Number of Curves.	Radius.	Length.	Total Degrees of Curve.		
	Feet.	Miles.	°	′	″
2	17,189	1.53	26	51	10
8	11,459	6.80	179	31	50
4	8,594	4.31	151	40	50
1	8,385	1.43	51	44	30
2	7,814	1.90	73	28	30
1	7,759	1.73	67	16	50
5	6,876	4.64	204	34	40
2	5,927	2.40	122	41	20
16	5,730	11.08	584	47	40
2	5,289	2.27	129	45	50
1	5,209	1.15	66	38	30
2	5,056	1.22	73	17	40
1	4,982	.82	49	49	00
3	4,911	2.75	169	36	00
1	4,297	.63	44	19	50
1	4,175	.81	58	20	40
4	4,045	3.82	285	25	40
56		49.29	2,339	50	30

the dam site may be taken at about 55 feet above the sea. Inasmuch as the greatest elevation of the water in the lake is supposed to be about 110 feet, it will be seen that its surface will be but 55 feet above the present elevation, making its maximum depth at that point about 105 feet if there should be no fill on the upstream side of the dam, inasmuch as the present depth of water in the river at the stage assumed is about 50 feet.

This dam would be a structure of concrete masonry with cutstone facing only at a few points where it would be advisable to use that material. A large part of the flood discharge, or the discharge of other surplus water, would be made over a properly designed crest of the dam; hence its outline would be that shown in the accompanying figure, shaped so as to prevent the overflowing sheet of water from damaging the structure. This dam will be founded upon pneumatic caissons, and the borings made by the commission show that the deepest of them would reach satisfactory bed-rock at no greater depth than 25 feet below sea-level, or about 80 feet below the ordinary stage of water in the river. The construction of this dam therefore would involve no unusual operations, but it would all be performed within the more usual and easy limits of the pneumatic process of con-

structing foundations. The masonry crest of this dam would be finished at the elevation of 97 feet above sea-level, or about 13 feet below the highest elevation of water in the lake. The length of that part of this masonry dam, located on pneumatic caissons, would be 731 feet, but the total length of the entire masonry structure would be 1310 feet. The total length of crest,

Castillo Viejo, on the San Juan River, about thirty-seven miles from the lake and at the Castillo Rapids. The old fort is shown on the right at the summit of the hill.

including the masonry piers on it, over which the surplus waters would flow, would be 810 feet, but there are twenty piers 9 feet thick, so that the net length of crest available for overflow of waste-waters would be about 630 feet. The piers to which reference is made are those required for the support of the movable gates of the Stoney type which would be employed to regulate the discharge over the dam. The maximum elevation of the tops of these piers required for the support and operation of the Stoney gates is 132 feet above sea-level. The masonry dam thus furnished with movable gates can be used in times of flood to prevent the water of the lake rising above about 110 feet above sea-level. In times of low rainfall or during the dry season the gates would prevent the escape of water needed for storage.

The total available length of crest on this masonry dam is not sufficient to exercise all the control that is needed to keep

the lake within desired limits, and the commission was obliged to avail itself of a low depression or saddle between the hills less than a half-mile easterly of the dam site. The depression affords an additional total length of crest of 1239 feet, or, taking out thirty-one piers, each 9 feet wide, a net available length of 960 feet, making in combination with the crest of the main dam a total net available length of 1590 feet. The total wastage over these two structures, i.e., the main dam at Conchuda and the Conchuda wasteway on the Costa Rican side of the river, may be at the rate of 100,000 cubic feet per second, with a maximum depth over the crest of 7 feet, which is sufficient to meet the demands of the heaviest rainfall in the lake basin.

The plans and elevations on pages 421, 423, and 424 show all the main features of both the Conchuda dam and wasteway as designed by the commission.

340. Regulation of the Lake Level.—One of the most important engineering questions connected with the consideration of the Nicaragua route is that of the regulation or control of the surface of the water in Lake Nicaragua constituting the summit level of the canal.

As has already been stated, the drainage-basin of the lake, about 12,000 square miles in area, is subjected to an annual wet season extending from about the middle of May to the middle of December, the dry season extending over the remaining portion of the year. The average annual rainfall over the entire lake basin is not accurately known, although the Isthmian Canal Commission maintained rainfall records at several points on the lake shore and at other points in the basin during periods of $1\frac{1}{2}$ to 2 years, and records running back over periods of perhaps 12 to 15 years are available from Rivas, Granada, and Masaya. Fortunately, also, both the Nica agua and the Isthmian Canal Commissions maintained gauging-stations at various points on the San Juan throughout the periods of service of these commissions, so that the discharges of the river could be known from accurate measures at various seasons for at least two or three years. These observations, although not as extended as could be desired, yield sufficient data for a comparatively thorough treatment of the subject of lake-surface control.

Obviously throughout the rainy season of the year, except during years of low rainfall, some water would necessarily be wasted from the lake because its retention would raise the surface of the lake too high, causing damage, floods, or injurious overflows at various places around the lake shore. On the other hand, unless some water were stored from the rainy periods or wet seasons there would not be sufficient in the lake to supply

Village of Fort San Carlos at Entrance to the San Juan River. Lake Nicaragua is on the right and San Juan River in the middle ground.

during the dry period of the year, or during low rainfall years, the requisite quantity for the wastage of evaporation from its surface and for the operation of the canal, and at the same time maintain the minimum depth of water of 35 feet required in the canal. It was necessary, therefore, to design at least the general features of such regulating-works as would prevent the lake from rising too high in wet periods, and from falling too low in dry periods or low rainfall years.

341. Evaporation and Lockage.—The observations of both commissions show conclusively that the average evaporation from the surface of Lake Nicaragua is about 60 inches or 5 feet per year, varying from perhaps a maximum of 6 inches per month to a minimum of possibly about 4 inches per month. Furthermore, careful estimates of the quantity of water required for the

purposes of the canal, on the supposition that about 10,000,000 tons of traffic would pass through it annually, including lockage, leakage through the gates of the locks, evaporation, power purposes, and other incidentals, show that about 1000 cubic feet of water per second must be provided. Whatever may be the character of the season, therefore, there must be at least sufficient water stored in the lake to provide for the wastage of evaporation from the lake and canal surfaces and for the proper operation of all the locks throughout the length of the canal. The superficial area of Lake Nicaragua is but little less than 3000 square miles. The quantity of water required for the operation of the canal, amounting to 1000 cubic feet per second, would, for the entire year, make a layer of water over the lake surface of less than 5 inches in thickness. In other words, the operation of the canal, for a traffic of about 10,000,000 tons annually, requires an amount of water less than one twelfth of that which would be evaporated from the lake surface during the same period.

