THE ISTHMIAN CANAL

BY

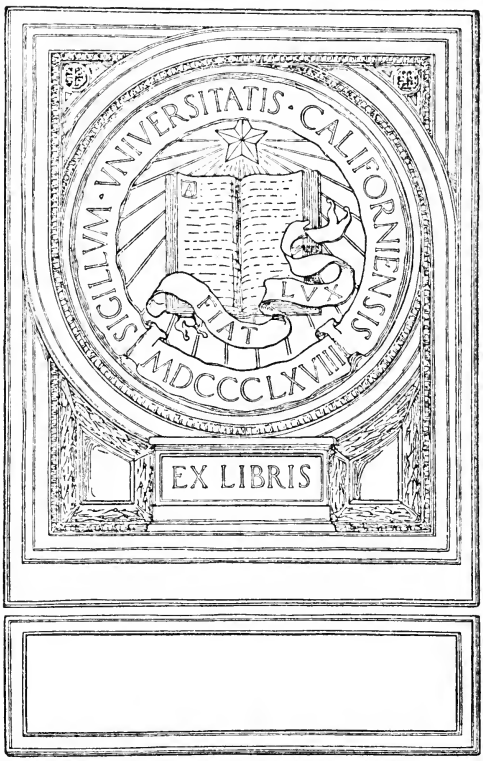
H. H. ROUSSEAU

CIVIL ENGINEER, U. S. NAVY
MEMBER ISTHMIAN
CANAL COMMISSION

PRESENTED AT THE TWENTIETH ANNUAL SESSION OF THE TRANS-MISSISSIPPI COMMERCIAL CONGRESS

HELD AT DENVER, COLO.
AUGUST 16–21, 1909

WASHINGTON
GOVERNMENT PRINTING OFFICE
1909


SIGILLVM · VNIVERSITATIS · CALIFORNIENSIS
FIAT LVX
MDCCCLXVIII
EX LIBRIS

THE ISTHMIAN CANAL

BY

H. H. ROUSSEAU
CIVIL ENGINEER, U. S. NAVY
MEMBER ISTHMIAN
CANAL COMMISSION

PRESENTED AT THE TWENTIETH ANNUAL SESSION OF THE TRANS-MISSISSIPPI COMMERCIAL CONGRESS

HELD AT DENVER, COLO.
AUGUST 16-21, 1909

WASHINGTON
GOVERNMENT PRINTING OFFICE
1909

TC774
R6

UNIV. OF
CALIFORNIA

THE ISTHMIAN CANAL.

By H. H. Rousseau.
Civil Engineer, U. S. Navy,
Member Isthmian Canal Commission.

In the days that are to come, the pages of history will mark as a milestone, in the progressive western trend of civilization, the completion of the Panama Canal, which can now be predicted to occur by January 1, 1915.

Its history is an interesting one, and has been over four centuries in the making; but since the first hardy adventurers, pushing westward from their native shores, landed on the American coast, there has been no more doubt that this project would not, as an indispensable factor in the future of the American continent, ultimately materialize, than that those selfsame pioneers would not continue their westward journey overland from the North Atlantic coast to the Mississippi River, thence over broad plains and rugged mountains, and finally, as has long since been seen, reach the Pacific Ocean, carrying with them and leaving in their trail the energy and spirit that have developed and now maintain the American nation.

In these centuries, during which the North American continent has been forging ahead, there has been no uncertainty as to the construction at the proper time of a canal between North and South America. Only three matters have been unknown:

First. By whom the canal would be built;

Second. Its location; and

Third. When it would be built.

Spain, England, Portugal, and France have all embarked upon the work, either directly or by giving aid and encouragement to their representatives, and failed. The time for success had not yet

M67199

arrived, for even if the funds with which to prosecute the work had been unlimited, the difficulties were then too great for engineering and medical science to solve.

It was President Grant who first advanced the policy of "an American canal under American control," and it was President Roosevelt who, voicing the sentiments of the entire American people, lent the aid of the United States in undertaking the work, which is being hastened to completion by President Taft.

It is interesting to review the various steps and numerous attempts which have led up to the construction of the canal.

First there was Balboa, who, driven from home by his creditors, landed on the Isthmus of Panama in 1500, where he married the daughter of an Indian chief. In 1513 he organized an expedition that crossed from the Atlantic to the Pacific afoot in twenty-three days over what is now known as the Caledonia Canal route, one of the score of projected routes that have been since advocated at various times by various persons. Old Panama, on the Pacific side, which afterwards became known as the richest city in the world of its time, was settled in 1517, and the highways from old Panama to Nombre de Dios, on the Atlantic coast, and from old Panama to Porto Bello, which were soon afterwards built, became the first regularly traveled routes across the Isthmus, over which passed all the spoils of conquest sent back to Spain from Peru. These highways, paved with stone, furnished ample facilities for the pack trains which traveled over them for many years, and to-day some parts of these roads are in good condition and can be traced for miles through the tropical vegetation in which they remain hidden and unused.

It was in those early days that the idea of a canal took birth, even while the existence of a natural strait was in doubt. A Spanish engineer, named Saavedra, one of Balboa's followers on the Isthmus, is reported to have been its first advocate, in 1517. After studying the subject for years he was about to forward his plans in 1529 to Charles V, King of Spain, when his death occurred. Surveys of the Isthmus with this object in view were ordered, but the work was reported to be impracticable, and with the tools available in those days this was certainly true. Philip II, successor to Charles V, in 1567, sent an engineer to survey the Nicaragua route, who likewise submitted a report unfavorable to the success of the work. In his

perplexity Philip is said to have laid the matter before the Dominican friars, who desired to obey the king's orders, but being unable to report intelligently on such a problem, after searching the Bible quoted the following verse as having direct reference to the Isthmian Canal:

"What God hath joined together, let no man put asunder." This was sufficient for King Philip, who laid the canal project on the shelf, where it remained through the reigns of his various successors for two centuries after his death.

