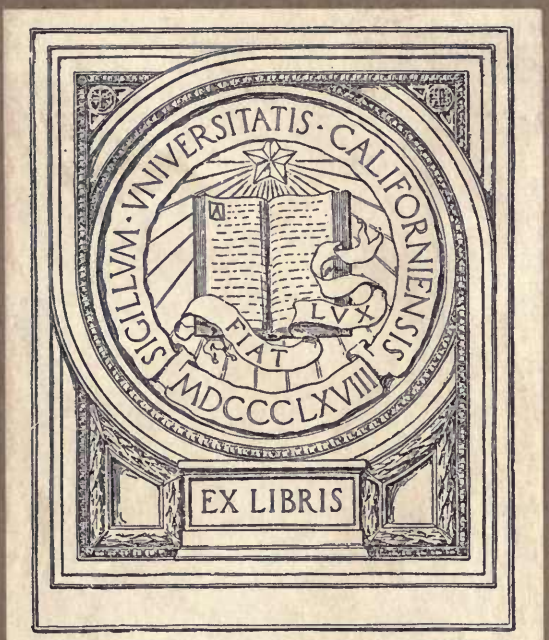

The Nicaragua Canal.

ITS DESIGN, FINAL LOCATION, AND WORK ACCOMPLISHED.

1890.

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THE NICARAGUA CANAL.

The idea of establishing a water-way across the American Isthmus dates back from the beginning of the Sixteenth Century, when the early navigators, perceiving the narrow neck of land separating the two oceans, were forcibly impressed by the advantages to be derived by cutting a canal through it. The Isthmus of Panama, being the narrowest part of that strip of land, and Nicaragua, on account of the evident natural facilities presented by the Lake and its outlet, the river San Juan, have always been the main points of attraction as possessing the most favòrable features for doing the work, and as early as 1550 the Portugese navigator, Antonio Galvao, proposed four routes; one of which was by way of Lake Nicaragua and the San Juan River, and another through the Isthmus of Panama. As the configuration of the Isthmus became better known, the belief in the practicability of joining the two oceans by a canal gradually increased; but it was not until the beginning of the present century, when, through the endorsement of Humboldt, who had studied the problem on the ground, and, later on, through the united efforts of the Central American Republics, that the question commenced to assume a well-defined shape. But, while these States and the Republic of New Granada were anxiously soliciting the co-operation of other nations and of capitalists in favor of the undertaking, no regular surveys had been made of any portion of the Isthmus, the routes proposed, and claimed to have been discovered, being the result of imperfect reconnoissances, or of the imagination. It was evident, moreover, that the work would require the expenditure of large sums of money; and, while it was universally admitted that the canal would be of great advantage to the world at large, it was not equally clear that the probable traffic seeking it would be sufficient to pay interest on the capital invested. But the gold discoveries following the acquisition of California by the United States, and the subsequent rapid development of the vast commercial and agricultural interests of the territories lying on the Pacific Slope, exerted a powerful influence in attracting attention to the commercial and political importance of the Canal. What had until then been regarded as a humanitarian scheme or a geographi-

cal desideratum, became a political and commercial necessity, and the attention of the American statesmen, capitalists and scientists was at once directed to finding the most practical solution of the problem.

The idea of establishing a continuous water communication between the two oceans has been always recognized as the only means of satisfying all the requirements of commerce, but a satisfactory solution of all the unknown quantities entering into such a vast undertaking could not be reached without serious surveys of the Isthmus, and these required time and the adjustment of political difficulties with other nations interested in the proposed work. In the meantime, the Americans, anxious to meet the increasing demand for means of communication between the two oceans consequent to the rapid development of the Pacific coast, turned their attention to an overland route, and, having obtained a concession from the Republic of New Granada, in 1849 organized a company and entrusted the surveys for a railroad to Col. G. W. Hughes and J. C. Trautwine, well-known civil engineers. This was the first authentic survey made across the Isthmus, and resulted in the construction of the Panama railroad between 1850 and 1855.

In the meantime, the Government of the United States, alive to the importance of the Canal, had ordered a reconnoissance of the Isthmus of Tehuantepec, and, by diplomatic negotiations with Nicaragua, had encouraged and supported the organization of the Atlantic and Pacific Ship Canal Company, which had obtained from Nicaragua the right to build the Canal, and, pending the completion of the work, to establish a transit between the Caribbean Sea and the Pacific Ocean, to facilitate the commerce between the two oceans, by way of the river San Juan and Lake Nicaragua.

This company entrusted the survey for a ship canal to Col. O. W. Childs, a conscientious and able engineer. He examined in 1850 several routes between Lake Nicaragua and the Pacific Ocean, and is entitled to credit for the discovery of the lowest depression in the Cordilleras between the Arctic Sea and Cape Horn. Through this divide, which he found to be 152 feet above sea level, he located a route for the Canal extending from the mouth of the river Lajas, on the west shore of the Lake, to the Port of Brito, on the Pacific, the main features of which have stood the test of many subsequent surveys aud rectifications in that region, and have been incorporated in the plan of the final location of the Canal across that country. Col. Childs' plan contemplated the use of the Lake as the summit level, and of the valley of the River San Juan, its outlet, to its delta, through which he proposed to excavate a canal following the left bank of the river to Greytown. This survey was the first on the Isthmus for a ship canal conforming to the

requirements of engineering, and its accuracy has been fully confirmed by subsequent explorations.

Much might be said here to show the great interest evinced by the Government of the United States in the building of a canal, and to demonstrate the fact that the only thorough surveys made on the Isthmus with the view of establishing the practicability and cost of the work, have been done either by the Government directly, or by American citizens under its auspices.

It is interesting and instructive to follow, step by step, the American explorations on the Isthmus from Tehauntepec to the Gulf of Darien, but this paper deals with the proposed Nicaragua Canal, which is believed to be the only practicable route for connecting the two oceans by a ship canal. This conclusion is the result of forty years of exhaustive studies over the whole Isthmus, and of a valuable lesson so dearly taught by an unfortunate attempt to prove the practicability of building a canal by the expenditure of vast sums of money in useless excavations and wild schemes for removing insuperable natural obstacles, prior to a thorough examination of the physical conditions.

The period from 1870 to 1876, during the administration of Gen. Grant, was one of marked activity in the explorations of the Isthmus, and it may be said that the question as to the route possessing the greatest advantages was settled in February, 1876.

The Commission appointed by President Grant in 1872 to report upon the various plans submitted by the surveying parties, consisted of Gen. A. A. Humphreys, Chief of the United States Corps of Engineers; Mr. C. P. Patterson, Superintendent of the Coast Survey, and Commodore Daniel Ammen, Chief of the Bureau of Navigation of the Navy Department.

On February 6th, 1876, the Commission submitted its decision to the President of the United States, in which it was said: "After a long, careful and minute study of the several surveys of the various routes across the continent, we unanimously report, That the route known as the Nicaragua route, possesses, both for the construction and maintenance of a canal, greater advantages, and offers fewer difficulties from engineering, commercial or economical points of view, than any of the other routes shown to be practicable by surveys sufficiently in detail to enable a judgment to be formed of their relative merits, as will be briefly presented in the appended memoranda."