342. The Required Slope of the Canalized River Surface. — The dam located at Conchuda and fitted with suitable movable gates affords means of accomplishing the entire lake-surface control. That dam is located, however, nearly 53 miles from the lake, and in order that the requisite discharge may take place over it during the rainy season there must be considerable slope of the water surface in the canalized river from the lake down to the dam. It was necessary, therefore, to compute that slope, from data secured by the commission, with the lake surface at various elevations between the minimum and maximum permitted. These slopes were found to be such that the difference in elevations of the surface of the water at the dam and in the lake might vary from about 6 to 9 feet, those figures representing the total fall for the distance of 53 miles.

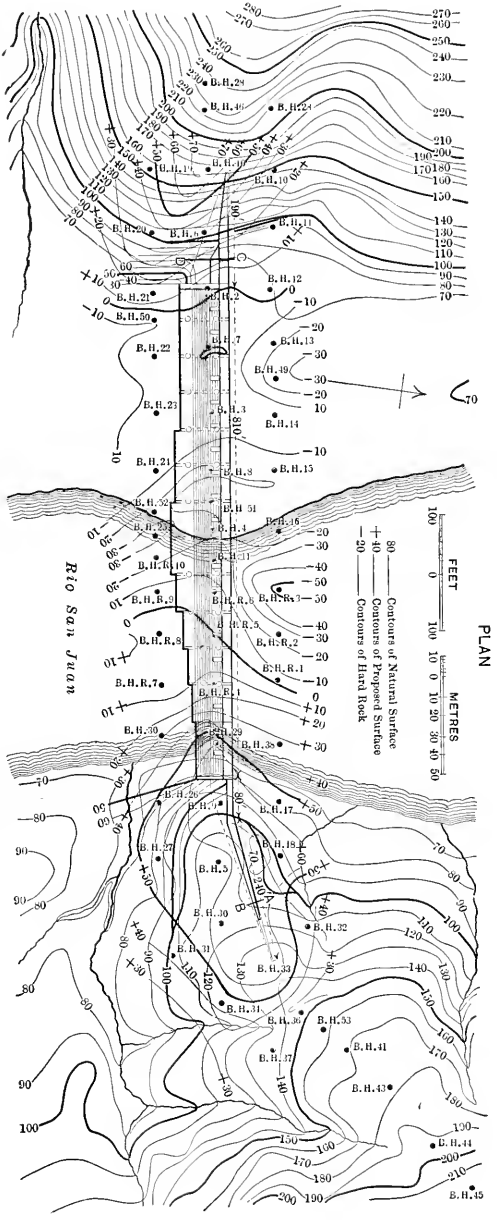
343. All Surplus Water to be Discharged over the Conchuda Dam.—The Nicaragua Commission contemplated the construction of dams not only on the San Juan River at Boca San Carlos, about 6 miles below Conchuda, but also another a few miles west of the lake at La Flor, so as to discharge the surplus waters at both points, but by far the largest part over the dam at Boca San Carlos. The Isthmian Canal Commission, however, decided

to build no dam on the west side of the lake, but to discharge all the surplus waters over the dam at Conchuda.

344. Control of the Surface Elevation of the Lake.—The rainfall records in the lake basin have shown that a dry season beginning as early as November may be followed by an extremely low rainfall period, which in turn would be followed by a dry season in natural sequence, lasting as late as June. It may happen, therefore, that from November until a year from the succeeding June, constituting a period of nineteen months, there will be a

The Active Volcano Ometepe in Lake Nicaragua, showing Clouds on Leeward Side of the Summit. The crater is nearly eleven miles from the canal line.

very meagre rainfall in the lake basin, during which the precipitation of the seven low rainfall wet months may not be sufficient even to make good the depletion of evaporation alone during the same period. It would be necessary, then, at the end of any wet season whatever, i.e., during the first half of any December, or in November, to make sure of sufficient storage in the lake to meet the requirements of the driest nineteen months that can be anticipated. That condition was assumed by the commission, and the elements of control of the lake surface, in its plans, are



Plan of Conchuda Dam Site, showing Location of Boring.

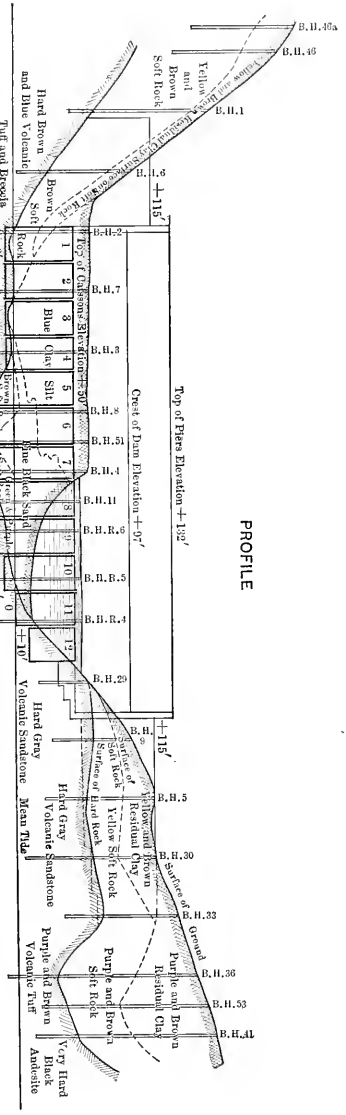
such as to afford resources to meet precisely those low-water conditions.

The commission's study of these features of the Nicaragua Canal problem resulted in plans of works to prevent the surface of the lake ever falling below 104 feet above sea-level, or rarely if ever rising higher than the elevation of 110 feet above the same level, thus making the possible range of the lake surface about 6 feet between its lowest and its highest position.

Obviously at the end of a dry season the gates at the dam will always be found closed, and there will be no water escaping from the lake except by evaporation and to supply the needs of canal operation. It is equally evident that the gates will also remain closed so as to permit no wastage during the early part of the wet season. As the wet season proceeds the surface of the lake will rise toward, and generally quite to its maximum elevation; the operation of wasting over the weirs will then commence. The time of beginning of this wastage will depend upon the amount and distribution of the rainfall during the wet period. Indeed no wastage whatever would be permitted during such a low-water wet season as that shown by the records of 1890, which was almost phenomenal in its low precipitation. The rainfall for the entire drainage-basin would be impounded in the lake in that case, and it would then fall short of restoring the depletion resulting from evaporation and requirements of the canal. On the other hand, during such a wet season as that of 1897 wastage would begin at an early date. In general it may be said that neither the rate nor the law of the rise of water surface in the lake can be predicted. There will be years when no wastage will be permitted, but generally considerable wastage will be necessary in order to prevent the lake rising above the permissible highest stage.

