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There was the same number of Commissioners, but the first three were named an Executive Committee which virtually should exercise the powers of the entire body. Thus power was taken from seven and concentrated in three members. Mr. Shonts was to be in charge of the Washington office and Messrs. Wallace and Magoon on the Isthmus.

Again following Mr. Wallace's suggestion, the directory of the Panama Railroad was reorganized, the United States on April 15, 1905, for the first time electing the members. Mr. Shonts was made president and Mr. Wallace, vice-president and general manager. This would further concentrate control in the Chief Engineer over a vital factor in canal construction.

These changes and other matters kept Mr. Wallace in Washington from March 29th to May 24th, about two months. The employees in the Canal Zone naturally caught something of the spirit of unrest which attended the reorganization of the Commission, and, of course, the hostile press was playing up everything that could embarrass the administration and damn the project. Then the yellow-fever epidemic broke out in April, 1905, to add a terrible phase to life on the Isthmus.

Having secured every change he desired, Mr. Wallace left Washington with expressions of cordial appreciation to the President and his Secretary. He arrived at Colon on June 2d, and the White House believed that a crisis in the career of the project had

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been passed successfully. They looked forward to smooth sailing with every confidence.

Their surprise and chagrin, therefore, was immeasurable when Mr. Wallace cabled Secretary Taft, on June 8th, asking that he be recalled to Washington for a conference. He intimated that the conference might result in his resignation as Chief Engineer. After a disheartened interview with the President, Secretary Taft cabled him to return. At the same time he cabled Gov. Magoon for a confidential view of Mr. Wallace's conduct. Gov. Magoon expressed the opinion that Mr. Wallace was quitting for a better salary, the yellow-fever epidemic was raging, the wife of Mr. Wallace's secretary had died from the disease, and Mr. Wallace believed that he had had an attack of it.

Without intimating that he was leaving for good, Mr. Wallace quietly packed up or sold off his household furniture and sailed from Colon on June 16th. The employees scented some important movements and the subordinate officials felt restrained from decisive action, although Mr. Wallace left authority to that effect with the engineer next in rank to him.

Gov. Magoon cabled that the working force, already shaken by the yellow-fever epidemic, were further demoralized by the belief that the Chief Engineer was seeking a softer berth. Every ship that left Panama at that time was carrying capacity passenger lists, and only the limited number of vessels prevented a wholesale exodus. It was truly a time that tried men's souls.

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President Roosevelt and Secretary Taft then decided upon a drastic course toward Mr. Wallace, as a means of reviving the morale of the canal workers, and also of bringing the American people sharply to a realization that the canal project was in peril, through a display of weakness in the face of danger, that would make our experiment in Panama an international disgrace.

Secretary Taft, with William Nelson Cromwell, met Mr. Wallace at the Manhattan Hotel in New York on June 25th. Secretary Taft listened to his reason for resigning, which in the main was that he had under consideration a position that would carry with it a remuneration of approximately \$65,000 a year. One of the peculiar conditions of the new employment was that under no circumstances was he to return to the Isthmus, but that he would gladly remain a member of the Commission resident in the United States. He made some side criticisms to the effect that Col. Gorgas was incapable of handling the yellow-fever epidemic, that government red tape was distracting, and conditions generally were such as to make the new employment look attractive.

Secretary Taft did not conceal his disappointment in Mr. Wallace's course. He began by reviewing how the government had taken him from a position paying \$15,000 a year to make him Chief Engineer of the canal at \$25,000 a year; how that the formidable obstacles to be met, the supreme necessity of a canal to the nation, made it a patriotic work for any Amer-

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ican and an honor to be placed at the head of the greatest enterprise of the age.

“For mere lucre,” Mr. Taft continued, “you change your position overnight without thought of the embarrassing position in which you place your government by this action.”

Secretary Taft then reviewed how the Commission had just been reorganized to meet Mr. Wallace's wishes, and every change had been approved by the Chief Engineer. He closed by demanding the immediate resignation of Mr. Wallace. This came the next day, and was made public on June 28th, with Secretary Taft's hot rebuke, which, in the Canal Zone, had a most salutary effect. It put an entirely new complexion on their work to be told that the nation expected every man to do his duty, that they were not down there for the money they could make, nor were they expected to leave because of the hardships they would meet, but that the object of their exile was to give the nation something vital to its welfare. The desertions began to diminish at once, and the announcement on June 30th, that John F. Stevens, a Hill man, had been appointed Chief Engineer, further strengthened the morale of the canal organization.

Theodore Roosevelt never appeared to better advantage as a supremely able executive than during this crisis in the history of the canal. Before his enemies, and the canal's enemies, could shout their glee at the demoralization of the enterprise, he had closed the breach with the selection of another great Chief En-

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gineer. Even if the situation had been brought about by interests with sinister designs, it could not have been met with a more magnificent courage, and the canal project was strengthened by the ordeal.

CHAPTER XII

THE CANAL UNDER STEVENS

ANOTHER notable figure in the railroad world had been chosen Chief Engineer of the Panama Canal. John F. Stevens in 1903 was general manager of the Great Northern Railroad Company, and of his selection as Chief Engineer, James J. Hill said that if the whole country had been ransacked no better man could be found.

Mr. Stevens was about to start to the Philippine Islands to superintend the construction of government railroads, when drafted for the canal. It is not possible to estimate the mischief that might have resulted if the selection of a successor to Mr. Wallace had been long delayed. His salary was to be \$30,000 annually, or \$5,000 more than that paid to Mr. Wallace. He was facing a situation in Panama that justified the figure.

The long continued "knocking" of the canal project was having its effect. Not only were the men on the ground difficult to retain, but new ones would not come unless for exceptional considerations. The yellow-fever epidemic was still uncontrolled. An invoice of the situation as left by Mr. Wallace showed that considerable pioneer work had been done, but the housing, feeding, and general preparations for the comfort of employees were unsolved problems.

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Mr. Stevens arrived at Colon on July 27, 1905. As a railroad man his eye first was attracted by the congestion of freight on the wharves and the self-evident fact that the Panama Railroad was in a near state of collapse. Freight was piled up in the streets in prodigious quantities and was moving over the railroad at a snail's pace. His first report hit off the situation in one sarcastic sentence:

"About the only claim for good work heard made was that there had been no collisions for some time. A collision has its good points as well as its bad ones—it indicates there is something moving on the railroad."

As for the railroad tracks in the Culebra cut, he said they were "lines, which by the utmost stretch of the imagination could not be termed railroad tracks." Mr. Wallace had found the Panama Railroad, after half a century without competition, far behind the times in equipment, and practically no discipline or efficiency existed among the employees. When Mr. Stevens took charge there was an improved situation, but the long absence in Washington of Chief Engineer Wallace, and his sudden departure, had caused the railroad to begin a retrograde movement.

For 31 miles the main line of the railroad had been retracked with American rails and the work of double-tracking it was just getting under way. The principal shops were at Matachin, with a capacity of overhauling five locomotives and 150 dump cars a month. The canal employees soon saw the caliber of man at their head by the way Mr. Stevens straightened out

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the railroad tangle, for the freight began to move, lax methods were rooted out of the system, and the semblance of an efficient organization, operating along modern lines, appeared.

The Commission visited the Isthmus in July and August and with Mr. Stevens reached the conclusion that construction work should be reduced to a minimum, even to turning away employees, and all energies bent to building up a system of feeding and housing the men and their families. Preparatory work was given the right of way over construction, which accounts for the comparatively little excavation done under the Stevens régime. The general verdict was that the ground work done by Mr. Wallace was good, in spite of disorganized conditions, and that no insuperable obstacles stood in the way of building the canal. Delays in filling requisitions undoubtedly accounted for the lack of some of the equipment and supplies.

Mr. Wallace had left the following organization worked out on paper, with the explanation that large salaries had not attracted competent heads of departments, so that Mr. Stevens found many important positions unfilled:

The Department of Engineering and Construction was divided into five divisions, running from the Atlantic to the Pacific and known as the Colon, Chagres, Gamboa, Culebra, and La Boca Divisions.

Bureau of Personnel, Transportation and Quarters.
Bureau of Supplies.