The routes considered by this Commission were, the Tehauntepec, the Nicaragua, the Panama, and the Atrato-Napipi. The surveys conducted by

the Government of the United States at other points, did not develop physical conditions favorable enough to justify a location sufficiently in detail to form an estimate of the cost, and the results of the explorations were examined by the Commission only in so far as was necessary to show their impracticability or inferiority as compared to other routes.

The survey of the Nicaragua route by the United States Government was commenced in March, 1872, and continued until July, 1873. Eight different routes between the Lake and the Pacific were carefully examined. The correctness of Childs' survey, from the mouth of the River Lajas to Brito, was carefully confirmed, and, while the low divide was a strong feature in favor of his location, the problem of properly draining the valley of the Rio Grande was not, at the time, satisfactorily solved, and the next best route, extending from the mouth of the small stream Del Medio at the Lake, north of Lajas, to a point on Childs' line nine miles west of the Lake, and thence following Childs' line to Brito, was adopted and carefully located.

In this, as in all projects for a canal across Nicaragua, the Lake was taken as the summit level, and in this location its mean level was assumed to be 107 feet above sea level. East of the Lake, slack-water navigation was secured in the river San Juan, for a distance of sixty-three miles, by the construction of four dams; the lower dam being below the confluence of the San Juan and San Carlos Rivers. Below that point the canal was proposed to be excavated for a distance of 41.9 miles on the right bank and following the general direction of the river to the outlet, San Juanillo, where it turned almost directly to Greytown. Twenty-one locks, with an average lift of ten feet, were proposed, ten on the Atlantic and eleven on the Pacific slope. This project was a decided improvement on that proposed by Childs, but in its general outline the design did not differ very materially from his. Its main features were as follows:

Canal in excavation, - - - -	61.74
Slack-water navigation in the River San Juan, -	63.02
Lake navigation, - - - - -	56.50
Total miles from ocean to ocean, -	181.26
Number of locks, - - - -	21.
Number of dams across the river San Juan,	4.

The total cost was estimated at $65,222,147.

The writer, who had been the Chief Engineer of the Government surveys, recognized the practicability of the canal by this route, but was

not satisfied with the location. The Lajas line, with its low divide of 152 feet, had been reluctantly abandoned on account of difficulties in the drainage problem, and the Medio route, with ninety feet greater depth of cutting, had been adopted instead; thereby increasing the difficulties in construction, and, by several millions of dollars, the cost of the work.

In the Eastern Division the frequent interruptions of the river navigation by the interposition of dams, was not a desirable feature, and the sharp curves and too close proximity of the canal in excavation to the river, in several places, should, if possible, be eliminated from the problem. There were, also, too many locks, which together with the long stretch of canal in excavation, would, necessarily, tend to retard navigation and restrict the capacity of the canal for traffic.

The Government surveys were intended to show the practicability of the canal, and that object had been fully attained in the comparatively short time devoted to the work, but it was quite evident that before the project was finally adopted as a commercial enterprise, important modifications should, and could, in my opinion, be introduced in the original designs. To what extent this has been accomplished will be shown in the description of the route finally located and adopted by the present Nicaragua Canal Construction Company. In 1876–77, while surveying the delta of the San Juan and harbor of Greytown, for the purpose of devising plans for the improvement of the navigation of the river and the restoration of the harbor, I had occasion to make extensive reconnoissances in a direct line connecting Greytown with the end of slack-water navigation in the San Juan River, my object being to find, if possible, a direct route joining those points, in lieu of the long and tortuous line following the bank of the river. These explorations, conducted from both ends of the desirable location, and in opposite directions, could not be completed within the time then at my disposal. There remained a gap of four or five miles yet to be examined, but, so far as carried out, the results of the explorations were extremely gratifying, with strong indications of physical conditions favorable to a satisfactory solution of the problem.

In 1880 I devoted my attention to a rectification of the Lajas location, and succeeded so far as to reduce the length of the route by 1 1-4 miles, eliminate several curves and enlarge the radius of others; decrease the amount of excavation in the narrow valley of the Rio Grande, and, what was of the greatest importance, found a satisfactory solution of the drainage problem by diverting the waters of the Grande, above its confluence with the canal, through an artificial channel, and the rivers Juan Davila and Lajas

into the Lake; thus leaving the narrow valley of the stream free for the Canal.

That much having been accomplished in the Western Division towards the contemplated improvement of the original location, a greater interest was naturally felt for a thorough rectification of the Eastern section. In 1885 the Government of the United States, immediately after having completed a treaty with Nicaragua for the construction of the Canal, directed me, at my own suggestion, to proceed to Nicaragua with a party of competent assistants and ascertain the practicability of introducing favorable modifications in the Eastern section of the canal location. The results attained by this last examination, together with what had been previously secured west of the Lake, were all calculated to attract the attention of engineers and capitalists, and the organization of the Company chartered by the United States Congress and now building the Canal, soon after followed. The results of this survey can be found in detail, in book form, in my report to the Hon. Secretary of the Navy, dated November, 1885, and entitled, "Report of the United States Nicaragua Surveying Party," Ex. Doc. No. 99, 49th Congress, 1st Session.

The Company was well aware, however, that while these surveys were ample to prove the practicability of the Canal, and sufficient in detail to arrive at an approximate cost of the work, yet they were only intended as a preliminary location, and more thorough studies, comprising the minutest details were still wanted before actual construction could be commenced. Therefore the first work undertaken by the Company, immediately after its organization, was to fit out and send to Nicaragua a numerous corps of competent engineers, with instructions to make a thorough re-location of the whole route and accessory works, so as to eliminate all doubtful elements and to arrive at an accurate estimate of the character, amount and cost of all the work required for the completion of a canal ample for the navigation of the largest ships afloat, and the passage of the maximum traffic likely to seek it.

Six land surveying parties, one hydrographic party, and two boring parties, have been for two years and a half making this verification, and although the axial distance of the land survey (exclusive of the lake and river) is less than fifty miles, the length of lines actually surveyed by transit and level, in cross-sectioning, location of locks, dams, embankments, railroads, flowage lines, drains, etc., etc., is not less than 4,000 miles, or at the rate of forty miles of actual instrumental survey for every mile of final location. The result of this laborious work has been a verification of the location

of 1885 in its essential features, but with marked improvements in the details, and the final location of the route upon which the Canal is now being constructed, and which I will proceed to describe in a concise form.

THE PROPOSED ROUTE.