Detailed computations based upon the statistics of actual rainfall records in the basin of Lake Nicaragua may be found by referring to pages 147 to 152 of the Report of the Isthmian Canal Commission, and they need not be repeated here. Those computations show among other things that October is often a month of excessive rainfall, and that the greatest elevation of the lake surface is likely to follow the precipitation of that month. Hence

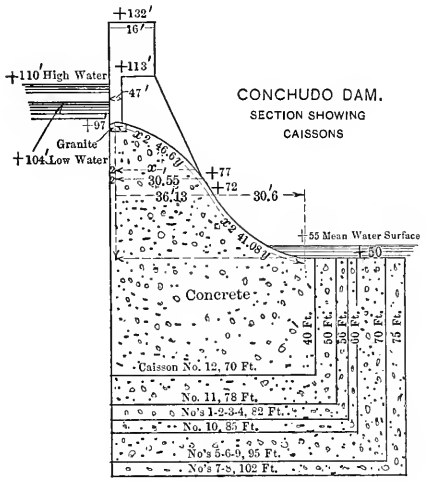
the greatest discharge of surplus waters over the Conchuda dam may be expected in consequence of the resulting run-off or inflow

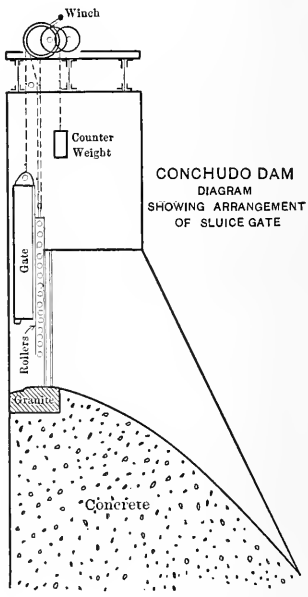


Profile of Site of Conchu lo Dam showing Borings.

into the lake. Those computations also show that at long intervals of time the lake surface might reach an elevation of nearly

112 feet above sea-level for short periods, causing the discharge in the canalized river or over the Conchuda dam to reach possibly 76,000 cubic feet per second, the elevation of the water at the dam being 104 feet above sea-level. Furthermore, the Sabalos River and one or two other small streams, emptying into the San Juan above the dam, might concurrently be in flood for at least a few hours and augment the discharge over the dam to 100,000 cubic feet per second. The regulating-works at the dam, consisting of the movable (Stoney) gates, were devised by the commission to afford that rate of discharge, an aggregate net or available length of overflow crest at the dam and wasteway of 1590 feet being necessary for that purpose with a depth of water on the crest not exceeding 7 feet.





The commission states on page 156 of its report:

"While, therefore, no detailed instructions can be set forth regarding the condition of the sluices at the wasteway on specified dates, the general lines of their operation should be stated below, viz.:

"1. A full lake with surface probably a little above 110 feet on December 1.

"2. Wasteway sluices closed at least from about December 1 to some date in the early portion of the succeeding rainy season, or throughout that season if it be one of unusually low precipitation.

"3. A variable opening of wasteway sluices, if necessary, during the intermediate portion of the rainy season, so as to maintain the lake surface elevation but little, if any, below 110 at the beginning of October.

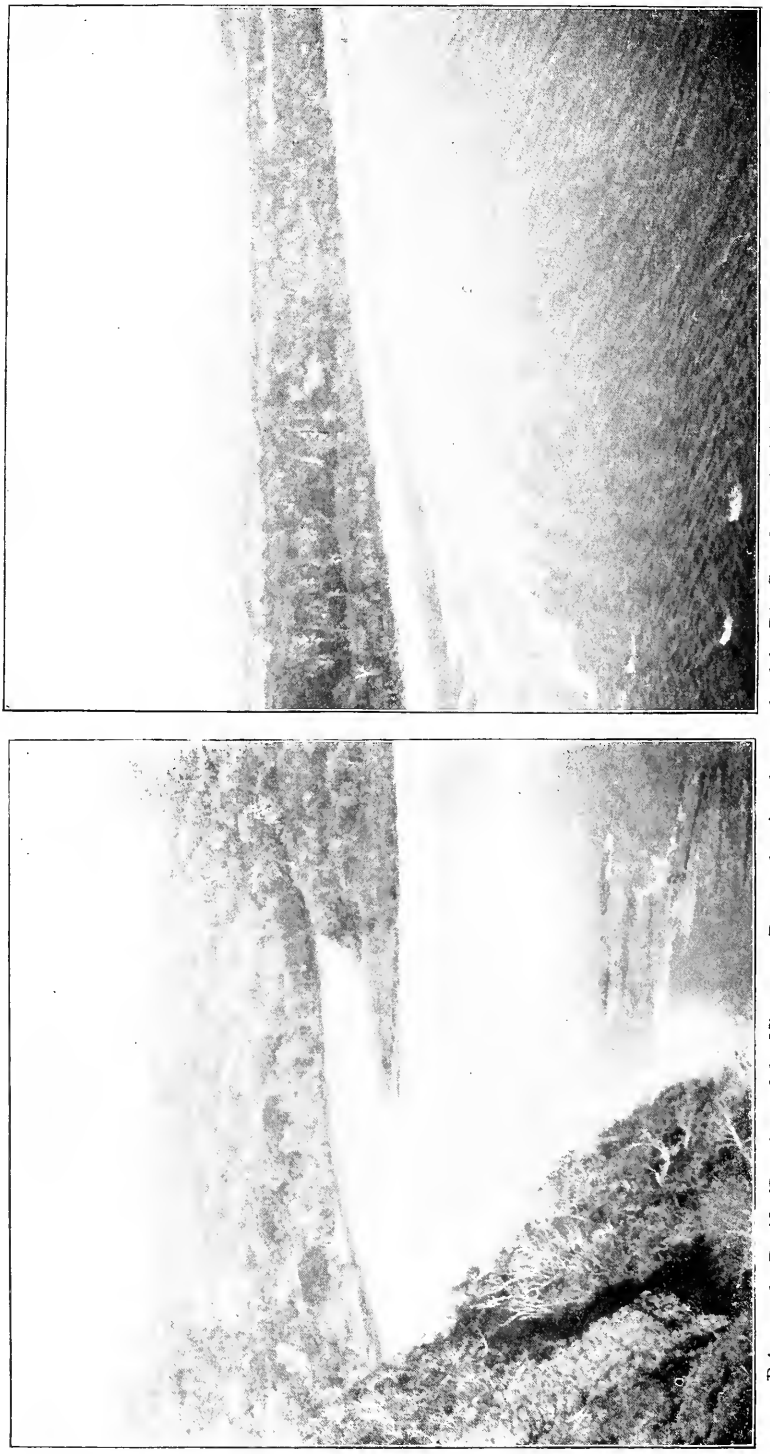
"4. The operation of wasteway sluices during October and November so as to reach the 1st of December with a full lake, or lake elevation p obably a little above 110 feet."