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Bureau of Waterworks, Sewers, and Roads.

Bureau of Machinery and Equipment.

Bureau of Architecture and Equipment.

Bureau of Meteorology and Hydraulics.

Bureau of Mapmaking and Printing.

Bureau of Communication.

There were 8,312 men in the department of engineering and construction, and other employees brought the total to 9,500, not including the Panama Railroad. Municipal improvements in Colon and Panama, and certain Canal Zone towns, were well under way. Effective progress had been made in the work of surveying the canal route, in making borings for lock sites, and in other engineering preliminaries. As noted, 741,644 yards had been excavated and nine steam shovels were at work. The 357 renovated French buildings and 48 new structures housed the employees, except those who provided shelter for themselves in Colon and Panama. There were no commissary and hotels.

On December 1, 1905, the Commission made its annual report to the President, containing Mr. Stevens' first review of the canal. Both he and the Commission pleaded for "a thorough business administration, unhampered by any tendency to technicalities, into which our public works sometimes drift." Like Mr. Wallace, Mr. Stevens found government red tape galling. Civil service and the eight-hour day were just as obnoxious, the Commission urging that "it is a mistake to handicap the construction of the Panama

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Canal with any laws save those of police and sanitation.”

An Executive Order had made the Civil Service cover the Canal Zone on November 15, 1904, but both Mr. Wallace and Mr. Stevens protested so earnestly against the restrictions of this order that on January 12, 1906, President Roosevelt removed all employees, except clerks, from the scope of the act, thus allowing Mr. Stevens to employ anyone he saw fit on any terms he chose. The eight-hour day restriction likewise was lifted, but agitation in the United States caused the President later to reimpose both limitations, with whatever increase in time and cost of constructing the canal they might involve.

The Americans had been in Panama more than a year, and still the type of canal to be built was undecided. Mr. Wallace's service had terminated and a full year of Mr. Stevens' administration before the choice was made. In the meantime, Mr. Stevens rapidly was rounding into shape an organization of workers, getting suitable quarters erected for the employees who were coming in large numbers, organizing the commissary and hotel systems, securing mechanical equipment, and bringing the transportation facilities to a satisfactory standard. Gov. Magoon simultaneously was organizing a civil government along the lines blazed by Gov. Davis. Police, courts, schools, fire departments, post offices, recreation club-houses, churches, in short, duplicating on a scale suitable to the Canal Zone the civilization of the United States.

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By June, 1906, the end of his first year as Chief Engineer, Mr. Stevens had made a remarkable showing in every phase of the work. There were 39 steam shovels at work as against 9 in 1905; the working force had increased to 23,901, of whom 3,264 were Americans. But, as showing how closely his efforts were concentrated on preparatory work, the total excavation for the year was only 1,499,562 yards, the highest figures for one month being in March, 1906, when 239,178 yards were removed.

Col. Gorgas and his sanitary department got on top of the yellow-fever epidemic in September, 1905, and in general so dominated the hitherto unhealthful Isthmus, that even the hostile press began to show a change in heart on this score, with the result that the immigration of workers largely increased. Recruiting agencies already had been opened in the West Indies, Europe, and the principal American cities. More than 12,000 men were imported in 1906 on contract with the Commission. The common labor was estimated by Mr. Stevens to be about 33 per cent as efficient as similar American labor. It was not until 1906 that the wives and families of the Americans began coming to the Canal Zone in considerable numbers, although there had been a heroic band of them throughout the trying days before the tropical terrors had been conquered.

Early in his connection with the canal, Mr. Stevens discovered that practically all the material in the Culebra cut would have to be blasted before it could be handled by the steam shovels. "The problem of Cu-

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lebra cut," he wrote in the first annual report, "is one of transportation (including disposal) pure and simple." He had to be careful in selecting dumps so as to insure that they would not become an obstruction to any type of canal or route that might be selected. "As the gift of prophecy is withheld from us in these latter days, all we can do now is to make such arrangements as may look proper as far ahead as we can see," he wrote in his report of 1905 on the unsettled question of a sea-level or lock-type canal.

The high wages and salaries for which the Canal Zone is noted originated under Mr. Stevens. So bad a name had been given the Isthmus in the past that extra inducements had to be made to attract workers, free quarters, pay from 30% to 60% higher than in the United States, and a rate of \$20 from New York to Colon on steamers operated by the government, with other perquisites, being some of the advertised attractions. Besides, in the latter part of Mr. Stevens' régime, the United States was enjoying unexampled prosperity, the palmy days before the panic of 1907. Mechanics and all kinds of workers could obtain employment at home at high wages and would not come to Panama unless for the unusual inducements enumerated, and, in addition, vacations with full pay, sick leave on pay, and cheap food and other necessities.

THE BATTLE OF THE LEVELS

Although the French had abandoned the idea of a sea-level canal in favor of a lock type, there still was



Clinedinst photo, Washington, D. C.

JOHN F. STEVENS.

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a good deal of life in the idea among the American people. For one thing, a sea-level canal was so much more easily grasped by the popular mind, and then all engineers concede that it is the ideal canal where it is practicable. In Panama, the division of opinion arose over this point of practicability.

A sea-level canal aptly has been described as "a wide and deep passage navigable at all times, day or night, at all seasons and in all weathers, by all sorts and sizes of vessels." The lock type involves operations not readily portrayed to the lay mind, but eminently simple when seen in practical use. Popular opinion, and the daily and periodical press, divided and fought bitterly from the time the Canal Zone was taken until it finally was decided by Congress, and even then the sea-level advocates kept up an anvil chorus against the lock type.

The Walker Commission of 1901 had estimated the cost of a sea-level canal at \$145,000,000. The Spooner act authorized \$135,000,000 for any type that might be chosen, but leaned toward the lock type. The Commission of 1905 recommended a sea-level type to cost \$230,500,000. Mr. Wallace later estimated the cost at sea-level at \$300,000,000, exclusive of the \$50,000,000 paid for the Canal Zone and French property.

That these American estimates should come, in the main, under the amount actually spent by the French, who little more than scraped the surface, shows, for one thing, that the Americans believed there had been gross extravagance and inefficiency in the French oper-

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ations, and for another thing, that the Americans had no adequate grasp upon the task they were undertaking. This same insufficiency of estimates continued until 1908, when Col. Goethals faced the situation frankly and announced the cost for a lock type to be \$375,000,000, which was far ahead of the highest estimate for a sea-level canal. In 1909, Col. Goethals said a sea-level canal would cost \$563,000,000 and take six years longer to build than a lock canal, which was before the slides in the Culebra cut became so formidable and a sea-level canal had been shown thereby to be all but impossible. It is probable that a sea-level canal would cost around a billion dollars, and take from ten to twenty years longer to build, if engineers should now decide it practicable.

President Roosevelt took a characteristic step to end the dispute. On June 24, 1905, a few days before the appointment of Mr. Stevens as Chief Engineer, he named the following International Board of Advisory Engineers to recommend a type of canal:

MAJ.-GEN. GEORGE W. DAVIS, U. S. A., *Chairman*,
CAPT. JOHN C. OAKES, U. S. A., Corps of Engineers,
Secretary,

BRIG.-GEN. HENRY L. ABBOTT, U. S. A., retired,
ADOLPH GUERARD, Inspector-General of Public
Works, France,

EDOUARD M. QUELLENEC, Consulting Engineer, Suez
Canal,

HENRY HUNTER, Engineer of Manchester Canal,
England,

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HERR EUGENE TINCAUSER, Engineer on Kiel Canal,
Germany,

J. W. WELCKER, Engineer Dyke System, Holland,
ISHAM RANDOLPH, Chief Engineer, Chicago Drainage
Canal,

FREDERICK P. STEARNS, Hydraulic Engineer, Boston,
WILLIAM H. BURR, Consulting Engineer, New York,
JOSEPH RIPLEY, Chief Engineer, Sault Ste. Marie
Canal,

ALFRED NOBLE, Chief of Pennsylvania R. R. Im-
provements, N. Y. C.,

WILLIAM B. PARSONS, Chief Engineer, Subway Sys-
tem, New York.