San Juan del Norte (Greytown) on the Atlantic, and Brito on thePacific, are the termini of the Canal, the total distance from port to port being 169.448 miles, of which 26.783 miles will be excavated canal and 142.659 miles free navigation by Lake Nicaragua, the River San Juan, and through basins in the valleys of the streams Deseado, San Francisco and Tola. Lake Nicaragua is necessarily the summit level of the Canal, and its elevation above mean sea level is taken at its mean at 110 feet. It will be connected with the Pacific by two sections of canal in excavation and the Tola basin, and with the Atlantic by slack-water navigation through the valley of the River San Juan, and a series of basins in the valleys of the San Francisco and Deseado, connected by short sections of canal, the sea level on each side being reached by three locks which have been located as near as possible to the extremities of the Canal, viz: 3 1-2 miles from Brito and 12 3-4 miles from Greytown, thereby giving a clean summit level of 153 1-4 miles in extent out of a total distance of 169 1-2 miles, as stated above. For purposes of description the route has been divided into four divisions, viz: Eastern, San Francisco, Lake and River, and Western.

EASTERN DIVISION.

From the Inner Harbor of San Juan del Norte (Greytown) to the San Francisco Basin, 18.864 *miles.*

The line selected and located starts from the inner harbor of San Juan del Norte and extends in a southwesterly direction for a distance of 9.297 miles to Lock No. 1, in the valley of the small stream Deseado, which descends from the high ridge separating the valley of the San Juanillo from that of the Caño San Francisco. Where the stream Deseado interferes with the course of the Canal, it is to be diverted by artificial channels. These first 9.297 miles of canal will be at the level of the sea, forming, practically, a prolongation of the harbor of Greytown, the width proposed allowing ample room for the passage of vessels going in both directions. The excavation will be entirely through flat alluvial deposits, as shown by the numerous borings taken along the whole line.

The first lock from this reach will have a lift of 30 feet, and the uniform dimensions of chamber adopted for all the locks, viz.: 650 feet long and 70 feet wide. A suitable rise of ground for the site of the lock is met with

in the lower valley of the Deseado. From the head gate of Lock No. 1, to Lock No. 2, the Canal follows the valley of the Deseado, which is here partially flooded by the construction of four low embankments connecting the site of Lock No. 1 with the sides of the valley. In this manner the canal excavation, which here consists chiefly of stiff red clay underlying a thin stratum of loam, is much reduced, and the drainage economically and efficiently controlled by suitable weirs of maximum flood capacity.

Lock No. 2, located 1.258 miles above the headgate of Lock No. 1, has a lift of 31 feet and will rest on solid ground, a hill on the south side of the valley affording an excellent site for it.

Lock No. 3, with a lift of 45 feet, is located 12 3-4 miles from Greytown and 1.927 miles from the headgate of Lock No. 2. This section of the Canal occupies the lower basin, made in the valley of the Deseado by the erection of a dam 38 feet high and 1,300 feet long across the stream, and two embankments of an aggregate length of 1,400 feet and about 20 feet high, on the top of the confining ridges. The only excavation needed through this basin is in cutting across three low hills of red clay.

At this point the valley of the Deseado is spanned by an embankment 70 feet high and 1,050 feet long, resting on two high hills, and the gaps on the ridge connecting this embankment with the sides of the valley are closed with small embankments aggregating 5,800 feet on the crest, with an average heigth of 20 feet to the level, 112 feet above sea level. By this means a basin 3.086 miles long is created in the valley of the stream in which a depth of from 30 feet to 70 feet is obtained, without excavation, for a distance of 2.598 miles. It is proposed to retain the water in this basin at an elevation of 106 feet above sea level; in other words, the summit level of the Canal is carried across the "Divide" and extended to Lock No. 3, or to within 12 3-4 miles of the Atlantic, and but 3 1-2 miles from the sea level, which, as stated above, reaches 9 1-4 miles up from Greytown. The advantage of these two large reservoirs in close proximity to the locks need not be commented upon, and the facilities afforded as a "turn-out" for ships in waiting and traveling in opposite directions cannot be over-estimated. The dam is proposed to be built of stone or what is termed "rock-fill," with earth backing, and will have a weir 600 feet long on the crest, and a fall of 45 feet for the discharge of the surplus water into the lower basin. This will be supplemented by another weir 800 feet long, located on the south side of the valley in a gap between the hills enclosing the upper basin, giving a total length of weir of 1,400 feet.

At the western extremity of this basin begins the "Eastern Divide Cut," connecting the valley of the Deseado with that of the Caño San Francisco. This cut is 2.917 miles long, has a maximum cut of 298 and average depth of 111.2 feet above the level of the water, the depth in the Canal being 30 feet, and contains about 21 per cent. of the total excavation estimated for the whole Canal.

The magnitude of this work grows less striking as we proceed to examine its importance as a factor in the solution of the problem, the local advantages for its execution, its permanency when finished, and the advantageous and economical disposition of the material to be excavated.

FIRST.—It will be observed that this cut is almost in a direct line between Ochoa and Greytown, which are the two objective points of the Canal; the former being the point at which it must, of necessity, leave the San Juan River, and the latter equally necessary as its terminus on the Atlantic.

SECOND.—It is the lowest point along the whole ridge which intervenes between these two points, and nearly equidistant from each.

THIRD.—It is also the narrowest pass, by several miles, of any other on the ridge, the valleys of the Deseado on one side and the San Francisco on the other, here penetrating it farther than elsewhere, thus allowing the greatest possible extension of their basins with the least excavation.

Besides the above there are several other important advantages connected with this particular pass entitled to much consideration.

FIRST.—The material to be removed is in the main solid rock; therefore the volume of excavation is reduced to a minimum, and the cut, when made, will remain so forever without further expense.

SECOND.—The material is needed for the construction of the dam at Ochoa, for the embankments between Ochoa and Greytown, for the construction of the locks, for the breakwater at Greytown, and for pitching the sides of the Canal, and the surplus can be dumped in the immediate vicinity.

THIRD.—The center of distribution is most conveniently located, and were not this material available, at the sole expense of transportation down grade, it would have to be obtained at considerable cost from quarries in the vicinity, as there is no rock easy of access between Ochoa and Greytown, except in this ridge.

FOURTH.—The locality is one of the healthiest in Nicaragua, the drainage is perfect, and water abundant and excellent for domestic uses.

FIFTH.—There is close at hand on both sides of the ridge an inexhaustible water power for the economical and convenient operation of all the machinery required to do the work.

Possessing, therefore, as it does, this truly marvelous coincidence of favorable circumstances, it would seem as though the very hand of Nature had made this particular spot with the view of facilitating the execution of the greatest undertaking of this or any other age. With proper appliances and good management, so much of the work in the adjacent sections being dependent upon the material to be got from this cut, an even rate of progress can easily be maintained and the whole work be pushed to completion well within the six years estimated as the time for completing the Canal.

SAN FRANCISCO DIVISION, 12.500 MILES.

From the Western End of the Divide Cut to the River San Juan at Ochoa.

On the Western slope of the Divide, the Canal follows the valley of the Limpio for 1.477 miles to the end of the cut. Before falling into the San Francisco basin it passes for .738 miles through a rolling country in the lower valley of the Limpio, the average depth of the cutting for this distance being 16 feet above the bottom of the Canal.