It is thus seen that while the measures for control and regulation are entirely feasible, they are not sharply defined, nor so simple that some experience in their ope ation might not be needful for the most satisfactory re ults.

345. Greatest Velocities in Canalized River. — It is necessary to ascertain whether the velocitie; induced in the canalized portions of the San Juan Rive would not be too high for the convenience of traffic during the highest 1 ainfall season. The following table and the succeeding paragraph, taken from the commission's report, show that no sensible difficulty of this kind would exist.

Elevation of Lake.	Elevation of Water at Dam.			
	103 Feet.		104 Feet.	
Feet.	Feet per Second.	Miles per Hour.	Feet per Second.	Miles per Hour.
110	4.16	2.8	3.9	2.7
111	4.51	3.1	4.2	2.9
112	4.85	3.3	4.5	3.1

"The discharge of the river corresponding to the velocity of 2.7 miles per hour is 63,200 cubic feet per second; while that corresponding to 3.3 miles per hour is 77,000 cubic eet per second. These estimated high velocities will occur but rarely, and they will not sensibly inconvenience navigation. In reality they are too high, for the reason that while the overflow at the minimum



Brito, at the Pacific Terminus of the Nicaragua Route, showing the mouth of the Rio Grande on the left and the easterly side of Brito Head.

river section materially increases the areas of those sections, it has been neglected in this discussion."

346. Wasteways or Overflows.—At a number of places on the route there are some small streams which must be taken into the canal, and which when in flood require tha certain wasteways or overflows from the canal prism should be provided at or near where such streams are received. These wasteways are simply overfall-weirs with the crests at the elevation of the lowest water surface in the canal prism. The principal works of this kind are on the east side of the lake and involve a total drainage area or area of watershed of about 107 square miles. Ample provision has been made by the commission for all such structural features.

347. Temporary Harbors and Service Railroad.—Before actual work could be begun at either end of the Nicaragua route temporary harbors would have to be constructed both at Greytown and at Brito to enable contractors to land plant and supplies or other material. These temporary harbors would probably require no greater depth of water than 18 feet, but they would be works of considerable magnitude, and provision was made for them in the commission's estimate of cost. Again, a service railroad of substantial character would have to be built from Greytown up to Sabalos, approximately half-way between the Conchuda dam and Fort San Carlos, as well as from the west shore of the lake to Brito, making a total line of about 100 miles. The commission estimated the cost of this railroad and its rolling stock at $75,000 per mile.

348. Itemized Statement of Length and Cost. — The following table gives the lengths of the various portions of the canal and the principal items of its cost, so arranged as to show the classification of the various items of the total sum to be expended for all purposes during the construction of the entire work.

The commission estimated the total time required in preparing for and performing the actual construction of the work at eight years, but the writer believes that at least two years more should be allowed for the work.

	Miles.	Cost.
Greytown harbor and entrance	2.15	$2,198,860
Section from Greytown harbor to lock No. 1, including approach-wall to lock	7.44	4,899,887
Diversion of Lower San Juan	.....	40,100
Diversion of San Juanillo	.....	116,760
Lock No. 1, including excavation	.20	5,719,689
Section from lock No. 1 to lock No. 2, including approach-walls, embankments, and wasteway	10.96	6,296,632
Lock No. 2, including excavation	.20	4,050,270
Section from lock No. 2 to lock No. 3, including approach-walls, embankments, and wasteway	16.75	19,330,654
Lock No. 3, including excavation	.20	3,832,745
Section from lock No. 3 to lock No. 4, including approach-walls, embankments, and wasteway	2.77	4,310,580
Lock No. 4, including excavation	.20	5,655,871
Section from lock No. 4 to San Juan River, including approach-wall and embankments	5.30	8,579,431
Conchuda dam, including sluices and machinery	.....	4,017,650
Auxiliary wasteway, including sluices, machinery, and approach-channels	.....	2,045,322
San Juan River section	49.64	23,155,670
Lake Nicaragua section	70.51	7,877,611
Lake Nicaragua to lock No. 5, including approach-wall to lock and receiving-basins for the Rio Grande and Chocolata	9.09	19,566,575
Diversion of the Las Lajas	.....	199,382
Lock No. 5, including excavation	.20	4,913,512
Dam near Buen Retiro	.....	125,591
Section from lock No. 5 to lock No. 6, including approach-walls and wasteway	2.04	3,259,283
Lock No. 6, including excavation	.20	4,368,667
Section from lock No. 6 to lock No. 7, including approach-walls, embankments, and wasteway	1.83	2,309,710
Diversion of Rio Grande	.....	176,180
Lock No. 7, including excavation	.20	4,709,502
Section from lock No. 7 to lock No. 8, including approach-walls, embankments, and wasteway	2.43	1,787,496
Diversion of Rio Grande	.....	117,580
Lock No. 8, including excavation	.20	4,920,899
Section from lock No. 8 to Brito harbor, including approach-wall	.23	553,476
Brito harbor and entrance, including jetty	.92	1,509,470
Railroad, including branch line to Conchuda dam site, at $75,000 per mile	.....	7,575,000
Engineering, police, sanitation, and general contingencies, 20 per cent	.....	31,644,010
Aggregate	183.66	$189,864,062

PART VI.

THE PANAMA ROUTE FOR A SHIP-CANAL.

