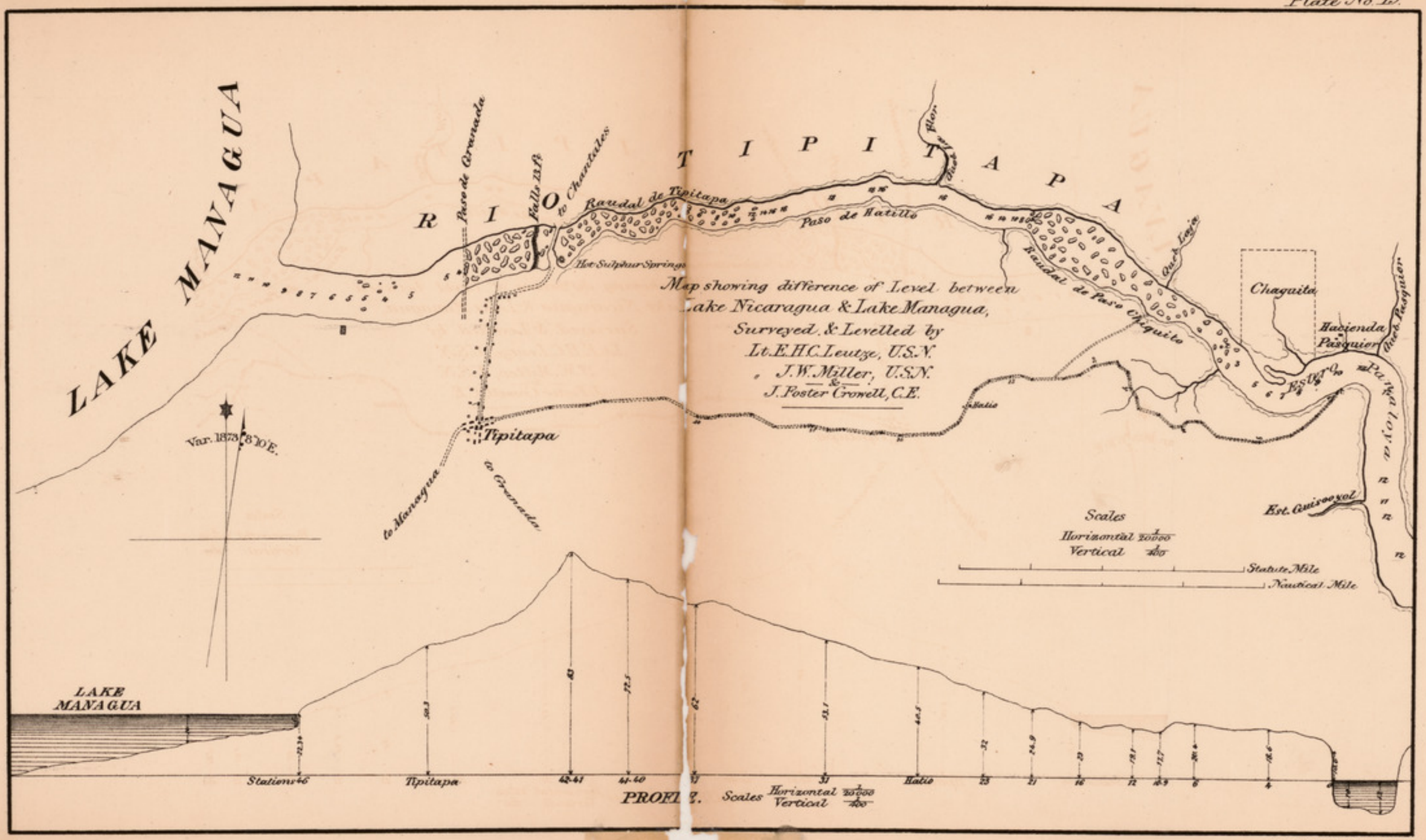
Surveyed 1873, by Com^r. E.P. Hall, U.S.N.

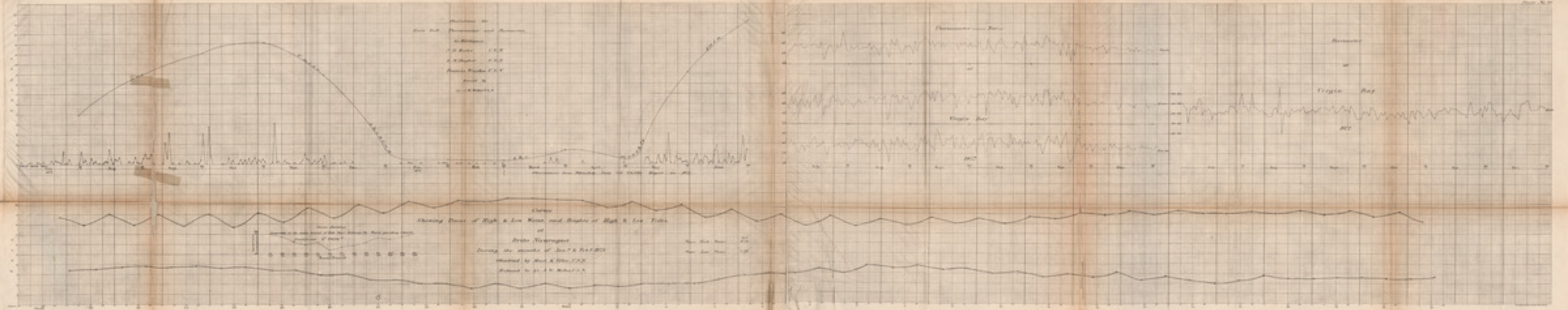
ASSISTED BY

Commander A.V. Reed, U.S.N.
Col. Von Sonnenstern, C.E. of Nicar^a.
Lieut. J.A. Chesley, U.S.N.
" F.G. Hyde, U.S.N.

Scale $\frac{1}{20,000}$

THE GRAPHIC CO. PHOTO-LITH. 39 & 41 PARK PLACE, N.Y.


LAKE MANAGUA
R I O
T I P I T A P A
Paso de Granada
Falls 15 ft.
to Chantales
Raudal de Tipitapa
Paso de Hatillo
Hot Sulphur Springs
Raudal de Paso Chiquito
Chaguita
Hacienda Pasquier
Est. Quirosqui
Tipitapa
to Managua
to Granada
Var. 1873 8°10' E.
Map showing difference of Level between Lake Nicaragua & Lake Managua, Surveyed & Levelled by Lt. E. H. C. Leutze, U.S.N. " J. W. Miller, U.S.N. & J. Foster Crowell, C.E.
Scales
Horizontal 1/20000
Vertical 1/400
Statute Mile
Nautical Mile
LAKE MANAGUA
Station 46
Tipitapa
42-41
41-40
Hatio
PROFILE.
Scales Horizontal 1/20000 Vertical 1/400



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