Passing into the basin of the Caño San Francisco it follows the valleys of the Limpio and Chanchos to near the confluence of the latter with the San Francisco, and then up the valley of the last named stream, skirting the hills on the west to a favorable pass in the hill range separating this valley from the swampy region called Florida Lake, extending towards Ochoa. The line of location follows this swamp to its western extremity, where it strikes the high rolling country intervening between this low region and the valley of the Machado, and following a tributary of the latter, it enters the River San Juan, 1,600 feet above the mouth of the Machado. The distance from the western end of the Divide Cut to the bank of the River San Juan, is 12.500 miles, of which 7.481 miles are tangents and 5.019 miles comprised in eleven curves of from 4,000 to 11,459 feet radius. The hills surrounding the basin on the south do not form an unbroken range rising at all points above the level of the water, which, in this section also, is maintained at 106 feet above sea level. Eight gaps will have to be closed by embankments aggregating in length to 2,440 feet, measured on the valley floor, and 12,260 feet on the crest, the maximum depth being 60 feet below the level of the water in the basins.

In addition to the above, 59 smaller embankments aggregating in length 18,280 feet on their crest, rising six feet above water level and vary-

ing in height from one to fifty feet, will be required from Ochoa to the main ridge of the Divide. All embankments resting on the valley or swamp level are designed of rock fill and earth backing, with three parallel rows of sheet piling between abutments.

The total length of basin secured by this plan is 11.267 miles from flowage line to flowage line, of which 8.697 miles are in water varying from 30 to 60 feet in depth. That is, of the 12.500 miles in the Division, but 1.233 miles will be wholly, and 2.570 miles partly, in excavation. This is not, however, the only advantage gained by the creation of this basin. Without it the cut across the "Divide" would be of such proportions as to make the route commercially impracticable, and the basin of the Deseado an impossibility. Not less important are the additional considerations of free navigation through a wide and deep basin, instead of a restricted excavated channel. In the former, vessels can travel at full speed, lie at anchor or pass each other at all points, while in the latter, the position and speed of all ships must conform to rigid regulations.

Attention is also invited to another striking feature of this work, as compared with that close to the bank of the San Juan.

In a country subject to observed rainfalls of more than six inches in twenty-four hours, the problem of drainage involves a contest with forces of Nature whose enormous destructive powers are a constant menace to engineering works, however careful and skillful their design and execution. And it is of the utmost importance, therefore, to reduce these forces to a minimum before the construction of works to withstand them.

The large territory embraced between the ridge confining the basin to the south and the "Lower Route," which term is used to designate the Canal line formerly proposed, and which lies on the right bank of the San Juan River to Greytown, is, by the adoption of the "Upper Route," or that over which the Canal is being built, entirely eliminated from the problem of drainage, leaving only that portion of the watershed north of the ridge, from the Divide to the valley of the Machado to be provided for. The area of this catchment basin is about 65 square miles.

It is proposed to build all embankments across the valleys in the disconnected portions of the ridge, of rock fill and earth backing, the crest to be 107 feet above sea level, and with the top and outer slope so shaped and paved with large stones, as to admit the free flow of water over the surface without danger of injury, all other embankments to be 112 feet above sea level. All these embankments will be, in fact, so many waste weirs for the discharge of the surplus water at several points in the basin, with an

aggregate length of 4,720 feet of spillway, and assuming that the embankments are perfectly tight, which will not be the case until several years after construction, and therefore, that all the surplus water passes over the weirs, the maximum depth on the crest will not exceed fifteen inches.

An extraordinary freshet in the San Juan above the dam would probably send some of the river water towards the basin, but it will be observed that the weirs in the basin alone are capable of discharging 90,200 cubic feet per second before the water reaches the top of the high embankments, and that, in such extreme cases, the basin would also be discharging through the Divide Cut, over the Deseado dam and weirs, and, if need be, through the culverts of Lock No. 3. As an additional precaution a guard gate is provided in the first cut east of the Machado, by which the waters of the River San Juan may be shut off from the basin. With these ample provisions the destruction of the smaller earth embankments by an overflow of the basin seems to be well guarded against.

Lake and River Division, 121.04 Miles.

From Ochoa to Western Coast of Lake Nicaragua.

This Division extends from the western extremity of the San Francisco Division in the valley of the Machado to the entrance of the Canal on the west shore of Lake Nicaragua. The total distance is 121.04 miles, divided as follows: Navigation by the River San Juan, 64.54 miles; Lake Nicaragua, 56.5 miles. The section of the river from Ochoa to the Lake is to be made navigable by the construction of a dam at Ochoa, just below the Machado, maintaining the water at the summit level of 106 feet above sea level. It may be here explained that this elevation hitherto treated as the summit level is four feet below the Lake, a fall of three-quarters of an inch to the mile being allowed for the slope necessary to discharge its waters, although for all the purposes of navigation, that portion of the river is converted into an extension of the Lake.

The dam is located between two steep hills, and its length of weir on the crest will be 1,250 feet, and abutments 650 feet. The average depth of the water in the river was, at the time of the survey, eight feet, and the maximum depth, close to the southern abutment, fourteen feet, the width between the banks being 950 feet. With a mean flow in the river of 20,000 cubic feet per second, the depth of water on the top of the weir will be about three and a half feet.

The dam is proposed to be built of rock fill and earth backing, in all respects similar to all the other large embankments and weirs already

described. Its average height above the river bottom is 61 feet, its thickness at the top, 25 feet, and at the bottom, 500 feet. The core of the rock portion will be made of smaller stones, gravel, and refuse from the rock cuts, with three rows of sheet piling from abutment to abutment, and substantial concrete core walls from the ends of the sheet piling carried well into the abutment hills and up along the slope beyond the maximum flood level. The upper portion and long flat apron will be composed of stones of the largest dimensions that can be handled and arranged, the interstices being filled from behind with small stones, gravel and earth dumped from suitable trestles.

By this dam, slack-water navigation in the River San Juan will be obtained in the whole distance from the Lake, in which, with the exception of the 28 miles above Toro Rapids, the navigable channel will be at no point less than 1,000 feet wide, with depths varying from 28 to 130 feet. Between the Lake and Toro Rapids rock blasting under water and dredging to an average depth of four and a half feet will be required at several places, amounting in all to 24 miles, most of the rock blasting occurring at Toro. The average depth of water, as raised by the dam, over the shallow places where deepening has been estimated for, is 23 feet, and the excavated channel is 125 feet at the bottom, the slopes varying with the character of the material.

A further important effect of the dam will be to raise the water from the River San Carlos to the level attained by the San Juan at their confluence above Ochoa, converting the valley of that stream into a spacious lake or port, and an integral part of the summit level and of the Canal itself. Thousands of square miles of the territory of Costa Rica, now inaccessible by land or water, will thus become the richest portion of that Republic; and the sediment now being brought down by the rapid current of the river will then be deposited, for want of transporting power, at the mouths of the ravines and mountain torrents emptying into the basin. In fact, the area now scoured will be so much reduced, that comparatively little material will be transported.