In 1814, feeling the necessity of reviving its waning prestige in its Central American colonies, Spain entered upon, by decree, the construction of an Isthmian canal, but before any steps could be taken to carry out this purpose her Central and South American colonies obtained their independence. With the successful termination of the revolt of the Spanish provinces Spain passes from the history of the Isthmian Canal, except through furnishing some of the laborers to dig the American canal.

All the enthusiasm of those early days in regard to the canal idea was unavailing for lack of proper tools and sufficient capital. Moreover, the old stone highways filled requirements very well. The Atlantic terminus of the road from old Panama, which passes through Cruces, on the Chagres River, had been changed from Nombre de Dios to Porto Bello about 1597. This route was followed by Morgan in his raid, which resulted in the destruction of old Panama in 1671, two years after he had sacked Porto Bello.

England entered the lists with Lord Nelson and Baron von Humboldt as its representatives, who made researches and reports on the Nicaragua and other canal routes in the latter part of the eighteenth and the early part of the nineteenth centuries. Goethe's far-seeing prophecy, at this time, of American settlement and control of the Pacific coast, and the necessity of an Isthmian canal as a connecting link between our east and west coasts deserves especial attention.

In 1825, President Bolivar, of the Republic of New Granada, gave to a Frenchman, Baron Thierry, a franchise for a canal at Panama, who failed in raising the required capital. President Bolivar then commissioned a British engineer, Mr. J. A. Lloyd, to survey the Isthmus for either a road or canal.

While some negotiations were undertaken by citizens of the United States prior to 1830, the year 1835 really marks the entrance of the United States into the history of the canal, through a resolution introduced in the Senate by Henry Clay, in pursuance of which President Jackson commissioned Mr. Charles Biddle to visit the Isthmus and report on the availability of the different routes for interoceanic communication. Mr. Biddle proceeded to Chagres, the only available Atlantic port, thence to Cruces by boat, and to Panama by mule back. He was much impressed with the advantages and practicability of the Panama route, and afterwards visiting Bogota, with the assistance of Don José Obaldia, the father of the present President of the Republic of Panama, obtained a franchise to build a railroad across the Isthmus. He returned to the United States without making an examination of the Tehuantepec and other Central American routes, as he had intended. On account of the panic of 1837, the United States was not in any condition to finance an undertaking like this, and the matter was dropped.

In 1838 a concession was granted to a French company for the construction of highways, railroads, or a canal across the Isthmus. The Government of France became interested, and sent an engineer, Napoleon Garella, to report on the enterprise. He advocated a canal as the only adequate means of communication across the Isthmus. The concession was, however, allowed to lapse without performing any work, on account of lack of capital.

The attention of the American people was again turned to transportation via the Isthmus by the settlement of the Northwest boundary question, by which we came into possession of Oregon, and by the Mexican war, which added California to our possessions. Communication overland to the Pacific slope was difficult and dangerous, which deflected the main current of immigration via Cape Horn. To render this newly acquired territory more accessible, lines of steamers from New York to the Isthmus and from the Isthmus to California and Oregon were inaugurated by Americans having in view the construction of a railroad as a connecting link across the Isthmus, from which they would derive the greater part of their profits. Securing a franchise therefor from the Government of New Granada in 1848, Messrs. Aspinwall, Stephens and Chauncey entered upon the construction of the Panama Railroad, and after

to the Chagres River. Afterwards a tidal lock near the Pacific was provided and also a dam was to be constructed at Gamboa to control the Chagres. The tunnel through the divide was changed, also, to an open cut. Subscriptions for stock had been, meanwhile, called for yearly and were dwindling. In 1887 the evident impossibility of completing the work within a reasonable cost led to the substitution for the sea-level plan, of one involving temporary locks, with the summit level placed above the flood line of the Chagres River, and supplied with water from the Chagres by pumping. Work was continued until 1889 when the company went into bankruptcy. A receiver was appointed and work was suspended on May 15. Over $260,000,000 had been spent and about 66,700,000 cubic yards of excavation had been accomplished, at a cost of nearly $4 per cubic yard.

The new Panama Canal Company was formed in October, 1894, and resumed operations on the canal, principally in Culebra cut, in accordance with plans recommended by a commission of engineers. This company continued to do sufficient work to maintain its franchise until all of its rights and property were transferred to the United States Government in 1904. It excavated about 11,400,000 cubic yards. During this time, also, very thorough investigations of all engineering matters pertaining to the construction of the canal were made, which have since proved of great value. The plans of this company provided a sea-level channel on the Atlantic side, about 17 miles in length, from Limon Bay to Bohio, where a dam with a flight of two locks made an artificial lake extending to Bas Obispo. The summit level from Bas Obispo to Paraiso was reached through two locks at Bas Obispo. The level of the summit was 102½ feet above sea level. The depth of water was 34½ feet and the bottom width of the channel 98 feet. The summit level was supplied with water through a feeder from a reservoir formed by a dam at Alhajuela on the Chagres River, about 11 miles above Gamboa. Four smaller locks were located on the Pacific side, the two middle ones at Pedro Miguel being combined in one flight, and the others being located at Paraiso and Miraflores. The locks were in duplicate, each with usable dimensions of 738 feet in length and 82 feet in width. It was contemplated at the proper time to consider the adoption of the alternative plan of making the summit cut deeper and omitting the upper

level. Between Bohio and the sea two diversion channels were provided to take care of floods from the rivers that would otherwise enter the canal.