Out of this number, five were foreigners and the remainder Americans. The Board visited the Isthmus in October, 1905, and reported to the President on January 10, 1906. The majority, composed of eight engineers, and comprising all of the foreigners, recommended a sea-level canal. Messrs. Davis, Burr, and Parsons were the three Americans who signed the majority report. The minority of five Americans recommended a lock-type canal with a lake at 85 feet above sea-level formed by a dam across the Chagres River at Gatun. They estimated the excavation at 103,795,000 cubic yards, and the cost, exclusive of sanitation and civil government, at \$139,705,200. Nine years, or until 1915, was the time estimated for completing the canal. There were to be three locks in flight at Gatun, each 95 by 900 feet usable dimensions, and on the Pacific side, one lock at Pedro

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Miguel, and two at La Boca, at the entrance, the distance between Pedro Miguel and La Boca, 8 miles, to be a second artificial lake. The Culebra cut was to be 200 feet wide for 5 miles and 300 feet wide for 4 miles.

Chief Engineer Stevens and all but one member of the Commission concurred in the minority report. Secretary Taft's visits to the Isthmus had converted him to the lock type, and President Roosevelt consistently had favored it.

The situation was one where the choice would be decided by the weight the President should throw to either report. To reject the majority report favoring a sea-level canal, and to advocate the minority report for a lock-type canal, was a responsibility of unusual magnitude for an Executive who professed to have no technical engineering knowledge. Yet President Roosevelt made the momentous decision without hesitation, sending a strong message recommending the minority report. It was, perhaps, the greatest crisis in the history of the project, and the American people have to thank his sound judgment in preventing a sea-level experiment that, undoubtedly, in the light of recent years, would have exhausted the patience and maybe the finances of the nation.

Congress debated the issue until June 21st, when the Senate by the close vote of 36 to 31 decided for a lock type, and on June 28th, the House concurred, the bill becoming law on June 29, 1906. The sea-level advocates were beaten, but they watched operations sullenly and flared up into hot criticism fre-

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quently, with dismal prophecies of the impending collapse of the lock canal.

Of the three Chief Engineers who have directed the construction of the canal, Mr. Wallace alone favored the sea-level plan. He uniformly opposed a dam at Gatun, expressing the opinion that there was not a foundation at that point for so heavy a structure, nor did he believe from his investigations that the earth there would support the great locks contemplated in the minority report. Any type of canal, he reasoned, which would require years to repair a break was inadvisable, and even a lock type should be convertible to a sea-level canal, if such action should appear desirable. Messrs. Stevens and Goethals were equally unwavering in their advocacy of a lock canal.

Two years and two months had passed from the time the Americans came to Panama, in May, 1904, to July 1, 1906, before this decision was made, and at last the Commission knew what plan of canal was to be followed. In September, 1906, Mr. Stevens started the excavations in the sites for the Gatun locks, the Pedro Miguel lock, and the Gatun Dam Spillway. Surveys were begun for relocating the Panama Railroad which, for a considerable distance, would be swallowed up by the completed canal. The fifteen months' preparatory work was beginning to tell in the increased excavations in the Culebra cut as the organization was getting its stride. Commissaries, which sold everything the canal employee needed, were in operation in the principal towns, the hotels for the bachelors were well organized, quarters had

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been erected until all were housed, though at times rather crowded, machinery, supplies, and equipment were on hand, or ordered, to the extent of 80 per cent of what would be needed to complete the canal, health conditions were admirable, and the whole situation was shaping for the real work of building the canal.

President Roosevelt paid the Canal Zone a visit in November, 1906. It was a trip of exploration for him, and the way he ignored the formal plans for his entertainment delighted the employees. Subordinate officials were rather anxious that he should inspect just the things they had spick and span for him to inspect, but from the time he landed at Colon, where he jumped on a horse instead of into a waiting carriage and rode down the unpaved side streets, noting the mud and unfinished improvements, until he ate in the line hotels with the dirt-covered employees, inspected the kitchens and quarters, and had nosed in and out of every part of the canal, he led them a merry chase. The enthusiasm for the "daddy" of the project was boundless, and the shortcomings he noted resulted in better conditions of employment for the men.

One evidence of the growing luxury of living conditions in the Canal Zone was the installation on January 1, 1907, of electric lights in the quarters of the married and bachelor employees at Empire and Culebra. Other towns soon were furnished with electricity. The first public school had been opened a year before this event, or on January 2, 1906. Gov. Magoon, on September 25, 1906, had been transferred

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to Cuba by the President, occasioning the first break in the Shonts Commission. The summer and fall of 1906 and the winter of 1907 saw another great controversy raging around the canal, which, like the battle of the levels, was to be decided arbitrarily by President Roosevelt.

THE CONTRACT PLAN

Chairman Shonts long had entertained the opinion that the canal should be constructed by private contractors. He pressed the plan so vigorously, and the popular opinion of the inefficiency of the government was so strong, that the President authorized Secretary Taft to ask for bids on October 9, 1906.

By this time conditions had so improved in the Canal Zone that the employees viewed the assumption of control by contractors as likely to militate against their interests. Mr. Stevens was making admirable headway, both in the creation of an effective organization and the physical equipment to do the actual work of construction. He had little enough patience with governmental methods, but on the point of securing competent workers, which Mr. Shonts seemed to think the government could not do so speedily and well as a contractor, Mr. Stevens said in his report of 1905: "The very liberal and wise policy which the Commission is carrying out in its care of its employees and in its treatment of them in every way must, after patient and careful selection, result in a personnel entirely capable of producing good results."

The plan Mr. Shonts advanced for turning the job

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over to a private contractor, left in the hands of the government the last word on every vital question that might arise. Viewed to-day, the terms of the invitation for bids seem to have been drawn with so much rigidity as completely to have robbed any contractor of the very flexibility of action which appeared to be the main drawback of a government enterprise. The government was to decide upon the cost and plans and the contractor was to receive a percentage of that amount for his services. Civil government and sanitation were to remain in the hands of the government.

It is safe to assume that had the plan been adopted, it would have broken down in less than three months, because the contractor either would have settled to the mere foremanship of the job, with the government engineers the court of last resort on all issues, or he would have asserted an independence of judgment and action which the terms of the contract did not permit. Either result would have been disastrous to the canal project.

Those who favored the contract plan had some considerations which were potent with them, but which they did not shout from the housetops. They knew that the terms of the contract on which bids were invited practically reduced the contractor to the position of superintendent, but by nominally placing the work in his hands they would get the private contractor's freedom of action as to hours of work, standard of wages, fitness of employees, and cheapness of markets for materials. In other words, so long as the

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government itself built the canal, the eight-hour day, civil-service regulations, and the whole web of official procedure that enveloped the undertaking, would be operative. The contract plan offered a neat way of sidestepping these cumbersome conditions of doing business.

Mr. Wallace heartily favored the contract plan, expressing his belief in "the utter impossibility of the United States Government carrying on a constructive enterprise in a common sense, businesslike manner." Whatever his attitude at first, toward the last Mr. Stevens opposed the contract plan, as he believed that the work he had done in the Canal Zone was efficient, and if a little relaxation in red tape was indulged, the canal could be built more advantageously by the Government.

Bids for constructing the canal by private contract were opened at Washington on January 12, 1907, and rejected on the ground that they failed to meet the requirements of the government. The Oliver-Bangs syndicate was nearest in its bid to the specifications. The real reason for rejecting the bids was that both the country and the administration had undergone a change of heart as to the wisdom of the contract plan.

Another epoch in the life of the canal project was marked by the President's action in definitely committing the enterprise to direct government supervision. Chairman Shonts resigned, effective March 4, 1907. An executive order then consolidated the offices of Chairman and Chief Engineer in Mr. Stevens. On March 16th the remainder of the Commission, except

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Col. Gorgas, resigned, to be followed on April 1st by the resignation of Chief Engineer Stevens. His resignation came like a sickening accident to the canal employees. "The Chief," as he was called familiarly, had established himself firmly in their minds and hearts as a thoroughly competent engineer and just administrator. No official explanation of the motive for his quitting had been made, but the general understanding is that he opposed the assignment of government engineers to the Commission as likely to create friction with civilian engineers and partly to a stiff communication he sent the President on the limitations of red tape and governmental methods generally. His departure was featured by a remarkable demonstration at Colon, when he was presented with a gold watch, a diamond ring, and a silver service by the employees, who did not restrain their emotion at his loss.