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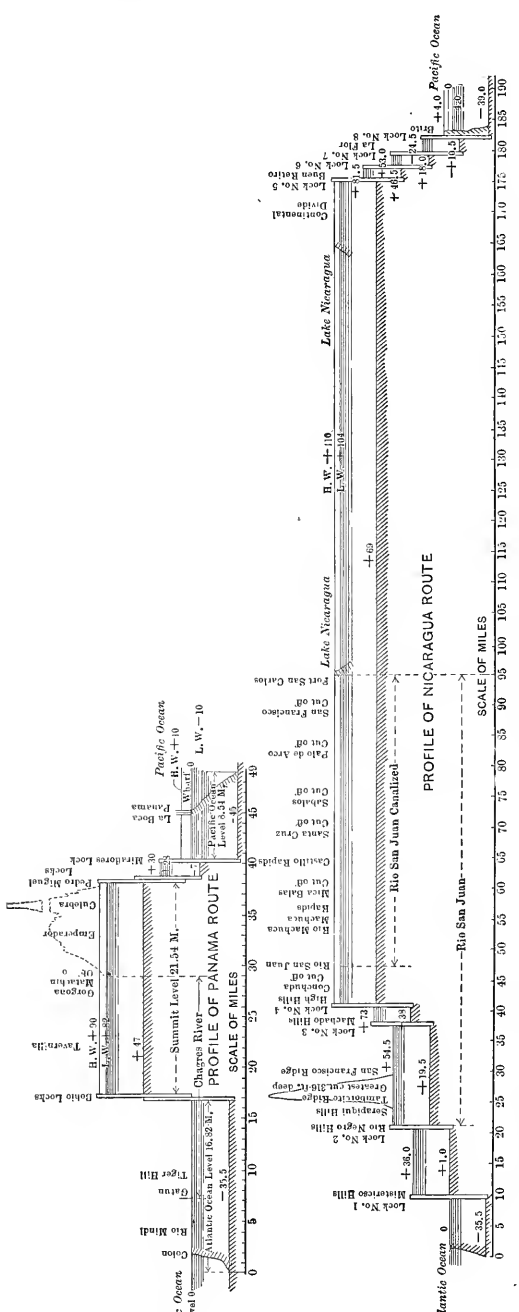
349. The First Panama Transit Line.—The Panama route as a line of transit across the isthmus was established, as near as can be determined, between 1517 and 1520. The first settlement, at the site of the town of old Panama, 6 or 7 miles easterly of the present city of that name, was begun in August, 1517. This was the Pacific end of the line. The Atlantic end was finally established in 1519 at Nombre de Dios, the more easterly port of Acla, where Balboa was tried and executed, having first been selected but subsequently rejected.

The old town of Panama was made a city by royal decree from the throne of Spain in September, 1521. At the same time it was given a coat of arms and special privileges were conferred upon it. The course of travel then established ran by a road well known at the present time through a small place called Cruces on the river Chagres, about 17 miles distant from Panama. It must have been an excellent road for those days. Bridges were even laid across streams and the surface was paved, although probably rather crudely. According to some accounts it was only wide enough for use by beasts of burden, but some have stated that it was wide enough to enable two carts to pass each other.

350. Harbor of Porto Bello Established in 1597. — The harbor of the Atlantic terminus at Nombre de Dios did not prove entirely satisfactory, and Porto Bello, westerly of the former point, was made the Atlantic port in 1597 for this isthmian line of transit. The harbor of Porto Bello is excellent, and the location was more



Profiles of the two Canal Routes. The horizontal scales are different, but the vertical scales are the same.

healthful, although Porto Bello itself was subsequently abandoned, largely on account of its unhealthfulness.

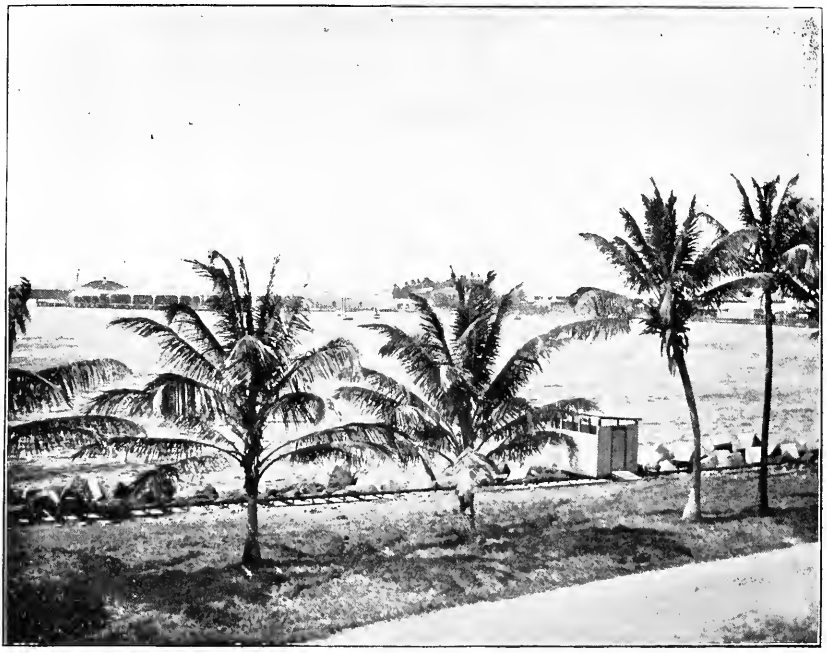
351. First Traffic along the Chagres River, and the Importance of the Isthmian Commerce.—As early as 1534, or soon after that date, boats began to pass up and down the Chagres River between Cruces and its mouth on the Caribbean shore, and thence along the coast to Nombre de Dios and subsequently to Porto Bello. The importance of the commerce which sprang up across the isthmus and in connection with this isthmian route is well set forth in the last paragraph on page 28 of the report of the Isthmian Canal Commission:

"The commerce of the isthmus increased during the century and Panama became a place of great mercantile importance, with a profitable trade extending to the Spice Islands and the Asiatic coast. It was at the height of its prosperity in 1585, and was called with good reason the toll-gate between western Europe and eastern Asia. Meanwhile the commerce whose tolls only brought such benefits to Panama enriched Spain, and her people were generously rewarded for the aid given by Ferdinand and Isabella in the effort to open a direct route westward to Cathay, notwithstanding the disadvantages of the isthmian transit."

352. First Survey for Isthmian Canal Ordered in 1520.—This commercial prosperity suggested to those interested in it, and soon after its beginning, the possibility of a ship-canal to connect the waters of the two oceans. It is stated even that Charles V. directed that a survey should be made for the purpose of determining the feasibility of such a work as early as 1520. "The governor, Pascual Andagoya, reported that such a work was impracticable and that no king, however powerful he might be, was capable of forming a junction of the two seas or of furnishing the means of carrying out such an undertaking."