Progress having practically ceased at Panama under the new French Canal Company, to meet the growing sentiment in favor of more satisfactory interoceanic communication, on March 3, 1899, the Congress of the United States passed an act authorizing the President to make full and complete investigations of the Isthmus of Panama with a view to the construction of a canal to connect the Atlantic and Pacific oceans.

This marks the opening of the last chapter in the construction of the Panama Canal, the end of which is now, by the early completion of the canal, in sight. The commission appointed in accordance with the above act was called upon to investigate particularly the Nicaragua and the Panama routes and to report which was the more practicable and feasible, and the cost. In November, 1901, it reported in favor of the Nicaragua route, considering the demands of the New Panama Canal Company for its franchise and property more than balanced the other advantages of the Panama route. The price fixed by the Panama Canal Company was $109,000,000. By subsequent negotiations the French company was induced to reduce its price to $40,000,000, and the commission in January, 1902, submitted a supplemental report in favor of the Panama route. The plan recommended by the commission was for a lock canal, with a sea-level channel from Colon to Bohio. A dam at Bohio, across the Chagres Valley, was to create a summit level 82 to 90 feet above the sea to be reached by two locks. The lake extended to Pedro Miguel, where two locks lowered the level to 28 feet above sea level. At Miraflores sea level was reached through a third lock. The bottom width was to be 150 feet, except in Panama Bay, where it was 200 feet, and in Limon Bay, 500 feet, with turning basins 800 feet wide. The minimum depth was 35 feet. The locks were to be 740 feet long and 84 feet wide.

In accordance with this report, act of Congress of June 28, 1902, known since as the "Spooner Act," authorized the President of the United States to proceed with the construction of a canal by the Panama route, provided arrangements could be made with the New Panama Canal Company for the purchase of its property and fran-

chise for not exceeding $40,000,000, and provided arrangements could be made with the Republic of Colombia for the control of the necessary right of way. In the event of failure of these negotiations the Nicaragua route was to be adopted. The law provided that the canal should be "of sufficient capacity and depth as shall afford convenient passage for vessels of the largest tonnage and greatest draft now in use and such as may be reasonably anticipated." Appropriations were made to carry out the provisions of the act, and a bond issue of $130,000,000 was authorized. The bond issue was based on the estimates accompanying the report of the commission of 1901 recommending a lock canal.

Satisfactory arrangements were completed for the purchase of the French company's rights, etc., for $40,000,000 and negotiations with the Republic of Colombia were carried on to secure other necessary rights and privileges not held by the French company. After a long delay, a satisfactory treaty was formulated, which was rejected by Colombia in 1903.

The province of Panama, an integral part of Colombia, thereupon seceded and organized an independent republic. This resulted in the negotiation of a satisfactory treaty with the new Republic of Panama, including the payment, under certain terms, of $10,000,000 by the United States to the Republic of Panama. Under this treaty the United States guaranteed the independence of the Republic of Panama and secured absolute control over what is now called the Canal Zone, a strip of land about 10 miles in width, with the canal through the center, and 45 miles in length from sea to sea, with an area of about 448 square miles. The United States also has jurisdiction over the adjacent water for 3 miles from shore. To all intents and purposes it is a perpetual lease from the Republic of Panama to the United States of all governmental rights and privileges in this territory, and yet, strictly speaking, it is not United States soil, for residents therein acquire no rights of United States citizenship and have no voice in United States elections, while citizens of the Republic of Panama residing in the Canal Zone are protected in their electoral rights and are accustomed to go to Panama and Colon to vote in the Panamanian elections. The cities of Panama and Colon and a certain water frontage adjacent thereto, while within the 5-mile limit from the center line of the canal, which bounds the Canal Zone, are excluded

from the Canal Zone and are considered Panamanian territory, although the United States has, under the treaty with the Republic of Panama, the right to regulate sanitary matters therein, and, if necessary to preserve order, to enter those cities with armed forces and take possession of them.

There is no doubt that the United States received ample consideration for the $40,000,000 paid to the New French Canal Company, viz:

Excavation by the French useful in the present project, estimated at not far from 40,000,000 cubic yards, has been conservatively valued at $27,500,000.

The Panama Railroad, with its franchise and all rights, etc., which had been purchased for over $18,000,000 by the old French company, was valued at $7,000,000, the par value of outstanding stock.

About 43,000 acres of land went with the Panama Railroad property and 33,000 acres were acquired from the French Canal Company, a total of 76,000 acres.

The maps, drawings, and all other technical data that were taken over from the French company were valued at $2,000,000, and buildings, machinery, etc., at $3,500,000; the whole totaling $40,000,000.

Up to the present time French machinery, conservatively appraised at $1,000,000, has been used, and the net value of French buildings which are in use, not including cost of repairs, is not far from $2,000,000.

The principal point of excellence in regard to this French machinery, which has weathered so well on the Isthmus for the past twenty-five years, is the quality of material and workmanship. In design, speed, and size of units it is far behind the present standards. However, it was the best of its kind in that day.

In consideration of the $10,000,000 paid to the Government of Panama for the rights conveyed, there was turned over to the United States, in addition, all public lands in the Canal Zone, amounting to about 120,000 acres. This makes the United States Government the direct owner of 70 per cent of the land in the Canal Zone, the remaining 30 per cent being held by private owners, mostly citizens of the Republic of Panama. The United States exercises governmental rights over all.

The act of Congress of 1902 placed entire jurisdiction in regard to the construction of the canal in the hands of the President of the

United States, the particular functions in regard thereto being exercised by a commission composed of seven members appointed in accordance with the act of Congress, presided over by one member as chairman. For convenience in administration the canal operations have been placed under the Secretary of War.