Mr. Stevens was not soured by the termination of his services as Chief Engineer. His faith in the ultimate success of the project has remained unshaken, and in the *Engineering News* of December 31, 1908, a year and three quarters after his resignation, he wrote that the public criticism of the locks and dams was erroneous, and advised that Col. Goethals be backed up in his admirable efforts. The greatest tribute to his work as Chief Engineer is found in the fact that the organization of employees was so thorough and the foundational work so well done that the enterprise was not harmed by a change in managing directors.

CHAPTER XIII

THE CANAL UNDER GOETHALS

PRESIDENT ROOSEVELT had at last found public sentiment educated to the point where the canal could be put exclusively in the hands of government engineers, following the untimely resignation of Mr. Wallace, the belief that private interests were seeking to grab the project, and the loss of Mr. Stevens. It had taken three years to reach this attitude. The personnel of the third Commission he appointed, on April 1, 1907, was as follows:

LIEUT.-COL. GEORGE W. GOETHALS, *Chairman and Chief Engineer,*

MAJ. D. D. GAILLARD, U. S. A.,

MAJ. WILLIAM L. SIBERT, U. S. A.,

MR. H. H. ROUSSEAU, U. S. N.,

COL. W. C. GORGAS, U. S. A., *Medical Corps,*

MR. J. C. S. BLACKBURN,

MR. JACKSON SMITH,

MR. JOSEPH BUCKLIN BISHOP, *Secretary.*

The President also took advantage of the reorganization of the Commission to further consolidate power in the Chairman. Not only was Col. Goethals made Chairman of the Isthmian Canal Commission, and Chief Engineer of the Panama Canal, but the executive power in the Canal Zone, formerly exer-

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cised by the Governor, was vested in him, as well as the Presidency of the Panama Railroad Company, thus making every official and employee, and the members of the Commission, subordinate to him.

In former years the Governor had exercised extensive and supreme powers within his sphere, ranking higher than the Chief Engineer. Where the Chairman, Chief Engineer, and Governor had rival powers, friction was sure to develop, and did so develop. Under the new order the Governor was reduced to the title of Head of the Department of Civil Administration, reporting to the Chairman, as did the Chief Sanitary Officer and Division Engineers. Thus the former concentration of the power of a Commission of seven members into an Executive Committee of three, was still further concentrated into one man and so gave Col. Goethals the absolute authority he ever since has exercised in the Canal Zone, acknowledging only the Secretary of War and the President as his superiors.

Mr. Jackson Smith's appointment to the Commission is the only instance of a civilian coming to the Canal Zone as an employee and attaining to the position of Commissioner. He had shown such remarkable ability as the head of the Bureau of Labor, Quarters, and Subsistence, in recruiting workers, housing them and supplying them with food, that his services were recognized by elevation to the Commission. Mr. Blackburn, of Kentucky, was the head of the Department of Civil Administration, and Mr. Bishop was to edit a weekly Canal Record, the official Commission

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publication, the first issue of which appeared on September 4, 1907, and every Wednesday since. Five of the new Commissioners and the Secretary have been on the job continuously from that day to this, the changes coming in the other two members on September 14, 1908, when Mr. Smith resigned and was succeeded by Lieut.-Col. H. F. Hodges, and Mr. Blackburn being succeeded by Mr. Maurice H. Thatcher, on April 12, 1910.

Col. Goethals appreciated the feeling the employees had over the prospect of army engineers for directors of the enterprise, and in his first speech in the Canal Zone dispelled the idea of militarism in the canal management. He promised a fair hearing to every man with a grievance, the manner in which he carried out this promise being one of the distinctively great qualities he later revealed as an administrator. Few persons in the Canal Zone had heard of Col. Goethals before his appointment as Chief Engineer. He had visited the Isthmus in 1905 to study it with a view of recommending plans for fortifications, but the employees who had been with the job then scarcely were impressed by his presence. Yet, his previous experience had qualified him ideally for the important work now in hand. He had been building locks and dams, had been Chief of Engineers in the Spanish-American War, was a graduate of and had taught in West Point, and had seen other construction experience that made him at home in any kind of work the canal should require. Messrs. Stevens and Wallace lacked his knowledge of lock building, and they lacked the

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military point of view which was to become essential in directing the fortification work, and the general policy of treating the Canal Zone as a military reservation, even though the project is neutral and open to the nations of the world.

Looking back from this perspective of years it seems fortuitous that the canal has had the impress of both civilian and army engineers. When Mr. Stevens left, the enterprise was ready for just the treatment it has received under Col. Goethals, which is, that we are not investing \$375,000,000 as a mere adjunct to commerce, but as a means of national defense vitally necessary. The military coloring Col. Goethals has given the canal will not impair its utility in the world's trade, yet it will keep it ready for the emergencies of war in a manner that the civilian view point hardly could have been expected to produce.

Contrast, for a moment, the situation as faced by Col. Goethals with that faced by Mr. Stevens in 1905. In 1907, fire was under the boiler and steam was up. When Mr. Stevens relinquished the throttle, the army of workers had begun to come close to the million mark in monthly excavations in the Culebra cut. There were 63 steam shovels at work on the canal; 100 French and 184 American locomotives, and 2,700 cars of all kinds were in use; the Panama Railroad had been double-tracked throughout, and the mileage in the Culebra cut and elsewhere brought up to 106.78 miles; 18 Lidgerwood unloaders, 13 bank spreaders, 33 unloading plows, 3 track shifters and 7 pile

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drivers were in service; the machine shops at Gorgona and Empire were equipped for any kind of repair work or original construction.

There were approximately 30,000 employees, and the recruiting agencies in Europe, the West Indies, and the United States constantly were sending additions. Quarters for employees, office buildings, and all other structures consisted of 2,009 buildings of American design, and 1,536 remodeled French buildings. The commissary for supplying food, clothing, and general merchandise to employees was organized and had branches in seven Canal Zone towns. There were fifteen hotels in operation for bachelor employees and four recreation clubhouses had been constructed, beside church and lodge buildings. Twenty-four public schools afforded educational facilities to the Canal Zone children. The police system, the courts, post offices, and fire departments were thoroughly organized. In short, the preparatory stage of the canal had passed and the constructive stage had begun.

As compared with the total excavation required for the completed canal, in round numbers 221,000,000 yards, the record made by Mr. Stevens, in removing from the Culebra cut during the twenty-one months he was Chief Engineer, 5,073,098 yards, is not significant. The construction of the canal distinctly is the work of the Goethals administration; still, the preparatory work had to be done because, as Col. Goethals himself states:

“It was only after these various yet necessary adjuncts had been provided and the forces for their

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operation were organized that the principal work in hand—the building of the canal—could be pushed forward with any hope of success, and too much praise cannot be given those who conceived and established them in a working condition.”

Necessarily, all the basic work accomplished under Wallace and Stevens is lost sight of in view of the magnificent superstructure erected under Col. Goethals. The modern sightseer has nothing to remind him of the wretched conditions of the first two years, the battle with disease, the arduous labor of creating in the jungle a duplicate American civilization, the tantalizing struggle with government red tape before a stick of timber, a pound of iron, a shipment of food, or an efficient workman could be secured.

The first vivid impression to-day upon the tourist viewing the colossal locks and the artificial canyon called the Culebra cut, the beautiful towns, and the whole paraphernalia of a well-ordered civil government is similar to that experienced upon the first sight of Niagara Falls, with this exception: The Panama Canal is the work of man, and the responsibility for it may be fixed. An outburst of praise is the spontaneous result, and Col. Goethals, being the visible head of the project, naturally bears the brunt of this admiration. Yet, excluding the construction work, all the collective activities, such as feeding and housing and providing for the needs of the army of employees, as well as the whole civil government, was the work of the Stevens and Wallace administrations.



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COL. GEORGE W. GOETHALS.