The confining ridge to the east of the valley of the San Carlos, is a generally high range, extending in a nearly straight line from the south abutment of the Ochoa Dam, about S. 15° W. seven and one-third miles, to the foot of the high mountains of the interior. The length of the ridge, following its crooked crest-line, is about ten miles. The hills forming the ridge do not form an unbroken range at all points higher than the level of the water, which is here also maintained at 106 feet above sea level. A number

of short depressions will have to be closed by embankments, the tops of which will be at an elevation of 112 feet.

The total number of embankments necessary is twenty-one. Of these eight will be very small, the ridge being now above the water line, but below 112 feet. Only two will reach the floor of the valley, having a depth of of 48 feet. The remaining eleven have an average depth of nineteen feet. The aggregate length of embankments on crest is 5,540 feet; on floor of valley 130 feet.

The embankments proposed will be entirely of clay, fifteen feet wide on top, with slope of three to one on both sides.

It is proposed to build a large waste weir in the ridge about two and two-thirds miles from the Ochoa Dam. This weir having its crest of 106 feet elevation, will discharge the flood waters of the San Carlos into the San Juan independently of and below the dam.

The valley of Cureño creek runs directly from the site of the proposed weir to the San Juan, 5 1-2 miles below Ochoa, hence no channel for the discharged waters need be provided.

In the east side of Lake Nicaragua, dredging in soft mud will be needed for a distance of about fourteen miles to reach the depth of 30 feet, the average depth of the cut being 9.8 feet, and the proposed channel 150 feet wide at the bottom, with side slopes of three to one to the present bottom of the Lake.

From the end of this cut to within 1,400 feet of the west coast, at the entrance of the Canal, the depth in the Lake varies from 30 to 150 feet. The excavation on the west side is estimated as rock. No borings were taken on this side of the Lake, but the indications on the shore and the result of the borings in the vicinity point to rock as predominating in the sub-aqueous excavation.

In view of the nature of the bottom and the prevailing winds on that coast of the Lake, it is deemed advisable, if not essential, to estimate for two crib piers or breakwaters at the entrance of the Canal and extending into deep water a distance of 1,800 feet and 2,400 feet respectively. These piers will have the effect of arresting débris drifting along the coast by the action of the waves, ensure smooth water at the entrance of the Canal, and serve as guides to approaching vessels.

Western Division.

From the Lake to Brito, 17.04 *miles.*

This section of canal connects the Lake with the Pacific Ocean. It is 17.04 miles long from the shore of the Lake when at 102.5 feet above the

sea level, the elevation at the time the surveys were made, to the port at Brito.

As the Canal is now estimated for, 11.44 miles of that distance will be wholly in excavation and 5.60 miles through a basin in the valleys of the rivers Grande and Tola.

In this basin from 30 to 70 feet of water can be had for a distance of 4.568 miles. The basin has an area of 4,000 acres, an extreme width of 12,500 feet, and an average of 5,500 feet. An alternative route has been located through the valleys proposed to be flooded, for a canal in excavation, should it be found more economical on account of the value of the land through which it passes. The only new feature of this division is the basin now introduced.

The first section begins at the mouth of the River Lajas, on the west shore of Lake Nicaragua, and follows the valley of that stream for a distance of 8,260 feet, in which the width of the canal is 120 feet at the bottom, and the side slopes one and one-half to one, both in rock and earth. The River Lajas here turns to the south, and it is proposed to divert it and make it discharge into the Lake a short distance south of its present mouth. The Canal continues on the same straight line, crosses a plain about three-quarters of a mile wide, and enters the valley of the Guiscoyal, a small tributary of the Lajas, and at 4.70 miles from the Lake it crosses the highest elevation on the line between the Lake and the Pacific. This point is 42 feet above high lake, or 152 feet above mean tide in the Pacific, and is situated in a valley about two miles wide, deserving special notice by reason of the fact that it is the lowest depression of the main ridge between the Atlantic and Pacific Oceans on the American Continent.

After crossing this divide, the line gradually descends at the rate of about nine feet per mile, and in one and three-quarter miles farther it meets the Rio Grande, a mountain stream which drains an extensive area of the western slope of the Cordillera. The line of the Canal follows the tortuous channel of the Grande, cutting across some of its sharp bends, or occupying a channel in short reaches. In one and a half miles it frees itself from this contracted valley and cuts across a broad plain as it turns to the westward, and enters the basin of the Tola, nine miles from the Lake. The distance across the basin by the sailing line is 5.504 miles. This basin is formed by the construction of an embankment 1,800 feet long and 70 feet high, resting on two high hills at a place called La Flor. The method of construction of this embankment is in all respects similar to that adopted for the construction of the Ochoa dam, and embankments in the San Fran-

cisco valley. The rock for the fill will be obtained from the excavations for Locks Nos. 4 and 5 in the north abutment, and the earth from the Canal excavation east of the basin. The level of the Lake will be extended through the divide cut and the basin to this dam, the top of which is established at 112 feet above sea level. Therefore, the Lake will have to rise more than two feet above the proposed summit level before any water runs over the weir. With a length of weir of 1,300 feet and the lock culverts capable of discharging not less then 4,500 cubic feet per second, the level of the Lake can be kept under control, even during extraordinary floods. Yet a guard gate is proposed in the section of Canal between the Lake and the "Divide" to shut off the water from the Lake in case of necessity. No special provision has been made for the control of the rivers Grande and Tola, and none is deemed necessary. These streams will flow into the summit level, one between the Lake and the Tola basin, and the other at the northern extremity of the basin. The waters will be distributed between the basin and the Lake, or partly used for feeding the locks, and should both rivers be in flood while the water in the basin is below the crest of the weir, and, therefore, most of the combined flow discharging into the Lake, the current in the Canal through its narrowest portion in the "Divide," will not exceed two miles an hour, which can do no harm to the rock cut, while in the larger portions of the Canal the velocity would, of course, be proportionately less.

From the western end of the valley of Tola to Brito, the Canal, after leaving Locks Nos. 4 and 5, cuts across a broad, flat country, with an inclination of about 9 feet per mile, to the port, a distance of 2.28 miles, in which the excavation does not exceed that required for the Canal prism.

Three locks are proposed to overcome the difference of level between the summit and the Pacific. Locks Nos. 4 and 5 are located in the hill north of La Flor Dam; their chambers are 650 feet long and 70 feet wide, and the lifts 42 1-2 feet in each. Lock No. 6, of the same dimensions of chamber, is situated 1.58 miles below, its lifts being 21 and 29 feet, respectively, at high and low tide. Between this lock and the port of Brito, a distance of .57 miles, the Canal will be at the level of the sea, with an enlarged section, and may be regarded as an extension of the harbor, similar to that at the Greytown end of the route.

HARBOR OF GREYTOWN.