The formal transfer of the property of the French Canal Company to the United States took place on May 4, 1904, and the first two and one-half years thereafter, or until January, 1907, were devoted largely to the work of preparation, consisting of building up a suitable organization; procuring the necessary plant and equipment; combating insanitary conditions, eliminating yellow fever, and reducing malaria; reconstructing and double-tracking the Panama Railroad; improving terminal facilities, and making provision for adequate and efficient transportation to the Isthmus from the United States, a large item in itself; the design and building of suitable quarters for the army of nearly 5,000 American employees and over 25,000 laborers; introducing a stable form of civil government and administration, including courts, schools, police, fire department, etc.—in other words, doing everything necessary to transform the jungle, infested with mosquitoes and various low forms of animal and vegetable life, injurious to health, into a comparatively healthful country with all the advantages and conveniences and equivalent conditions of life as regards comfort, food, and quarters, as are enjoyed by the average citizen in the United States. All of this took time and a great deal of money, but it has resulted in advancing the condition and developing the territory in question, which was practically in the same state that it was in the sixteenth century, to the plane of twentieth century civilization—and all in two and one-half years.

Attention was early drawn to the insanitary condition of the cities of Panama and Colon, and it was soon perceived that if a pestilence should obtain a foothold in those cities it would seriously affect canal work. To eliminate this danger, Panama has been provided with substantial brick pavements, has been well sewered and furnished with a supply of wholesome drinking water. The city of Colon has been transformed from a swamp into a town likewise comparable with a city of the same size in the United States, so far as pavements, water supply, and sewers are concerned. This work has cost about $2,275,000, and at the last session of Congress

$800,000 more was specially appropriated to carry on the additional work which has become necessary on account of the growth of the suburbs of Panama and the necessity of extending the building limits of the city of Colon, due to the large increase in population. Under the terms of the treaty the cost of all of this work is an obligation which the Republic of Panama assumes and will repay to the United States with interest, through water rates which are collected directly by the United States and turned into the Treasury. Payments at present are being made at the rate of $136,000 per annum. The sanitary conditions in these two cities and the advantages of good pavements are an object lesson to all travelers from South and Central America which is bearing its results, and the shipments of paving brick from the United States to South America have increased as a result of this work.

The situation in the city of Colon as regards ownership of land is peculiar. It is practically all owned by the Panama Railroad under its original franchise, under the terms of which ownership reverted to the United States of Colombia at the expiration of its franchise. This land, therefore, can not be sold by the Panama Railroad. By the treaty of 1904 the Republic of Panama, as the successor of the Republic of Colombia, transferred to the United States all of its rights accruing at the expiration of this franchise. Meanwhile the United States had purchased the Panama Railroad from the French Company. Therefore the present condition is that the United States, through the Panama Railroad, is the owner of land in Colon, but can not, under the railroad's franchise, sell it. This land, moreover, which it owns, will, through the expiration of the franchise of the Panama Railroad in 1966, be turned over to the United States, and the condition will arise of one government owning land in a foreign country. The land is under the jurisdiction and laws of the Republic of Panama, as it is not within the limits of the Canal Zone. This situation, however, can and will be easily straightened out, and ultimately some disposition will be made of the property, which is considered to be, even at the present time, very valuable. This land is now leased by the Panama Railroad in lots to the highest bidder for a term of years. Rents are high and lessees expect to get returns of 50 per cent and

upward per annum. The Panama Railroad, through its corporate powers, has proved a very useful and necessary adjunct in the construction of the canal, and it would disarrange and be a great hindrance to the work to have its charter canceled before the completion of the canal.

During the period of preparation, work was not neglected on the canal excavation, and every effort was made to make the "dirt fly." At first, the only tools available were some old French excavators, locomotives, dump cars, and drills. Modern American equipment, consisting of dredges, steam shovels, cars, locomotives, etc., was put into service as fast as it could be purchased and hurried down to the Isthmus. During 1904, 1905, and 1906 material was excavated as follows:

	Cubic yards.
1904	243,472
1905	1,799,227
1906	4,948,497
Total	6,991,196

Meanwhile the type of canal came up again, and in consideration of the international importance of the canal President Roosevelt appointed a Board of Consulting Engineers consisting of 13 members, including representatives of 5 European countries, and 8 Americans, which met in Washington in June, 1905. Eight members of this board, including the five foreign engineers, recommended that a sea-level plan be adopted. Five American engineers recommended a lock canal. Of the eight in favor of the sea-level canal, one, an American, stated that if it were a commercial enterprise for a private company he should vote for a lock canal. One of the foreign engineers qualified his vote in favor of the sea-level canal, in the report, by stating that he considered a high-level lock canal practicable, but that considerations of cost and time of completion with such a canal should not be taken as the governing considerations. This, notwithstanding the instructions to the board from the President that in addition to reporting on a feasible plan, the prime consideration was the shortest time of completion and a minimum amount of work; that is, minimum cost. In strict accordance with these instructions the vote would have been 7 for a lock canal and 6 for a sea-level canal. The members of the Isthmian Canal Com-

mission, with one exception, recommended to the President the adoption of the 85-foot level lock canal recommended by the minority of the Board of Consulting Engineers and indorsed by the then Chief Engineer of the Commission, for the following reasons:

1. Its first cost will be much less—nearly $200,000,000.
2. It will be completed much more quickly—fully six years.
3. Its cost of operation and maintenance, including fixed charges, will be less by several million dollars per annum.
4. It provides greater safety for ships and less danger of interruption to traffic, by reason of its wider, straighter, and deeper channel.
5. It provides quicker passage for large ships and large traffic.