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Col. Goethals simply has enlarged the organizations they left.

Perhaps the chief reason that Col. Goethals so generally is accepted as the sole genius of the canal is found in the fact that he stuck to the job which two others had abandoned. Justice, however, is not wholly served by this consideration. A simile may be found in the task of breaking a broncho. The canal job threw both Wallace and Stevens and then Goethals stuck in the saddle. But the energy that the broncho spent to dismount the first two riders so weakened him that by the time the third was in the saddle he was conquerable. The third rider may have been no better than the two who were thrown, and their efforts undoubtedly paved the way for his success.

Col. Goethals deserves the admiration that his service on the canal has evoked, but the generality of writers, looking at what exists to-day and heedless of the beginnings of the task, lose their perspective and commonly fall into the error of ignoring the very remarkable and wholly vital preparatory work under John F. Stevens. This writer believes that if Col. Goethals had been selected in 1904, there only would have been one Chief Engineer of the canal, barring his death, so eminent are the abilities of the army engineer, but candor requires the statement that he assumed control at a time when conditions were soft as compared with the early stages of the project.

President Roosevelt had selected in Messrs. Gaillard, Sibert, Rousseau, and later, Hodges, engineers

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of exceptional ability, who, with S. B. Williamson, picked by Col. Goethals, demonstrated capacities which in a large measure account for the splendid progress of the Goethals administration. Any one of them would have been available for the highest position in the organization.

It would be erroneous to assume that Col. Goethals had nothing to do but sit back and watch the signals on the main line of canal construction, as indicated by his predecessors. The decks, indeed, had been cleared for action and the blue-prints nicely finished and tied with ribbon, but the real struggle was just beginning. He had the tools for the job placed in his hands, but their skillful use devolved entirely upon him. Besides, changes were made in the original plans and unanticipated problems arose, which made Col. Goethals' direction of the enterprise in the highest degree complex and exceptional.

The first annual report of the Commission, to be written as of June 30th, the end of the government's fiscal year, was issued by Col. Goethals in 1907, three months after Mr. Stevens resigned. The President had asked Col. Goethals to report on the contract plan after an inspection of the canal, and this masterly argument against turning it over to private contractors is the report's most notable feature, aside from its unusual comprehensiveness. Incidentally, the argument is a high tribute to the work of Mr. Stevens.

Col. Goethals pointed out that the canal required special equipment which would be useless to a contractor after its completion, and therefore could be

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bought just as cheaply by the government; that the government had had more experience in lock building than any contractor, and had had sufficient experience in dredging and excavating to insure economy. When the profits a contractor would make were deducted, the government could equal his efficiency. He pointed to the Congressional Library at Washington as an example of work done satisfactorily by the government. No contractor had an organization that could cover all phases of the canal, and the government already had as good an organization as any contractor could get. The French had tried the contract system, antagonizing labor thereby, and Italy already had served notice that its citizens could not work in the Canal Zone if the government abandoned the job. Finally, endless friction between government inspectors and the contractor would result, and on the side of civil government and sanitation the contractor could not possibly equal the efficiency of the government.

Taking a survey of the conditions when he took charge, Col. Goethals found that 80 per cent of the plant for finishing the canal was on the ground or ordered. The preliminary work for relocating the Panama Railroad had been done, and actual construction of the new line was begun in June, 1907, shortly after his arrival. Excavations in the lock sites were uncompleted, and it was two years later, in 1909, before any concrete was laid. In April, the month he arrived, nearly 900,000 yards were removed from the Culebra cut, the best month's work to that date. By

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December, 1907, the million mark for the Cut was passed and never has been lowered except for one month, May, 1908. Dredging in the Atlantic and Pacific entrances of the canal had gone ahead steadily, though not extensively, the amount removed in the Atlantic entrance being 1,732,712 yards, and in the Pacific entrance, 1,956,895 yards, from 1904 to April 1, 1907. Less than 6,000,000 yards had been removed from the Culebra cut by both Wallace and Stevens.

In August, four months after Col. Goethals arrived, the organization in the department of construction and engineering had developed such a momentum that it was necessary to ask authority from the President to exceed the regular appropriation by \$8,000,000 for the fiscal year to end in June, 1908. This is additional evidence of the efficiency of the preparatory work under Mr. Stevens.

The fall of 1907 and the month of October presented a new problem in the canal construction which ever since has been one of the most formidable and uncertain factors in the project. A slide began at Cucaracha on the east side of the Cut near the town of Culebra and suddenly filled the Cut, closing it for transportation. In 1884, the French had noted this earth movement, and during Col. Goethals' first years on the canal it involved an area of forty-seven acres. Before dirt trains could move through the Cut, steam shovels had to work night and day for several weeks, and from that time onward the slides have been the bugbear of the organization, not because they were insuperable, but from the extra work they involved

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and the possibility that they might delay the completion of the project. In the closing days the slides are still the unknown factor.

Right then it was realized that the canal involved more excavation than the minority of the Board of Advisory Engineers had estimated. Several important changes in the plans for the canal came within the first eighteen months of the Goethals administration to make the job far more stupendous than contemplated in the plans of 1906. Col. Goethals recommended, and President Roosevelt approved on December 20, 1907, a change in the location of two of the Pacific locks. The revised plans changed two locks from La Boca, on the Pacific coast, to Miraflores, about seven miles inland, which not only would make them safe from bombardment, but was a more practicable engineering plan. A mile and a half farther inland were the Pedro Miguel locks, which would raise ships the final height to the great Gatun Lake, at its Pacific terminal, and between the Pedro Miguel and Miraflores locks was a small artificial lake. From Miraflores to the Pacific, a sea-level channel 500 feet wide was to be dug.

Another change in the plans was approved by the President on recommendations by the Navy Board, on January 15, 1908. The locks were ordered enlarged from 95 by 900 feet to 110 by 1,000 feet, usable dimensions, to meet the anticipated increase in the size of commercial and war vessels. Col. Goethals did not think a width of 110 feet necessary, favoring 100 feet width, but his judgment in this

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instance has proved to be wrong, as the latest Argentine battleship is 98 feet wide, leaving only 12 feet surplus in the width of the locks, at 110 feet. The *Pennsylvania* of our Navy will be 97 feet wide, leaving 13 feet, or $6\frac{1}{2}$ feet on each side of the ship in the locks. The *Imperator*, the latest giant of the Hamburg-American fleet, is 96 feet wide and 900 feet long, so that it appears that the locks may become too narrow before they become too short. The cost of the locks was increased \$5,000,000 by the change in plans.

A third vital change in the original plans came on October 23, 1908, when the President authorized the widening of the Culebra cut for five miles from 200 feet to 300 feet at the bottom. This would enable ships to pass going in opposite directions anywhere in the Cut, and increased the cost of this part of the canal by \$14,000,000. Since these three important changes there have been no substantial changes in the canal plans, except the decrease in the proposed height of the huge Gatun dam. Additional excavation to the extent of 70,871,594 cubic yards was necessitated by the new plans over the estimate of 103,795,000 yards made in 1906, or a total of 174,666,594 yards for the completed canal. But slides that later developed, and further changes in the plans since 1908 have added 47,000,000 yards to that total, bringing it up to 221,000,000 yards. Thus Col. Goethals has had to dig more than twice as much dirt as Mr. Stevens expected to take out, and is doing it in less time than was estimated for the original yardage! The original canal of 103,795,000 yards was dug by the Americans

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by April 6, 1910, six years after work began, and two years and a half of that time had been spent in preparatory work.