353. Old Panama Sacked by Morgan and the Present City Founded.—From that time on the city of Panama increased in wealth and population in consequence of its commercial importance. Trade was established with the west coast of South America and with the ports on the Pacific coast of Central America. In spite of the fact that it was made by the Spaniards a fortress second in strength in America only to old Cartagena, it

was sacked and burned by Morgan's buccaneers in February, 1671. The new city, that is the present city, was founded in 1673, it not being considered advisable to rebuild on the old site.



View of the Harbor of Colon.

354. The Beginnings of the French Enterprise. — The project of a canal on this route was kept alive for more than three centuries by agitation sometimes active and sometimes apparently dying out for long periods, until there was organized in Paris, in 1876, a company entitled "Société Civile Internationale du Canal Interocéanique," with Gen. Etienne Türr as president, for the purpose of making surveys and explorations for a ship-canal between the two oceans on this route.

355. The Wyse Concession and International Congress of 1879. —The work on the isthmus for this company was prosecuted under the direction of Lieut. L. N. B. Wyse, a French naval officer, and he obtained for his company in 1878 a concession from the Colombian Government, conferring the requisite rights

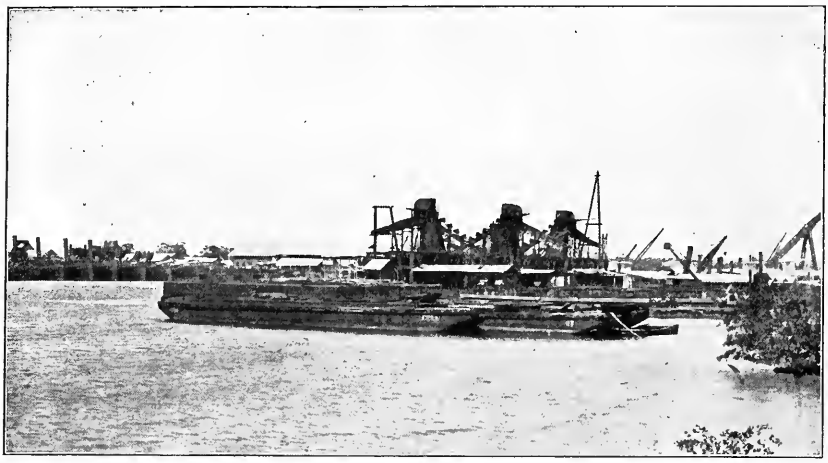
and privileges for the construction of a ship-canal on the Panama route and the authority to do such other things as might be necessary or advisable in connection with that project. This concession is ordinarily known as the Wyse concession.

A general plan for this transisthmian canal was the subject of consideration at an international scientific congress convened in Paris in May, 1879, and composed of 135 delegates from France, Germany, Great Britain, the United States, and other countries, but the majority of whom were French. This congress was convened under the auspices of Ferdinand de Lesseps, and after remaining in session for two weeks a decision, not unanimous, was reached that an international canal ought to be located on the Panama route, and that it should be a sea-level canal without locks. The fact was apparently overlooked that the range between high and low tides in the Bay of Panama, about 20 feet, was so great as to require a tidal lock at that terminus.

356. The Plan without Locks of the Old Panama Canal Company.—A company entitled "Compagnie Universelle du Canal Interocéanique" was organized, with Ferdinand de Lesseps as president, immediately after the adjournment of the international congress. The purpose of this company was the construction and operation of the canal, and it purchased the Wyse concession from the original company for the sum of 10,000,000 francs. An immediate but unsuccessful attempt was made to finance the company in August, 1879. This necessitated a second attempt, which was made in December, 1880, with success, as the entire issue of 600,000 shares of 500 francs each was sold. Two years were then devoted to examinations and surveys and preliminary work upon the canal, but it was 1883 before operations upon a large scale were begun. The plan adopted and followed by this company was that of a sea-level canal, affording a depth of 29.5 feet and a bottom width of 72 feet. It was estimated that the necessary excavation would amount to 157,000,000 cubic yards.

The Atlantic terminus of this canal route was located at Colon, and at Panama on the Pacific side. The line passed through the low grounds just north of Monkey Hill to Gatun, 6 miles from the Atlantic terminus, and where it first met the Chagres River.

For a distance of 21 miles it followed the general course of the Chagres to Obispo, but left it at the latter point and passing up the valley of a small tributary cut through the continental divide at Culebra, and descended thence by the valley of the Rio Grande to the mouth of that river where it enters Panama Bay. The total length of this line from 30 feet depth in the Atlantic to the



Old Dredges near Colon.

same depth in the Pacific was about 47 miles. The maximum height of the continental divide on the centre line of the canal in the Culebra cut was about 333 feet above the sea, which is a little higher than the lowest point of the divide in that vicinity. Important considerations in connection with the adjacent alignment made it advisable to cut the divide at a point not its lowest.

357. The Control of the Floods in the Chagres. — Various schemes were proposed for the purpose of controlling the floods of the Chagres River, the suddenness and magnitude of which were at once recognized as among the greatest difficulties to be encountered in the construction of the work. Although it was seriously proposed at one time to control this difficulty by building a dam across the Chagres at Gamboa, that plan was never adopted, and the problem of control of the Chagres floods remained unsolved for a long period.

358. Estimate of Time and Cost—Appointment of Liquidators.—It was estimated by de Lesseps in 1880 that eight years would be required for the completion of the canal, and that its cost would be $127,600,000. The company prosecuted its work with activity until the latter part of 1887, when it became evident that the sea-level plan of canal was not feasible with the resources at its command. Changes were soon made in the plans, and it was concluded to expedite the completion of the canal by the introduction of locks, deferring the change to a sea-level canal until some period when conditions would be sufficiently favorable to enable the company to attain that end. Work was prosecuted under this modified plan until 1889, when the company became bankrupt and was dissolved by judgment of the French court called the Tribunal Civil de la Seine, on February 4, 1889. An officer, called the liquidator, corresponding quite closely to a receiver in this country, was appointed by the court to take charge of the company's affairs. At no time was the project of completing the canal abandoned, but the liquidator gradually curtailed operations and finally suspended the work on May 15, 1889.