In his message to Congress of February 19, 1906, forwarding the board's report the President stated:

"The law now on our statute books seems to contemplate a lock canal. In my judgment a lock canal as herein recommended is advisable."

On June 29, 1906, the construction of a lock type of canal was authorized by Congress in accordance with the general plans of the so-called minority of the Board of Consulting Engineers and the work has since been carried on along these lines. During the three years which have elapsed, nothing has occurred on the work which has occasioned uneasiness on the part of those most intimately and responsibly concerned with the execution of the work, or which has caused them to doubt either the wisdom of this choice or the ultimate success of the undertaking; and at this late date with the lock canal far advanced a discussion on the relative merits of a lock versus sea-level canal is about as much out of date as a last year's spring bonnet, and is as interesting and illuminating a subject of conversation for those who are well informed in regard to canal work as the weather in Labrador in December. There is no engineering, commercial, or military reason for considering a sea-level plan at this stage of the work; and those who desire to discuss a dead issue like this, even from an academic standpoint, should first be required to give a better reason for making a change than one that might suffice for the selection of a suit of clothes of a particular cut or fabric, but which is not sufficient for the people of the United States who have already spent over $20,000,000 toward the construction of locks, which would be wasted were a change to a sea-level canal now made. The whole

matter may be summed up in the quotation from President Roosevelt's message to Congress last winter:

"That hereafter attack on this type, the lock type, is in reality merely attack upon the policy of building any canal at all."

The 85-foot lock canal which is being built consists of a sea-level entrance channel 7 miles long and 500 feet wide on the Atlantic side to the foot of Gatun locks. On the Pacific side there is a corresponding sea-level channel to Miraflores nearly 8 miles long. For 15 of the 50 miles the canal will be at sea level. At Gatun the 85-foot lake level is obtained by a great dam. The lake is confined on the Pacific side by a smaller dam between the hills at Pedro Miguel, 32 miles away. These two dams make a great lake 85 feet above sea level, with an area of 164 square miles. Ships pass from the sea level to the lake level, and vice versa, at Gatun by a series of adjoining locks, "in flight" as it is called, three in all, each with a lift of 28⅓ feet. The locks are in duplicate. On the Pacific side at Pedro Miguel, instead of dropping down at once to the sea level, there is one lift, with duplicate locks, by which vessels are lowered to a small lake called Miraflores Lake, which is 55 feet above the mean level of the Pacific Ocean. One mile from Pedro Miguel, through Miraflores Lake, are the Miraflores locks, where by two lifts, with locks in duplicate, vessels reach sea level on the Pacific side.

From deep water to deep water the distance is about 50 miles and it is expected that a vessel can easily make the transit within less than twelve hours.

The Atlantic channel has a depth of 41 feet below mean sea level, and the average range of tides is not over a foot. On the Pacific side the tides have a range sometimes as much as 20 or 22 feet, and in order to provide ample depth the channel is to be dredged to a depth of 45 feet below mean sea level. The elevation of both oceans is the same at half tide. At extreme high tide, therefore, the Pacific Ocean is 10 feet above the Atlantic and at low tide 10 feet below.

Gatun Lake will be a body of fresh water, and its level will be maintained at practically a constant height by the rivers which flow into it. The principal river is the Chagres, which rises in the hills to the east of the canal. It catches all the rain which runs off of an area of about 1,200 square miles. A second large river is the Trinidad, which will flow into the lake from the west. The Trinidad River has

a drainage area of 340 square miles. Its headwaters extend within sight of the Pacific Ocean.

Elaborate investigations and observations have shown that the annual rainfall is entirely sufficient to keep the lake amply supplied. The rainfall averages 100 inches per annum, varying from 120 to 140 inches on the Atlantic side to 60 to 80 inches on the Pacific. The rainy season extends from April to December, during which time practically all of the rain falls. From January to April there is little or no rain.

Evaporation will be one source of loss of water from Gatun Lake and averages not far from one-seventh of an inch per day, or 50 inches per annum. Water will be required to pass vessels through the locks and will also be used, so far as available, in generating electric current for use in lighting, in furnishing power for canal operations, and for the future operation of the Panama Railroad. This will be accomplished by installing a hydro-electric plant at Gatun, and making available the energy due to the 85 feet head of water. Any surplus water will be disposed of by allowing it to flow over a spillway, which is merely a large waste-weir.

In steaming through Gatun Lake, from Gatun to Pedro Miguel, a distance of 32 miles, vessels will traverse a channel varying from 1,000 to 300 feet in width and from 75 to 45 feet in depth. For the first 8 miles no digging is necessary, the natural elevation of the ground being so low that it is only necessary to clear the ground of trees and underbrush.

At Bohio there are a few high points to level off, and some of this work is being done by "task work" with pick and shovel. The thousand-foot channel continues for 15 miles from Gatun, enabling vessels to maintain full speed.

Toward Tabernilla the banks of the Chagres River and the adjacent land to be used as the canal channel rise above elevation +40. The ground will be excavated to that elevation in order that the depth of water in the entire channel may not be less than 45 feet. From Tabernilla the channel continues 800 feet wide for 4 miles, and thence to Bas Obispo 500 feet wide for a distance of about 4 miles. Many million cubic yards were excavated by the French between Tabernilla and Bas Obispo which will be useful in the present project. Between the Atlantic Ocean and Tabernilla none of the

French excavation enters into or is useful to the present plan except for construction purposes.