Basing his figures on the revised plans, Col. Goethals in 1908 issued the following estimate of the cost of the Panama Canal:

ATLANTIC DIVISION—7 MILES

Breakwater in Limon Bay.....	\$11,432,000
From Caribbean Sea, channel to Gatun Locks.....	17,736,000
Gatun Locks, three twin locks.....	25,824,000
Gatun Dam.....	13,572,000
	<hr/>
	\$68,564,000

CENTRAL DIVISION—32 MILES

Channel from Gatun Locks to Bas Obispo	\$7,977,000
Culebra Cut, Nine Miles, Bas Obispo to Pedro Miguel Lock.....	80,481,000
	<hr/>
	\$88,458,000

PACIFIC DIVISION—8 MILES

Pedro Miguel Lock.....	\$12,693,000
Pedro Miguel Dam.....	251,000
Miraflores Locks.....	19,715,000
Miraflores Dam.....	2,156,000
Channel, Pedro Miguel to Pacific....	13,170,000
	<hr/>
	\$47,985,000

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New Panama Railroad.....	\$8,164,000
Land Damages.....	500,000

GENERAL ITEMS

Municipal Improvements.....	\$12,114,000
Buildings	14,651,000
General Expenses, Salaries, Subsistence, etc.	23,730,000
Loans to P. R. R.....	8,300,000
Contingencies	20,000,000
Lighthouses, Ships, Wharves.....	3,850,000
Double-tracking, Land and Stock Purchases	1,450,000
	<hr/>
	\$84,095,000

Grand Total Cost of Construction.. \$297,766,000

ALL OTHER ITEMS

Sanitation	\$20,053,000
Civil Administration	7,382,000
Paid for French Property.....	40,000,000
Paid for Canal Zone.....	10,000,000
	<hr/>
	\$77,435,000

Total Cost for Completed Canal... \$375,201,000

Beginning July 1, 1908, Col. Goethals initiated changes in the organization, which was to be the final one for the canal. The Department of Engineering and Construction was divided into three grand divi-

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sions, to be known as the Atlantic, Central, and Pacific. The Atlantic division comprised that part of the canal which extended from deep water in the Caribbean Sea to, and including, the Gatun locks and dam, about seven miles of the canal. The Central division comprised the channel through the Chagres River valley from the Gatun Locks to Bas Obispo, where the Culebra cut began, and for nine miles through the continental divide to the Pedro Miguel Lock, about thirty-two miles of the canal. The Pacific division comprised the Pedro Miguel Lock and Dam, the short channel to the Miraflores Locks and Dam, and including those features, and the channel to deep water in the Pacific, about eight miles of the canal.

Of the forty-seven miles of the canal proper, the Central division had the greatest mileage, its construction was to be the costliest and the material handled to be far in excess of either of the other two divisions. It is in the Central division that the main excavation of the canal has been made, as the mountain chain had to be pierced with a cut, the bottom of which would be only forty feet above sea-level, necessitating digging down from the highest point on the surface, a depth of 272 feet, between Gold and Contractor's hills. The French dug down 161 feet at this point, but not so wide as the American plans required so that considerably more than 111 feet depth remained for the Americans to dig. From this highest point the mountains slope toward the Atlantic and Pacific with a consequent lessening of the depth of the excavations

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to reach the proposed bottom of the canal. Practically all the material had to be blasted before removal.

Since 1908 the organization has remained unchanged as to the heads of the divisions in the department of engineering and construction. As finally designed by Col. Goethals, the organization of the canal forces is as follows, with the incumbents as of July 1, 1912:

ENGINEERING AND CONSTRUCTION

COL. GEO. W. GOETHALS, *Chairman* and Chief Engineer, Culebra.

COL. H. F. HODGES, Assistant Chief Engineer, in charge of Lock and Dam construction, Culebra.

CIVIL ENGINEER H. H. ROUSSEAU, Assistant to the Chief Engineer, in charge of mechanical equipment and supervision of expenditures and estimates, Culebra.

LIEUT.-COL. D. D. GAILLARD, Engineer, Central Division, Empire.

LIEUT.-COL. WILLIAM L. SIBERT, Engineer, Atlantic Division, Gatun,

S. B. WILLIAMSON, Engineer, Pacific Division, Corozal,

A. L. ROBINSON, Superintendent, Mechanical Division, Gorgona.

ALL OTHER DEPARTMENTS

LIEUT.-COL. EUGENE T. WILSON, Subsistence Officer, Cristobal,

COL. C. A. DEVOL, Chief Quartermaster, Culebra,

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MR. MAURICE H. THATCHER, Head of Civil Administration, Ancon,
H. A. GUDGER, Chief Justice, Ancon,
FRANK FEUILLE, Counsel and Chief Attorney, Ancon,
COL. W. C. GORGAS, Chief Sanitary Officer, Ancon,
EDWARD J. WILLIAMS, Disbursing Officer, Empire,
H. A. A. SMITH, Examiner of Accounts, Empire,
MAJ. F. C. BOGGS, General Purchasing Officer, Washington, D. C.,
J. A. SMITH, Superintendent, Panama Railroad, Colon.

The headquarters of the division engineers and the department heads are in the towns nearest to the scenes of their activities. Beneath the higher officials are a host of assistants who exercise important supervisory functions, and then come the 35,000 employees.

How largely the Army and Navy have dominated the canal, since 1907, is shown by the foregoing organization, in which nine out of seventeen heads of departments are from the government forces. But this does not show the extent of this domination, because the full organization of subordinate officials shows twenty-two additional Army and Navy men in important positions.

The Pacific Division is the only one of the three grand divisions with a civilian engineer in charge, and there are no Army or Navy men in this division from top to bottom. The idea seems to have been to pit a civilian engineer against the Army men, who are in charge of the Atlantic and Central Divisions. The

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Pacific Division, under Mr. Williamson, substantially demands the same engineering ability as the Atlantic Division under Lieut.-Col. Sibert, because each includes lock and dam construction and channel dredging. The cost-keeping accountant has shown where the civilian engineer has done his work more cheaply than the Army engineer, but the difference is accounted for in the physical obstacles that must be surmounted in the Atlantic Division, in obtaining sand and rock for the locks.

None of the complaints at government red tape which bristled all through the annual reports of Messrs. Stevens and Wallace may be noted in Col. Goethals' reports. The Army men on the canal might exclaim, with Brer Rabbit, that they were born and bred in the briar patch of red tape, and were just in their element when dropped into the Big Ditch. Col. Goethals looked ahead in making up his annual estimates of appropriations needed for the year in advance, and in making orders for equipment, materials and supplies, so that much of the vexation of the early years was avoided. Every head of a department must hand in an estimate of what will be needed to run him for the ensuing year and this plan keeps the canal ahead of its demands in all lines.

The equanimity with which Col. Goethals has met every unexpected development in the construction work is a distinguishing feature of the man's mental processes. If he ever has for one moment entertained the shadow of a doubt of the success of the lock-type canal, he has not allowed his fears to be manifested.

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The slides, the slip in the Gatun dam, the volcanic evidences in the Culebra cut, the cracks in the lock walls, earthquake disturbances, and a host of lesser troubles have not shaken his faith. One can hear employees and subordinate officials voicing all kinds of dark forebodings, but never the Chief Engineer.

The mammoth Gatun dam had been begun in 1906, and by 1908 was taking form under the constant dumping of rock and earth from the Culebra cut. On November 20, 1908, a toe of the great dam slipped, where the dam intersected the old French canal channel, carrying about 200 feet of the structure away. The hostile press, and those who had consistently opposed a dam at Gatun, immediately raised a storm of criticism against the stability of the proposed artificial mountain. The old wound, caused from the battle of the levels, was reopened and so violent was the outburst that President Roosevelt took a characteristic step to quiet the issue.

He asked President-elect Taft to go to the Isthmus, accompanied by Frederic P. Stearns, Arthur P. Davis, Henry A. Allen, James D. Schuyler, Isham Randolph, John R. Freeman and Allen Hazen, all eminent engineers, to make an investigation. The report made on February 16, 1909, completely vindicated the plan for a dam at Gatun with the statement that if any error had been made, it was on the side of precaution. They found the dam started along lines so excessively stable that they recommended that the height be cut from 135 feet above sea-level to 115 feet, which would still

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leave the top of the dam thirty feet above the level of Gatun Lake.

An absolutely free hand always has been given to critics of the canal. Having nothing to conceal, and with firm faith in the technical soundness of the plans adopted, the government has had nothing it wished to keep from the light. Whenever criticism of any feature became especially severe, President Roosevelt promptly answered it by a full and scientific investigation with the inevitable result that the critics slunk into silence. Since President Taft has been in office the canal has been advanced to the point where the sceptical are cautious in criticism, and only some catastrophe of nature, in reasonable probability, can undo the achievement.