Thirty years ago this harbor had a comparatively narrow but safe entrance from the sea, with a deep and commodious inner bay, where the largest class

of sea-going vessels could lie with perfect safety. To-day this bay is converted into a fresh-water lagoon, separated from the sea by a continuous sand strip stretching across the old entrance. This sand bank is the work of the waves, which, striking the sandy coast at an angle varying with the direction of the wind, but always inside of the first quarter, drives the sand from east to west, to be deposited at the extreme western end of the hook, or east side of the entrance. This continuous operation caused the hook to advance until it struck the main coast on the west, thus completely enclosing the bay.

The plan for the restoration of the harbor is based on data gathered through many years of investigations, in which the nature and magnitude of the forces operating on the coast were carefully defined and considered. It became then an easy matter to create the means of opposing these forces, and the following plan has been adopted, and is now in process of execution.

It consists in the construction of a jetty, or breakwater, about 2,000 feet long, nearly normal to the shore of the sand strip separating the bay from the sea, and extending to the six fathom curve; then dredging from this latter depth off shore across the sand bank and in the inner bay.

The jetty is located to the windward of the proposed entrance channel, which it is intended to shelter from the sea and protect from the wash of the waves and the traveling sand of the coast. The shifting sand arrested by the pier will accumulate in the angle formed by the pier and coast until the deposit reaches the end of the breakwater, when there will be a tendency to shoal around the outer end and across the entrance. This can be again prevented by an extension of the pier, and the same process continued from time to time until the new coast line thus formed is perpendicular to the prevailing direction of the wind; when the shifting action of the sea will be permanently arrested and the work of the waves will be confined to piling the sand on the beach.

The first section of the jetty extending from the shore to 15 feet of water, is proposed to be built of creosoted timber, fascinage and stone, and that portion in deep water to be of "pierre perdue" or rubble, the stone to be obtained from the "Divide Cut." The entrance channel is estimated to have a depth of 30 feet and a width of 500 feet at the bottom, and the inner basin is designed of sufficient dimensions to afford easy access to the Canal and to accommodate a large number of vessels, its excavated area on the bottom being 206 acres, which, with the area of the enlarged section of the Canal at sea level to Lock No. 1, gives a total area of 341 acres of water 28 feet deep, exclusive of slopes of three to one and the remaining portions of the inner bay not deepened, yet having in many

places a depth of twenty feet, in which a large number of vessels of ordinary size can lie.

The first 700 feet of the pier have already been successfully built, and the results so far obtained fully confirm the expectations to be realized by the execution of the plan.

BRITO.

The recent surveys have greatly added to previous information as to the natural conditions of this locality, which, by reason of its being of necessity the terminus of the Canal on the Pacific Coast, has been spoken of as "the harbor," when, as remarked by Prof. Mitchell, it is not even a roadstead. Yet, the practicability of constructing a harbor at this point has not been disputed, the only difference of opinion being confined to details. The plan now proposed combines, as nearly as possible, the most economical form of construction with that best adapted to the physical conditions, and meets, it is believed, most effectually the objections raised against former designs.

The broad valley of the Rio Grande stretches to the coast at this point through a wide gap in the main range of hills extending along the Pacific coast. This valley, it is believed, formed once a considerable bay, but is now filled up for a distance of about 6,000 feet from the beach to about the level of high water. The proposed plan for the construction of the harbor consists, 1st, In a breakwater 900 feet long, extending from a rocky promontory projecting from the beach at the western extremity of the range of hills, and, 2d, another jetty, 830 feet long, normal to the beach nearly opposite the extremity of the one before mentioned. The proposed harbor will be partly in deep water confined by the jetties, but its main portion is proposed to be excavated in the alluvial valley, the whole forming a deep and broad basin penetrating 3,000 feet from the present shore line at high water, and 3,900 feet from the entrance between the jetties. As an extension of the harbor, the Canal itself is excavated at sea level with an enlarged prism, for a distance of 3,000 feet farther inland where the tide lock has been located. It is believed that, with the basin as designed and the prolongation of the sea level through the Canal, sufficient tranquillity will be secured at the lock and in the harbor, but should this prove not to be the case, an enlargement of the main basin by dredging in soft material would be a question of but comparatively small expense.

The breakwaters, as estimated for, are of "pierre perdue," the material to be obtained from the rocky promontory or from the western "Divide Cut," the price allowed being on the latter basis. The harbor has an area

of 95 1-3 acres on the bottom or excavated portion, and with the sea level section of the Canal the total area is 103 2-3 acres of water, 30 feet deep, exclusive of the slopes of three to one.

MATERIALS FOR CONSTRUCTION.

The whole line of the Canal is well supplied with timber, generally of excellent quality, though in some sections of the Eastern Division it has been deemed advisable to estimate for its use only on temporary works during construction, such as trestles, laborors' dwellings, etc., the sheet piling and most of the bearing piles being imported from the Southern States, and creosoted when necessary. On the Western Division, however, the wood growing on ground less moist, is of a very superior quality, and it is proposed to use it for all purposes, its durability having been amply proved in every class of construction throughout the country.

The rock proposed to be used for the dams, weirs and breakwaters will be got from the divide cuts, which consist chiefly of basalt and various descriptions of trap of excellent quality for the purpose.

Lime of the best quality is obtainable in the Western Division at many places, and the numerous specimens of work on which it has been used have stood the test of many generations, and are to-day in a state of perfect preservation, but it is calculated to supplement this supply with imported cement, which will be used largely in the form of concrete in the construction of locks, etc., clean, sharp sand being found in abundance in the beds of most of the streams in the vicinity of the Canal.

DIMENSIONS AND CAPACITY OF THE CANAL.

In establishing the dimensions of the Canal it has been my purpose to profit by the experience at Suez, where a yearly traffic of 6,000,000 tons could not be carried through without serious delays to navigation. The reduction in the length of excavated canal accomplished by the last location in Nicaragua, through the substitution of free navigation in deep and broad basins for a restricted channel, gives additional facilities for the construction of a waterway capable of accommodating not less than 12,000 vessels with a net tonnage of 20,000,000 a year, at but a small increased cost as compared with the advantages secured, both for the commerce of the world and the economical administration of the enterprise. In fact, the immediate and prospective benefits obtained by the enlargement, in the increased facilities for passing vessels and a considerable decrease in the cost of maintenance and preservation of the work, fully justify, it is believed, the additional expense

in the original cost. It will be seen on examination of the subjoined table that, of the 169.448 miles, the total length of the Canal from the Atlantic to the Pacific, 121.04 miles is unimpeded navigation in the River San Juan and in Lake Nicarágua and 21.619 miles through basins, making a total distance of 142.659 miles in which ships can travel with little or no restriction as to speed. Of the remaining 26.789 miles, .759 is taken up by the six locks, leaving but 26.030 miles of canal actually in excavation. Of this latter distance 18.189 miles are of canal large enough for vessels traveling in opposite directions to pass each other, the sectional area being in excess of the largest area of the Suez Canal. The two sections of canal with contracted prisms are in the eastern and western Divide Cuts; the first is 2.917 miles and the other 4.924 miles in length, and, located as they are, almost at the extreme ends of the summit level and in close proximity to the upper locks, it is believed that the slight additional facilities to navigation secured by enlarging the dimensions of the Canal in these heavy rock cuts, and the inconsiderable gain in the time of transit, would not compensate for the larger outlay necessary.