Between Tabernilla and Bas Obispo the Chagres River, pursuing its winding course, crosses the line of the canal not less than 15 times. At Bas Obispo the Chagres River turns abruptly to the northeast and the canal enters the 9-mile cut through the Cordilleras, which form the backbone of the continent, where the greatest amount of excavation is being done, and which is generally known as "Culebra cut." This cut ends at the Pedro Miguel locks. The minimum bottom width of the canal prism is 300 feet and the depth of water will be 45 feet. In general, the line follows the old French canal in this section, which took its course up the valley of the Obispo River to the deepest part of the cut at Gold Hill, whence it entered and descended the Pacific slope along the line of the Rio Grande River.

At Gold Hill, near Culebra, the highest point on the center line of the canal, the elevation was 333 feet on the axis of the French canal, 312 feet on the present axis (80 feet to the west), and 303 feet at the low point of the saddle or depression between Gold Hill on the east and Contractor's Hill on the west. The French began cutting through Gold Hill on the east side of the canal at elevation 534, which is the highest elevation where work was carried on. In this section of nearly 9 miles the French removed with their comparatively small excavating machines and by pick and shovel over 24,000,000 yards of material, most of which is useful in the present plan, including a large amount of soft overlying earth and clay. The present plans call for the removal of about 89,600,000 cubic yards between Gatun and Pedro Miguel, of which 77,700,000 is in "Culebra cut," in addition to what the French took out; 35,700,000 yards had been removed from Culebra cut to August 1, 1909.

The end of Gatun Lake is reached at Pedro Miguel locks. Miraflores Lake is a small body of water of less than 2 square miles in area, which is kept full by water entering with vessels through the Pedro Miguel locks, and also from water from the Rio Grande and Cocoli rivers, which flow into it. A spillway is located to the east of the Miraflores locks to dispose of any overflow. After passing through Miraflores locks vessels have a straight channel 8 miles in length to the Pacific.

It is thus seen that the present plan provides broad, deep channels, with a minimum of curves and bends.

The average width of channel will be about 650 feet, about three times as wide as the average width of the sea-level canal as proposed and estimated on, at much greater cost. The minimum bottom width of the channel will be 300 feet through Culebra cut. The width for the sea-level canal in earth was intended to be only 150 feet with sloping sides, and 200 feet in rock through Culebra cut with vertical sides.

The principal advantages derived from the raised lake level formed by dams at Gatun and Pedro Miguel are:

(1) The amount of excavation is enormously reduced, and the cost and time correspondingly diminished, even when the cost of the dams and locks is considered.

(2) Another most important advantage, and in fact a necessity, is the ease with which the rainy season floods of the Chagres and other rivers will be controlled by Gatun Lake. The dams at Gatun and Pedro Miguel will raise the water sufficiently to cause the lake to extend 4 or 5 miles above Gamboa. The Chagres River in the dry season is a peaceful, insignificant stream, at Gamboa not over 300 feet wide, and 2 or 3 feet deep. As a result of the torrential rainfall and the precipitous nature of the watershed, especially in its upper reaches, it is subject to large and rapid variations in height. At Gamboa the maximum rise has been nearly 40 feet within a period of twenty-four hours, which transforms it into a rapid, riotous stream, and it many times overflows its banks and floods the surrounding country. The maximum discharge recorded is considerably more than 100 times as great as the low-water discharge during the dry season. Gatun Lake will curb the floods of the Chagres, and the severest storm will have no more effect than to raise its level a foot or two.

(3) A third advantage is that a large portion of the silt and gravel which would be otherwise carried down into the canal past Gamboa will be deposited, owing to the slackening of the current, above Gamboa, outside of the canal prism.

By thus damming the outlet of the Chagres, the formation of Gatun Lake will provide the simplest, most practicable, and most desirable solution of the most perplexing engineering problem arising in connection with the construction of the canal.

The Atlantic and Pacific entrances of the canal will be fully protected, on the Atlantic side by a stone breakwater 2 miles long in 44 feet of water at the outer end, extending northeastward from Toro Point Light-House. The entrance channel will be likewise protected on the east side by a similar breakwater about three-quarters of a mile in length. The construction of these breakwaters has not yet been undertaken, as it was not fully decided until last February that they would be necessary. During the winter months occasional storms from the north occur, locally termed "northers," of such violence that all vessels have to leave Colon harbor, which is at present unprotected. Such storms, in the absence of breakwaters, would render entrance to and egress from the canal unsafe. The breakwaters will also provide a safe harbor and protect the channel from shoaling.

The Pacific side is never visited with any storms of sufficient duration and violence to require any special protection. The water is quite shallow for some distance from the shore, and the set of the current from the northeast is at right angles to the entrance channel and deeply laden with silt; the tendency is for large quantities to settle in that part of the canal channel, causing rapid deterioration of same. To prevent this shoaling, as well as to dispose of a large amount of spoil from the Culebra cut, a dike or breakwater is in the process of construction from the mainland at Balboa to Naos Island, one of a group of small islands about 4 miles from shore. This dike east of the canal is more than half completed, and the benefits arising from it in preventing the shoaling of the canal channel are very marked, and when it is entirely completed the shoaling resulting from these cross currents will be eliminated.

The present roadbed of the Panama Railroad will be submerged for many miles by Gatun Lake. In order to provide communication by rail across the Isthmus after the completion of the canal, and enable the railroad company while it exists as a corporation to comply with the requirements of its franchise, the railroad is being practically entirely rebuilt on a new location on higher ground to the east of the canal. The cities of Colon and Panama being both on that side, the railroad will therefore not cross the canal. From Gatun the railroad makes a wide circuit around Gatun Lake, crossing the Chagres River on a steel bridge, over a quarter of a mile in length, at Gamboa, and passes through Culebra cut on a broad bench or berm 10 feet above

the level of the lake. The reconstruction of the Panama Railroad is being paid from a special appropriation for the purpose. It is an undetermined matter how much through business will fall to the Panama Railroad after the completion of the canal. The local business between the cities of Panama and Colon and intermediate points should be sufficient in itself, however, for the road to operate without loss. It is expected in time that it will be operated by electricity furnished from the hydro-electric plant at Gatun spillway.