The six years from January 1, 1907, to January 1, 1913, constitute the main construction period of the Panama Canal. Col. Goethals has been Chief Engineer all but three months of that time. Steadily, foot by foot, the walls of the locks crept up and the bottom of the Culebra cut went down. By October, 1908, the preparatory work, substantially accomplished by Mr. Stevens, passed its highest point, and all energies were centered on the work of construction. Quarters, municipal work, road-making, subsistence and commissary were solved problems and the "No Help Wanted" sign was displayed, the labor problem, too, being substantially worked out. The chief business was to make the organization more efficient by anticipating needs of equipment and supplies, and keeping the morale of the workers to a keen edge through ab-

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solite justice. Col. Gorgas had the health problem in hand.

Sixty-three steam shovels, in 1907, were increased to 100; the 284 locomotives were augmented to 315; cars of all kinds from 2,700 to 4,356; the mileage in the Canal Zone was increased from 185 to about 500 miles for the Panama Railroad and Commission tracks; the number of unloaders, bank spreaders, track shifters and pile drivers was increased from a third to three times the number left by Mr. Stevens; twenty dredges were put in service, 560 drills for blasting, fifty-seven cranes, twelve tow boats, eleven clapnets, seventy barges and lighters, fourteen launches, beside much other machinery and equipment not so noteworthy. The foregoing figures do not include the Panama Railroad equipment, which consists of seventy locomotives, 1,534 cars and coaches, and various other rolling stock common to a railroad. Practically all repairs and creative mechanical work was concentrated in the Gorgona and Empire shops, with capacities commensurate with the equipment. The Empire shop specialized on steam shovel repairs, but in July, 1912, the bulk of its work was consolidated with Gorgona. The date when the equipment reached a maximum is fixed by Col. Goethals as July 1, 1910. About 350,000 tons of coal and 500,000 barrels of oil have been used annually.

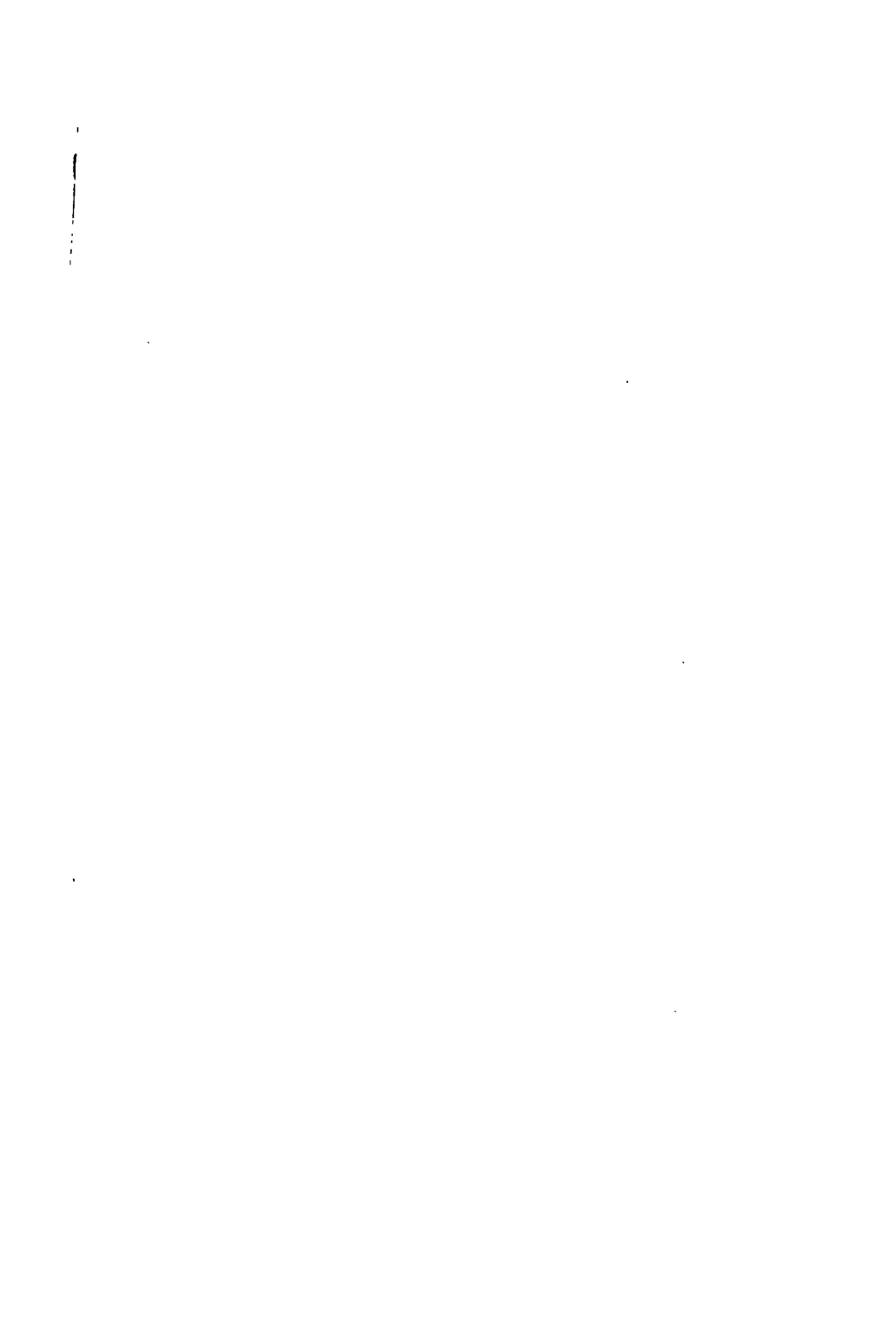
Dredging had progressed in the Pacific entrance to a point where five miles of the canal could be opened to navigation, on February 1, 1909. The *Newport* and *San Hose*, of the Pacific Mail Fleet, of American

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register, were the first ships to go through. Considerable excavating was done in both entrances by steam shovels, the water being held out by dikes.

A striking instance of miscalculating the cost of one phase of canal construction is found in the estimate made by Prof. Burr, of the first Commission, which placed the cost of private lands that would be used in the Gatun Lake and elsewhere at \$18,656,000. As a matter of fact something more than \$300,000 has been spent in this way and \$500,000 is the maximum as estimated by Col. Goethals, in 1908. The area of the Gatun Lake crosses into the Republic of Panama on the West side of the canal, and the private property so condemned as well as in the Canal Zone is valued by a joint commission of Panamans and Americans.

Columbus had been honored by naming Colon and Cristobal for him at the Atlantic entrance of the canal, and an Executive order on April 30, 1909, honored the discoverer of the Pacific by changing the name of the Pacific terminal from La Boca to Balboa. It is at Balboa that the permanent machine shops, dry docks, yards, wharves, warehouses, and general equipment to cost \$20,000,000 will be located. Col. Goethals' conception of making the canal adequate for all the needs of shipping has a military utility that is not sufficiently recognized. By making it possible for vessels to coal at the canal, secure fresh provisions, get repairs made and expeditiously handle cargoes, the United States makes it unnecessary for any foreign power to establish a coaling station and similar facili-





Photos, 1, Harris & Eving, Washington, D. C.; 2, 4, 5, Clineinst, Washington, D. C.; 3, Pictorial News Assn.

1. LIEUT.-COL. H. F. HODGES. 2. H. H. ROUSSEAU, U. S. N.
3. S. B. WILLIAMSON WITH PRESIDENT TAFT. 4. LIEUT.-COL.
D. D. GAILLARD. 5. LIEUT.-COL. WILLIAM L. SIBERT.

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ties in this hemisphere, on the pretext of caring for its merchant marine. With ice plant, cold storage, bakery and other subsistence and commissary facilities already established, it will be easy for the government to institute the practices mentioned at Balboa coincidental with the opening of the canal. Col. Goethals has been working toward that end for years and the bill passed in the 1912 Congress approves his ideas.