359. The "Commission d'Etude."—He determined to take into careful consideration the feasibility of the project, and to that end appointed a "commission d'études," composed of eleven French and foreign engineers, headed by Inspector-General Guillemain, director of the *Ecole Nationale des Ponts et Chaussées*. This commission visited the isthmus and made a careful study of the entire enterprise, and subsequently submitted a plan for the canal involving locks. The cost of completing the entire work was estimated to be $112,500,000, but the sum of $62,100,000 more was added to cover administration and financing, making a total of $174,600,000. This commission also gave an approximate estimate of the value of the work done and of the plant at $87,300,000, to which some have attached much more importance than did the commission itself. The latter appears simply to have made the "estimate" one half of the total cost of completing the work added to that of financing and administration, as a loose approximation, calling it an "intuitive estimate"; in other words, it was simply a guess based upon such information

as had been gained in connection with the work done on the isthmus.

360. Extensions of Time for Completion.—By this time the period specified for completion under the original Wyse concession had nearly expired. The liquidator then sought from the Colombian Government an extension of ten years, which was granted under the Colombian law dated December 26, 1890. This extension was based upon the provision that a new company should be formed and work on the canal resumed not later than Feb-

The Partially Completed Panama Canal, about eight miles from Colon.

ruary 28, 1893. The latter condition was not fulfilled, and a second extension was obtained on April 4, 1893, which provided that the ten-year extension of time granted in 1890 might begin to run at any time prior to October 31, 1894, but not later than that date. When it became apparent that the provisions of

this last extension would not be carried out an agreement between the Colombian Government and the new Panama Company was entered into on April 26, 1900, which extended the time of completion to October 31, 1910. The validity of this last extension of time has been questioned.

361. Organization of the New Panama Canal Company, 1894.—A new company, commonly known as the new Panama Canal Company, was organized on the 20th of October, 1894, with a capital stock of 650,000 shares of 100 francs each. Under the provisions of the agreement of December 26, 1890, authorizing an extension of time for the cons ruction of the canal, 50,000 shares passed as full-paid stock to the Colombian Government, leaving the actual working capital of the new Panama Company at 60,000 000 francs, that amount having been subscribed in cash. The most of this capital stock was subscribed for by certain loan associations, administrator , contractors, and others against whom suits had been brought in consequence o the financial difficulties of the old company, it having been charged in the scandals attending bankruptcy proceedings that they had profited illegally. Those suits were discontinued under agreements to subscribe by the parties interested to the capital stock of the new company. The sums thus obtained constituted more than two thirds of the 60,000,000 francs remaining of the share capital of the new company after the Colombian Government received its 50,000 shares. The old company had raised by the sale of stock and bond not far from $246,000,000, and the number of persons holding the securities thus sold has been estimated at over 200,000.

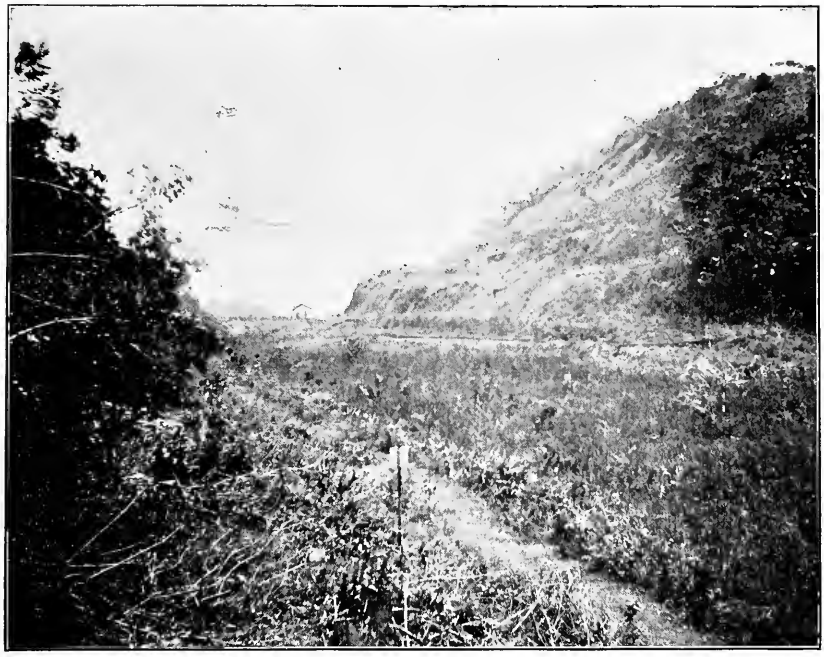
362. Priority of the Panama Railroad Concession.—The Panama Railroad Company holds a concession from the Colombian Government giving it rights prior to those of the Wyse concession, so that the latter could not become effective without the concurrence of the Panama Railroad Company. This is shown by the language of Article III of the Wyse concession, which reads as follows:

"If the line of the canal to be constructed from sea to sea should pass to the west and to the north of the imaginary straight line which joins Cape Tiburon with Garachine Point, the grantees

must enter into some amicable arrangement with the Panama Railroad Company or pay an indemnity, which shall be established in accordance with the provisions of Law 46 of August 16, 1867, 'approving the contract celebration on July 5, 1867, reformatory of the contract of April 15, 1850, for the construction of an iron railroad from one ocean to the other through the Isthmus of Panama.' " It became necessary, therefore, in order to control this feature of the situation, for the old Panama Company to secure at least a majority of the stock of the Panama Railroad Company. As a matter of fact the old Panama Canal Company purchased nearly 69,000 out of the 70,000 sha es of the Panama Railroad Company, each such share having a par value of $100. These shares of Panama railroad stock are now held in trust for the benefit of the new Panama Canal Company. A part of the expenditures of the old company therefore covered the cost of the Panama Railroad Company's shares, now held in trust for the benefit of the new company.

363. Resumption of Work by the New Company—The Engineering Commission and the Comité Technique. — Immediately after its organization the new Panama Canal Company resumed the work of excavation in the Emperador and Culebra cuts with a force of men which has been reported as varying between 1900 and 3600. It also gave thorough consideration to the subject of the best plan for the completion of the canal. The company's charter provided for the appointment of a special engineering commission of five members by the company and the liquidator to report upon the work done and the conclusions to be drawn from its study. This report was to be rendered when the amount expended by the new company should reach about one half of its capital. At the same time the company also appointed a "Comité Technique," constituted of fourteen eminent European and American engineers, to make a study of the entire project, which was to avail itself of existing data and the results of such other additional surveys and examinations as it might consider necessary. The report rendered by this committee was elaborate, and it was made November 16, 1898. It was referred to the statutory commission of five to which reference has already been made, which commission reported in 1899 that the canal

could be constructed within the limits of time and money estimated. On December 30, 1899, a special meeting of the stockholders of the new company was called, but the liquidator, who was one of the largest stockholders, declined to take part in it,



The Excavation at the Bohio Lock Site.

and the report consequently has not received the required statutory consideration.