Such is a general description of the plans recommended by the minority of the Board of Consulting Engineers in 1906, and these plans have been since followed throughout with such approved modifications in details as have been considered desirable to obtain the best results with the least expenditure of money. Among the changes are the following: The size and capacity of the canal have been increased in view of the large increase in size of war vessels which has recently taken place. This applies to the change in width and length of locks from 95 by 900 to 110 by 1,000 feet; and the width of channel from 200 to 300 feet through a large portion of Culebra cut. The location of the breakwaters on the Atlantic side has been changed. Likewise, from considerations of military defense and lessened cost, the Pacific locks have been moved inward from Balboa to Miraflores. This latter change was suggested in the report of the original board as being among those which should receive consideration. Every step in the construction has been carefully watched and studied not only by those on the ground who are responsible for its execution, but in addition thereto committees of the most distinguished engineers in the country have at various times made independent investigations on the ground and reports on particular points connected with the construction of locks and dams. The reports of these independent consulting engineers, in expressing the unanimous opinions of their members, have indorsed in every respect the present plans.

The present Isthmian Canal Commission assumed office in April, 1907, and has since been located on the Isthmus in direct contact with the work, taking it up where the labors of Mr. John F. Stevens, as Chairman and Chief Engineer, left off.

As at present constituted it numbers five engineers, with two other members acting as heads of the departments of Civil Administration and Sanitation, respectively.

The operation of the Panama Railroad Company is under the immediate charge of a General Manager. All of the work of the Commission and the Panama Railroad Company is under the complete and direct control of the Chairman and Chief Engineer of the Commission, which has contributed very largely to the efficiency and the smooth, steady progress of the work.

The plan of organization of the Engineering Department divides all construction work into three geographical districts, each under a Division Engineer with full control over and responsibility for all engineering work in his district. These divisions are:

(1) The Atlantic division, extending from deep water to Gatun Lake, including the Gatun locks and dam.

(2) The Central division, extending from Gatun to Pedro Miguel.

(3) The Pacific division, extending from Pedro Miguel to deep water in the Pacific Ocean.

In general, the work may be divided into three classes:

(1) Wet excavation, viz, excavation performed by dredges. This amounts to about 12 per cent of the total work.

(2) Dry excavation. This includes all material (rock and earth) removed by steam shovels and other power excavators, or by pick and shovel. This comprises 49 per cent of the work.

(3) The third class of work covers the construction of locks, dams, and spillways. The dams make the lakes, the locks enable vessels to pass from the sea level to the lake level, or vice versa, and the spillways take care of the overflow from the lakes. These comprise 39 per cent of canal construction work.

A brief description of the different classes of work will be given:

(1) Wet or dredging excavation amounts to about 73,000,000 cubic yards. One million yards is contained in a cube 300 feet on each side; 73,000,000 would be equivalent to a cube measuring about a quarter of a mile on one side. It consists of soft silt, earth, clay, coral, and hard rock. From 12 to 14 dredges are kept at work, and their monthly output is not far from 1,300,000 cubic yards. They include two new seagoing suction dredges, the *Culebra* and *Caribbean* of a type common in the United States, that draw the material up into bins in their own hulls by centrifugal pumps. When these bins are full, they steam to the dumping grounds, empty by opening bottom gates, and return for another load. These dredges work night

and day, stopping only for fuel and repairs. Owing to their method of operation and the material they handle, they have the largest output at the least unit cost of any of the dredges. Upon the completion of the canal it is expected that these dredges will be kept on the Isthmus for use on any small amounts of dredging that might be required for maintenance work.

Seven old French ladder dredges of Scotch and Belgian make which have been rebuilt are giving very satisfactory service in spite of the small size of their buckets (one-half yard capacity each) compared with the size of dredges now built. The output of these is hardly half that of the seagoing suction dredges. These ladder dredges discharge the spoil by chutes into self-propelling French barges called "clapets," and American scows which are towed to the dumping ground by tugs. Thirteen French clapets and a half dozen barges serve the stationary dredges with the aid of 4 tugs. There are also 3 dipper dredges and several clam-shell dredges with 5-yard buckets, and 1 Lobnitz rock-breaker consisting of a large ram mounted on a barge of suitable size, which is used to fracture and break up the rock on the bottom, which can then be easily removed by dipper or clam-shell dredges. Three sizes of rams are used, weighing from 10 to 19 tons and from 30 to 50 feet in length. When raised from 4 to 10 feet above the water and then dropped, they break the rock to a depth of 3 feet. Experience with this rock breaker has not demonstrated its superiority or economy as compared with subaqueous blasting.

The construction of the Gatun dam and locks also requires pipeline suction dredges and a large transportation equipment.

To rebuild, operate, and repair the fleet of vessels required to carry on dredging and transportation operations, the old French shops at Cristobal and Balboa have been remodeled, enlarged, and supplied with such new and improved equipment as has been found necessary to perform the required work. To make under-water repairs and to scrape and paint the exterior of the hulls, the French had an old dry dock cut out of the solid rock at their shops at Cristobal. This dock has been rebuilt and enlarged and lined with concrete and now is capable of docking a vessel 298 feet long, 50 feet beam, and 15 feet draft. Spanning the dock is a Gantry or movable overhead crane. Several hundred men are employed at these shops.

Vegetable and animal life in these tropical waters are particularly active in attacking the hulls of vessels, making it necessary to dock and paint them at frequent intervals.