TABLE

SHOWING THE DIMENSIONS OF THE SEVERAL SECTIONS OF THE PROPOSED CANAL.

Section of Canal.	Length, Miles.	Width, Top, Feet.	Width, Bottom, Feet.	Mean Depth, Feet.	Area of Prism, Sq. Feet.
Greytown to Lock No. 1.....	9.297	288	120	28	5,712
Lock No. 1 to Lock No. 2, Canal.....	1.258	210	120	30	4,950
Lock No. 2 to Lock No. 3, Canal.....	1.650	210	120	30	4,950
Lock No. 2 to Lock No. 3, Basin.....	1.762	...	...	30	.....
Lock No. 3 to Western End of Eastern Divide Cut, Canal.....	2.917	80	80	30	2,400
Lock No. 3 to Western End of Eastern Divide Cut, Deseado Basin.....	3.086	...	...	45	.....
Western End of Divide Cut to Ochoa, Canal.	1.233	184	80	30	3,673
Western End of Divide Cut to Ochoa, San Francisco Basin.....	11.267	...	...	40	.....
River San Juan to Toro Rapids.....	37.040	...	...	52	.....
River San Juan, where dredging is needed..	27.500	...	125	28	.....

TABLE

SHOWING THE DIMENSIONS OF THE SEVERAL SECTIONS OF THE PROPOSED CANAL (CONTINUED).

SECTION OF CANAL.	LENGTH, MILES.	WIDTH, TOP, FEET.	WIDTH, BOTTOM, FEET.	MEAN DEPTH, FEET.	AREA OF PRISM, SQ. FEET.
Lake Nicaragua	56.500	...	150	50	.....
Lake to Western Divide Cut, Canal	1.565	210	120	30	4,950
Western Divide Cut, Canal	4.924	80	80	30	2,400
Divide Cut to East End of Tola Basin, Canal.	2.519	184	80	30	3,673
East End of Tola Basin to Lock No. 4, Basin	5.504	...	...	50	.....
Lock No. 5 to Lock No. 6, Canal	1.582	184	80	30	3,673
Lock No. 6 to harbor of Brito, Canal	.570	288	120	28	5,712

RECAPITULATION.

	MILES.	LENGTH, MILES.
Canal Excavation, east side	14.870	
Canal Excavation, west side	11.160	
Six Locks, both sides	.759	26.789 Canal in Excavation.
Deseado Basins	4.848	
San Francisco Basin	11.267	21.619 Length of Basins.
Tola Basin	5.504	
River San Juan	64.540	
Lake Nicaragua	56.500	121.040 Natural Waterways.
From Atlantic to Pacific		169.448 Length of Canal.

In the Lake and in the greater part of the River San Juan vessels can travel with unrestricted speed, and in some sections of the river and in the basins, although the channel is at almost all points deep and of considerable width, yet the speed will be somewhat checked by reason of the curves.

Official reports show that, in the Suez Canal, steamers of 4,400 tons can travel at an average speed of six statute miles per hour, and that smaller

vessels travel through the Canal at the rate of from six to eight miles an hour. On this basis the following estimate of the time of transit has been prepared:

ESTIMATED TIME OF THROUGH TRANSIT BY STEAMER.

	H. M.
26.030 miles of Canal, at five miles an hour,	5.12
21.619 miles in the basins, at seven miles an hour,	3.05
64.540 miles in River San Juan, at eight miles an hour,	8.04
56.500 miles in Lake Nicaragua, at ten miles an hour,	5.39
6 Lockages, at 45 minutes each,	4.30
Allow for detentions in narrow cuts,	1.30
Total time of transit,	28.00

The traffic of the Canal will be limited by the time required for a vessel to pass a lock and on a basis of 45 minutes and that but one vessel will pass in each lockage, the number of vessels that can pass through the Canal in one day will be 32, or in one year 11,680, which, at the average tonnage of vessels going through the Suez Canal, will give 20,440,000 tons per year. This estimate is on the assumption that the traffic will not be stopped during the night, for, with abundant water power at the locks and at the basins, the whole Canal can be economically illuminated by electricity, and, with beacons and range lights in the lake and river, there seems to be no good reason why vessels should not travel day and night with perfect safety, and the outlay necessary for the illumination has consequently been included in the estimate.

WATER SUPPLY.

Lake Nicaragua has a surface area of about 2,600 square miles, and a watershed of not less than 8,000 square miles. Guages at its outlet, the River San Juan, at its lowest stage between the Lake and Toro Rapids, showed a minimum flow of 11,390 cubic feet per second. Col. Childs estimated the discharge with full lake in the wet season at 18,059 cubic feet per second, which gives a mean flow of 14,724 cubic feet per second, or 1,272,530,600 cubic feet per day.

WATER REQUIRED FOR LOCKAGE.

	Cubic Feet.
Water required for one lockage on the east side,	2,047,500
" " " " " west side,	1,933,750
" " " " " both sides,	3,981,250
" " for 32 lockages per day,	127,400,000

This gives a daily excess for the lake supply *only* of 1,144,753,600 cubic feet.

To the latter amount must be added the flow of the several tributaries of the San Juan River between the lake and the Ochoa Dam, and also the tributaries of the basins forming part of the summit level, which would fully compensate for leakage and evaporation.

It is expected that considerable leakage will take place at the rock-fill dams and embankments before they consolidate and become tight, but this may well be accepted as a desirable condition to aid in gradually disposing of the surplus water without a large discharge over the weirs.

The above statement shows that the lake discharge is about ten times larger than the maximum amount needed for the Canal, and it may be safely estimated that for many years after the Canal is opened for traffic, the surplus, from that source alone, will be double that amount, while at the confluence of the rivers San Juan and San Carlos, above the Ochoa Dam, the excess may even reach forty times the quantity needed for the Canal. It is evident, therefore, that as long as the summit level can be maintained at the required elevation, the leakage through the rock-fills, acting as safety valves, may be regarded as an element of security rather than one of danger, especially as the tightening of the dam may be regulated by depositing suitable material on the up-stream side, or by dumping more stone on the lower slopes or on the crest, so as to preserve the desired elevation of the surface of the water.

A detailed estimate of the cost of the Canal is foreign to the nature of this paper, but it may be proper to state that the probable total cost has been arrived at through careful computations based upon the data obtained by the last location and numerous borings along the whole route.

The Eastern "Divide Cut," less than three miles in length, is represented in the estimate with 7,000,230 cubic yards of rock in place, and twenty-two per cent. of the cost of the whole Canal. Reference has already been made, in describing the Eastern Division, to the existing facilities for doing the work and the several purposes to which the material to be removed can be economically applied in the construction of the Canal. In the Western Division the excavation in rock through the "Divide Cut" is estimated at 5,696,507 cubic yards, distributed over a distance of nine miles in which the deepest portion of the excavation is but forty-two feet above the surface of the water. There are ample facilities for the deposit of the waste material not needed for the construction of the breakwaters, the locks, the embankments, the dam, etc., etc.