364. Plan of the New Company.—The plan adopted by the company placed the minimum elevation of the summit level of the canal at 97½ feet above the sea, and a maximum at 102½ feet above the same datum. It provided for a depth of 29½ feet of water and a bottom width of canal prism of about 98 feet, except at special places where this width was increased. A dam was to be built near Bohio, which would thus form an artificial lake with its surface varying from 52.5 to 65.6 feet above the sea. Under this plan there would be a flight of two locks at Bohio,

about 16 miles from the Atlantic end of the canal, and another flight of two locks at Obispo about 14 miles from Bohio, thus reaching the summit level, a single lock at Paraiso, between 6 and 7 miles from Obispo, a flight of two locks at Pedro Miguel about 1.25 miles from Paraiso, and finally a single lock at Miraflores, a mile and a quarter from Pedro Miguel, bringing the canal down to the ocean elevation. The location of this line was practically the same as that of the old company. The available length of each lock-chamber was 738 feet, while the available width was 82 feet, the depth in the clear being 32 feet 10 inches. The lifts were to vary from 26 to 33 feet. It was estimated that the cost of finishing the canal on this plan would be $101,850,000, exclusive of administration and financing.

In order to control the floods of the Chagres River, and to furnish a supply of water for the summit level of the canal, a dam was planned to be built at a point called Alhajuela, about 12 miles from Obispo, from which a feeder about 10 miles long, partly an open canal and partly in tunnels or pipe, would conduct the water from the reservoir thus formed to the summit level.

365. Alternative Plan of the New Panama Canal Company.— Although the plan as described was adopted, the "Comité Technique" apparently favored a modification by which a much deeper excavation through Culebra Hill would be made, thus omitting the locks at both Obispo and Paraiso, and making the level of the artificial Lake Bohio the summit level of the canal. In this modified plan the bottom of the summit level would be about 32 feet above the sea, and the minimum elevation of the summit level 61.5 feet above the sea. This modification of plan had the material advantage of eliminating both the Obispo and Paraiso locks. The total estimated cost of completing the canal under this plan was about $105,500,000. Although the Alhajuela feeder would be omitted, the Alhajuela reservoir would be retained as an agent for controlling the Chagres floods and to form a reserve water-supply. The difference in cost of these two plans was comparatively small, but the additional time required to complete that with the lower summit level was probably one of the main considerations in its rejection by the committee having it under consideration.

366. The Isthmian Canal Commission and its Work.—This brings the project up to the time when the Isthmian Canal Commission was created in 1899 and when the forces of the new Panama Canal Company were employed either in taking care of the enormous amount of plant bequeathed to it by the old company or in the great excavation at Emperador and Culebra. The total excavation of all classes, made up to the time when that commission rendered its report, amounted to about 77,000,000 cubic yards.

The work of the commission consisted of a comprehensive and detailed examination of the entire project and all its accessories, as contemplated by the new Panama Canal Company, and any modifications of its plans, either as to alignment, elevations, or subsidiary works, which it might determine advisable to recommend. In the execution of this work it was necessary, among other things, to send engineering parties on the line of the Panama route for the purpose of making surveys and examinations necessary to confirm estimates of the new Panama Canal Company as to quantities, elevations, or other physical features of the line selected, or required in modifications of alignment or plans. In order to accomplish this portion of its work the commission placed five working parties on the Panama route with twenty engineers and other assistants and forty-one laborers.

367. The Route of the Isthmian Canal Commission that of the New Panama Canal Company.—The commission adopted for the purposes of its plans and estimates the route selected by the new Panama Canal Company, which is essentially that of the old company. Starting from the 6-fathom contour in the harbor of Colon, the line follows the low marshy ground adjoining the Bay of Limon to its intersection with the Mindi River; thence through the low ground continuing to Gatun, about 6 miles from Colon, where it first meets the Chagres River. From this point to Obispo the canal line follows practically the general course of the Chagres River, although at one point in the marshes below Bohio it is nearly 2 miles from the farthest bend in the river, at a small place called Ahorca Lagarto. Bohio is about 17 miles from the Atlantic terminus, and Obispo about 30 miles. At the

latter point the course of the Chagres River, passing up-stream, lies to the northeast, while the general direction of the canal line is southeast toward Panama, the latter leaving the former at this location. The canal route follows up the general course of a small stream called the Camacho for a distance of nearly 5 miles where the continental divide is found, and in which the great

The French Location for the Bohio Dam.

Culebra cut is located, about 36 miles from Colon and 13 miles from the Panama terminus. After passing through the Culebra cut the canal route follows the course of the Rio Grande River to its mouth at Panama Bay. The mouth of the Rio Grande, where the canal line is located, is about a mile and a half westerly

of the city of Panama. The Rio Grande is a small, sluggish stream throughout the last 6 miles of its course, and for that distance the canal excavation would be made mostly in soft silt or mud.

Although the line selected by the French company is that adopted by the Isthmian Canal Company for its purposes, a number of most important features of the general plan have been materially modified by the commission, as will be easily understood from what has already been stated in connection with the French plans.

368. Plan for a Sea-level Canal.—The feasibility of a sea-level canal, but with a tidal lock at the Panama end, was carefully considered by the commission, and an approximate estimate of the cost of completing the work on that plan was made. In round numbers this estimated cost was about $250,000,000, and the time required to complete the work would probably be nearly or quite twice that needed for the construction of a canal with locks. The commission therefore adopted a project for the canal with locks. Both plans and estimates were carefully developed in accordance therewith.

369. Colon Harbor and Canal Entrance.—The harbor of Colon has been fairly satisfactory for the commerce of that port, but it is open to the north, and there are probably two or three days in every year during which northers blow into the harbor with such intensity that ships anchored there must put to sea in order to escape damage. The western limit of this harbor is an artificial point of land formed by material deposited by the old Panama Canal Company; it is called Christoph Colon, and near its extreme end are two large frame residences built for de Lesseps. The entrance to the canal is immediately south of this artificial point. The commission projected a canal entrance from the 6-fathom contour in the Bay of Limon, in which the harbor of Colon is found, swinging on a gentle curve, 6560 feet radius, to the left around behind the artificial point just mentioned and then across the shore line to the right into the lowland southerly of Colon. This channel has a width of 500 feet at the bottom, with side slopes of 1 on 3, except on the second curve, which is somewhat sharper than the first, where the bottom width is made 800 feet