On the Pacific side, the Balboa shops perform the same offices for the Pacific fleet at work on that part of the channel. There is no dry dock on that side, and a marine railway is used for the small vessels. Advantage is also taken of the large range of the tides, which permits a vessel to be placed on a "gridiron" at Balboa at high tide; the tide receding lifts the vessel out of the water and permits any work to proceed which can be accomplished before the next high tide. For vessels like the seagoing dredge *Culebra*, it has been customary to run them broadside on the smooth sandy beach at Naos Island at high tide, where they can be painted and repaired as the tide lowers.

In the Pacific division, from the foot of Miraflores Lake southward about 2 miles, there are about 11,300,000 cubic yards of material, mostly dark loam, overlying 1,600,000 cubic yards of hard rock, which will have to be removed. Successive attempts with dredges have shown that it is not practicable to handle the material overlying the hard rock by this method with as great economy as by adopting the hydraulic method which has been developed and used with such success in the western States. It is proposed by this plan after throwing a dam across the channel, 2 miles below the locks, to attack the material with large jets of water under sufficient pressure to break it up and carry it to pools or sumps, whence the combined water and material will be removed by powerful centrifugal pumps having a capacity of 30,000 gallons per minute.

(2) *Dry excavation.*—To the casual visitor to the Isthmus, operations in connection with dry excavation are the most spectacular and interesting of any work in progress. The methods are somewhat similar to those in use in the United States, but nowhere else in the world have excavating operations been carried on on such a large scale and in the precise manner followed on the Isthmus. Some of the machines used have been developed as a result of the experience gained on the work. The construction of the locks involves in itself a large amount of excavation—about 10,000,000 cubic yards. This may be considered a part of the lock construction, and dry excavation under this head will be limited to the prism proper. About

93,000,000 cubic yards are involved, equivalent to a cube measuring about 1,380 feet, or over quarter of a mile on a side, or sufficient to cover 90 square miles with a layer 1 foot thick. Forty-four million yards, or about 47 per cent of this work, had been accomplished to August 1, 1909. Dry excavation is carried on almost exclusively with steam shovels, and at the present time about all of the soft overlying material has been removed, and the rock remaining requires blasting before it can be loaded on the cars. The present method of work is the result of three years' experience. From 50 to 60 steam shovels are being worked on the prism excavation with dippers varying in capacity from 2½ to 5 cubic yards. The other shovels are engaged on the lock and dam excavation at the rock quarries and on the Panama Railroad. The work is divided up into sections, the work in each section being under a superintendent who is responsible for all the work therein, and who is held strictly accountable for the daily output in his section.

The work accomplished in Culebra cut by the French, in general, was to make a deep, narrow cut, and in 1904 the summit near Gold Hill was 193 feet above sea level, having been reduced 140 feet by the French, and an additional cut of 153 feet was necessary. The first work undertaken by the Americans was to widen the cut to full dimensions before going any deeper. The work accomplished to date has consisted of this widening, and in addition the old summit level at Gold Hill has been lowered to elevation +120. At the ends of Culebra cut (Bas Obispo and Pedro Miguel) the excavation has been practically completed to the full depth—elevation +40. At the present summit level at Empire the cut will be made 85 feet deeper. For the purpose of drainage, the bottom slopes uniformly north and south from the summit, 23 feet per mile to the north and 36 feet per mile to the south. Loaded trains pass down grade each way from the summit on their way to the dumps. The present line of the Culebra cut traverses what was originally the valleys of the Obispo, Rio Grande, and other rivers which drain the surrounding country. To prevent the flooding of the cut and interruptions to the work, as well as to reduce the wash of the banks, the canal channel has been paralleled on each side from Gold Hill north to Bas Obispo, a distance of about 5 miles, by smaller artificial channels or canals,

called technically "diversions," which turn aside and convey into the Chagres, at Gamboa, on the east side of the canal, and at Matachin, on the west side, the storm waters that would otherwise flood Culebra cut north of the continental divide. The construction of these diversion channels would usually be considered work of more than ordinary size. The Obispo diversion has a bottom width of 50 feet, is 5½ miles long, and extends from Gold Hill on the south to the Chagres River on the north. It was completed two months ago, and involved the removal of over 1,000,000 cubic yards of material. The deepest cut was about 95 feet; 1½ miles of earth dikes were constructed. The diversion has been designed to carry a maximum flow of 6,000 cubic feet per second. On the west side of the canal there is a similar smaller diversion, from Empire north to beyond Bas Obispo, in which the storm waters flow partly through a natural channel, partly through an artificial channel built by the Americans, and also through an old French tunnel and channel at Bas Obispo. To the south of Gold Hill the drainage from the west, including the overflow of the Rio Grande reservoir, is carried off in the bed of the Rio Grande River and an old French diversion channel. The remainder flows from the east into the cut and will be permitted to flow through the Pedro Miguel locks as soon as the floors are laid; meanwhile it runs through an old culvert under the abandoned railroad to the west of the locks, which has been lowered sufficiently to effect this. At the north end of the cut the low-water level of the Chagres River is at elevation 43 and of the finished canal 3 feet lower, viz +40. The Chagres River has been shut off by a dike with drain pipes at different elevations, which will free the cut from water by gravity in case the dike is overflowed. Under ordinary working conditions three large pumps will remove the water.

At various points along the banks of the Culebra cut the excessive rainfall and the character and slope of the material results in the movement of soft material on layers of slippery clay. These moving masses of material are called "slides." All estimates and calculations for work have provided for the removal of a considerable amount of material which thus slips into the prism. The best known slide is the Cucaracha slide, just south of Gold Hill, which has been a source of annoyance since the days of the French, in 1884.