Of the 26.789 miles of Canal in excavation, more than twelve miles will be done by dredging at the level of the sea, the material to be deposited directly on both sides of the Canal prism.

A railroad has been estimated for between Greytown harbor and the river San Juan above the Ochoa Dam, and on the Western Division between the Lake and the Pacific, which, together with the lake and river and the smaller streams penetrating the valleys of the Deseado and San Francisco, will afford easy and economical communication along the whole route.

It is admitted that the cost of this work will be greater than that of similar work located in a well developed country. A large percentage of the increased cost is chargeable to the transportation of machine tools, and to the difficulty of obtaining and providing for the workmen, the country from Greytown to the Lake being uninhabited and covered with a dense forest and intercepted by extensive swamps and ridges of steep hills; and that between the Lake and the Pacific but sparsely populated. The erection of houses for the protection of property and the accommodation of employés, will also be a necessary item of considerable expense, but the country is exceptionally healthy, and these structures need not be either substantial in character or expensive. They need be, as a rule, but temporary sheds built with material gathered along the line of the Canal, at but little more cost than the labor of handling it. Yet much delay and expense will be found unavoidable in the preliminary preparations for commencing the work of excavation.

Another contingency which may cause a marked increase in the cost of the work is the physical inability of the imported workmen to perform the ordinary labor, as compared with that accomplished in a more temperate climate. The laboring classes of Nicaragua, when under proper control, are capable of an activity and endurance under great fatigue and exposure to the elements scarcely equalled in any other country, and with no apparent injury to health; yet the same capabilities cannot be expected in unacclimated foreigners accustomed to different conditions of life. It is believed that not less than 6,000 excellent laborers can be obtained from the Central American States, and that with a judicious management all the help needed can be had from the Gulf States in this country where the climatic conditions are in many respects similar to those prevailing over a large portion of the Canal route. The number of skilled laborers employed will be comparatively small. On the west side of the Lake, where the greater number of laborers will be employed, the climate is not excelled for salubrity by any other portion of Central America, and in that portion of the Eastern section from Ochoa to Greytown, which is the only locality where trouble from climatic causes might be expected, the unexceptional good

health enjoyed by the employés of the Company during more than two years of constant exposure to the influence of the climate, while undergoing all kinds of hardships and privations, seems to be an evident demonstration that no apprehension need be entertained as to the climate. It will be observed that in this section the work is divided into two large classes, viz: the "Divide Cut" and dredging. The first is located in the most elevated and healthy portion of the line, and in the second the number of employés is reduced to a minimum, as manual labor is almost entirely excluded. The small force necessary to handle and care for the machinery will be either housed on the dredges or in quarters in the "Divide" where, with the purest of waters from the mountain streams and the cool "Trades" constantly sweeping in from the sea, the slightest sanitary regulations will ensure perfect health at all times.

It is believed that with an intelligent and business-like management the Canal can be completed in six years for the work of actual construction, and one year in making the necessary preparations to commence active operations, and that the total cost will not exceed $90,000,000, exclusive of banking commissions, interest during construction, and other expenses not included in the engineer's estimate.

WORK ACCOMPLISHED.

The first expedition for construction left New York on the 25th of May, 1889, and on the 3d of June landed at the proposed entrance to the Canal, near Greytown, on a sandy, uninhabited coast, without harbor or shelter from the elements, with no means of communication along the line of the Canal except through tortuous and much obstructed streams, some of which could not float a loaded canoe, and depending altogether on a base of supplies for construction materials and subsistance 2,000 miles distant, with only one line of steamers touching on that coast, and two weeks distant from the nearest telegraph station. The first work of the pioneers of the great enterprise was, necessarily, one of self-preservation. Rude temporary shelters had to be improvised for the protection of men and stores, while more permanent buildings could be erected; means of transportation along the route of the Canal through deep and extensive swamps and virgin forests had to be provided for, and telegraphic communication to the nearest station (more than 100 miles from the coast) and connecting the various camps about to be established with the base of operations, was felt from the start to be a necessary adjunct to prosecuting the work. Under these conditions, aggravated by an insufficient supply of an inferior class of labor, the first operations

were difficult, tedious and expensive, and it was not until the month of October following that the preliminary organization of the various departments had been completed, and the ordinary work of construction could be said to have commenced.

The opening of an entrance into what used to be the Bay of Greytown, was recognized from the start to be an indispensable requisite in the prosecution of the work. Ships now anchor about two miles off shore, and machinery and other supplies are brought ashore in lighters, through a shifting entrance and dangerous bar, with a variable depth, never exceeding six feet. This method of landing supplies involves considerable risk and expense, and is altogether inadequate for the discharge of the heavy machinery. The Company, therefore, has spared no effort in obtaining an entrance from the sea into the bay, and the construction of the breakwater was one of the first works undertaken by the Company, and pushed ahead with all possible despatch. This pier is now about 700 feet long, its outer end being in twelve feet of water, and so far has fulfilled, even beyond expectations, all that was expected to be accomplished by it. It affords already sufficient protection to the dredges excavating the channel, and the Company has already made a contract for the dredging of the entrance and inner bay, to a depth of twenty feet. Some of the dredges are now in Nicaragua and others are in process of construction and will leave soon for Greytown. It is expected therefore, that, within the next five months vessels drawing fifteen or twenty feet may be able to enter the bay and discharge their freight directly on the wharves of the Company.

Heavy machinery suitable for the work can then be safely landed, the work of preparation may be said to have been completed, and active operations can be undertaken along the whole route.

While prosecuting the harbor work the Company has also established permanent quarters, erected large storehouses, hospitals, dwellings, shops and other buildings. It has accumulated the necessary material for the construction of an aqueduct thirteen miles in length, (work on which is now actively pushed) which is to supply Greytown, the works on the Eastern section of the Canal, the harbor and the Company's headquarters, with fresh water from the mountains. It has erected wharves and warehouses for the receipt and storage of supplies. Parts of the San Juanillo, Deseado, San Francisco, and other streams, have been cleared of obstructions and made navigable for small craft, and several miles of the route of the Canal, between the harbor and the Eastern Divide, have been grubbed and cleared and made ready for dredging. The Company has built about ~~two~~ ten miles of broad

guage railroad and about seventy miles of telegraph and telephone lines, and has landed at Greytown large quantities of machinery, tools, lumber, piles, creosoted timber, boats, steam tugs and launches, lighters, pile drivers, and other materials and equipment necessary for the harbor and canal work. Large quantities of railroad supplies, locomotives, steam excavators, are now at Greytown, and a contract has been let for the construction of seventeen miles of railroad from Greytown to the Eastern Divide Cut, work on which has already been commenced, and, in short, it may be safely said that the whole work is being pushed forward as rapidly as the circumstances and condition of the country permit.

A. G. MENOCAL,
Chief Engineer.