In 1909, Col. Goethals seems to have had the idea of making the Canal Zone habitable, for an extensive scheme of road-making was begun, and \$75,000 was spent in a survey of the Canal Zone. The survey never was finished, and since then Col. Goethals changed his views, in favor of making the Canal Zone a military reservation, the part not in use to be left to the jungle and only canal employees allowed, without special permission, in the ten-mile limits. Critics in the United States displayed their ignorance by protesting that the land in the Canal Zone should be opened to settlement, like our western lands. The canal occupies 96 square miles of the 436 in the Canal Zone and 73 square miles are privately owned. There is very little of what is left that Americans would occupy. It is in the main mountainous, and without a system of roads that would be prohibitive in cost, would not be accessible in the rainy season. Col. Goethals disposes of the idea of settlement in his usual terse way when he says: "The inducements offered by farm lands in the Canal Zone are not likely to attract Americans. Other occupants are not desirable."

The Americans have made an investment at Panama

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which should be guarded from every possible danger. In times of war everybody in the Canal Zone, of course, would be subjected to scrutiny and possibly to ejection. It will, therefore, save trouble and expense to begin, right at the start, to treat it as a military reservation is treated in the United States. The expense of sanitation and civil government would be too great to make settlement profitable.

Work on the fortifications was begun in 1911, on Flamenco Island, three miles out in the bay at the Pacific entrance, and on Toro Point at the Atlantic entrance. The estimate for their cost, as fixed by the officers appointed to design them, is \$12,475,328, and Congress, in March, 1911, appropriated \$3,000,000 of that amount. The latest and largest disappearing rifles will be installed after the concrete work is finished. The locks at the Pacific end are nearly ten miles from the fortifications, which insures them against bombardment by an enemy's ships, and the Atlantic locks are seven miles from the fortifications. Some form of defense from airships must be worked out.

It would be just as logical to say that New York should remove its traffic policemen from Thirty-fourth Street and Broadway, as to argue that the United States should not fortify the canal. The policemen are there to aid traffic by enforcing the rules which make order possible, and fortifications are necessary at Panama to insure that no nation, whether fighting the United States or some other nation, shall disable a world transit route. Neutrality would be a myth without a strong police power at Panama. [It is to

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the interest of every nation that the canal be so policed and fortified that commerce could not be disrupted through the deliberate, or unintentional, actions of belligerent nations. Warships of all nations may pass through the canal, but if of nations engaged in war, they cannot linger at either end of the canal after or before passage.

When the canal is completed, the beautiful towns along the route will be abandoned. Gorgona, Bas Obispo, Las Cascadas, Empire, Culebra, and Paraiso will be razed. A permanent camp for the Army will be located on the East side of the canal, across the Cut from the town of Culebra. Marines have been in the Canal Zone since 1904, and in 1911 the Tenth Infantry was added to the permanent garrison, which will be further augmented by several regiments. The soldiers will police the Canal Zone after construction work is finished. Balboa and Cristobal will be the principal cities, though at Gatun and Pedro Miguel forces to operate the locks will be housed.

President Taft signed, on August 24, 1912, a bill for the permanent government and operation of the canal. Col. Goethals' ideas were followed almost to the letter in drawing this bill. The President is authorized, as soon as the canal is sufficiently near completion, to abolish the present Commission and to appoint a Governor, for a term of four years, at a salary of \$10,000 per annum. In time of war, the President may substitute an Army officer for this Governor. Salaries and wages are not to be more than twenty-five per cent greater than in the United States, and

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many of the perquisites now enjoyed by the employees are to be eliminated. The Canal Zone will be open to only such persons as the Governor may admit; American coast-wise ships are exempted from paying tolls for passage; foreign-built ships owned by Americans may register under the American flag; ships owned by railroads cannot pass through the canal; the Interstate Commerce Commission is given power to determine questions of competition; and the present judiciary system is continued with right of appeal to the Federal courts in the United States. In addition, the government may sell ships supplies and coal and provide facilities for repairing vessels at the canal terminals.

At the close of the fiscal year ended June 30, 1912, Col. Goethals could look forward to one year more of the arduous labor and heavy responsibility he has borne, before the big job would be in the clear. Invoicing conditions at that date, we find that the great Gatun dam was more than 90 per cent completed; the concrete work in the locks and spillway was about 90 per cent completed; the Culebra cut was approximately 90 per cent completed; the relocated Panama Railroad was finished, and the work of establishing permanent shipping facilities at Balboa and Cristobal was under way.

Owing to fresh slides in the Culebra cut, and to changes in plans in the Pacific division, a new estimate of the total excavation for the completed canal and accessory plant became necessary at the beginning of the last complete fiscal year of canal construction—July 1, 1912, to June 30, 1913. The revised estimate

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then placed the excavation at 212,227,000 cubic yards, of which amount 175,901,052 cubic yards had been removed at the end of July, 1912, leaving to be excavated for the completed canal, 36,325,948 cubic yards. The latest estimate, however, raises the total excavation to 221,000,000 yards. The canal organization cannot remove the uncompleted portion before the first ship is scheduled to pass through the canal, in September, 1913, but of the 47,000,000 yards left, more than 8,000,000 yards are to be excavated outside of the canal proper, or in the sites for the coaling station, dry docks and terminal at Balboa, so that the actual canal channel substantially will be finished before the passage of the first ship.

The Atlantic division in July, 1912, lacked 8,009,778 yards of completion; the Central division, including the Culebra cut, lacked 10,678,953 yards; and the Pacific division, 17,637,217 yards—a grand total for the whole canal of 36,325,948. The ancient trouble, slides, prevented the completion of the Culebra cut in 1912.

During the early part of 1912, the Gatun Lake was stationary at about 17 feet, but with the beginning of the rainy season in May it began to rise, and the plan was to hold the lake, by use of the spillway, at a head of water of 50 feet until the beginning of the rainy season in 1913, when it will be allowed to raise to 80 feet, and this would back the water up, by September, 1913, to a depth through the Culebra cut to permit the passage of some kind of a ship. The ultimate level of the lake will be 85 feet.

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There have been many estimates of Col. Goethals in the magazines and newspapers and in books. They all pay tribute to him as an administrator without a superior. Some writers have been so impressed by the man that they rate him a larger fact than the canal itself. Yet it is possible to gauge the man without overshooting the mark in that fashion. Congress gave him a credit of \$290,000,000 and allowed his estimates of annual expenditures. He has missed the worries of a private contractor who has to consider the financial ways and means of his operations, and besides, the dissatisfaction of employees have been stifled by an unparalleled standard of pay and by gratuities that make nearly every position in the Canal Zone in the nature of a sinecure. Contentedness has been bought by pouring millions of dollars into creating not merely comfortable, but even luxurious conditions of living for the employees.

No private enterprise could succeed for a moment on such a basis. On its economic side, the canal proves nothing because any competent organization could bring things to pass if only enough money is forthcoming, as has been the case under the government in Panama. An admirable job has been done in Panama, but it has not been economically done, in the usual understanding of that word. Nobody set out to do it economically. Every leak has been plastered with a dollar. At no point does the canal project affect a complete economic operation. Money is being spent but it is not being made. The work is being done without regard to its ever paying.

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Socialists, therefore, should be cautious in holding up the canal as an example of their theories in successful practice. Industrial life, even under Socialism, would have to do what the canal project has not done and is not required to do, namely, justify itself as a business proposition. The canal ultimately may do this, but it will not be because it was designed and constructed with that imperative end in view. Even the commissary and subsistence operations that usually evoke strong approval as evidences of governmental efficiency, possess no socialistic and slight communal aspects. The government has made them pay by arbitrarily exacting a profit under noncompetitive conditions. None of the forces of industrial life that tend to make for favorable or unfavorable economic conditions, can operate in a government job which secures its capital, not because of the intrinsic merit of the enterprise, but through the gratuitous function of taxation.

If we turn to the purely technical side of the project, unquestionably the highest praise is due to the Army engineers. On its engineering side, the canal proves that the government does not have to go outside its own forces to find the highest order of ability. The American people never again will clamor for private initiative and execution of any enterprise they may want accomplished.

Col. Goethals is indeed a great administrator. Even if the employees have had soft conditions of employment, it is an achievement to impress 35,000 men with a faith both in your capacity as an engineer and your

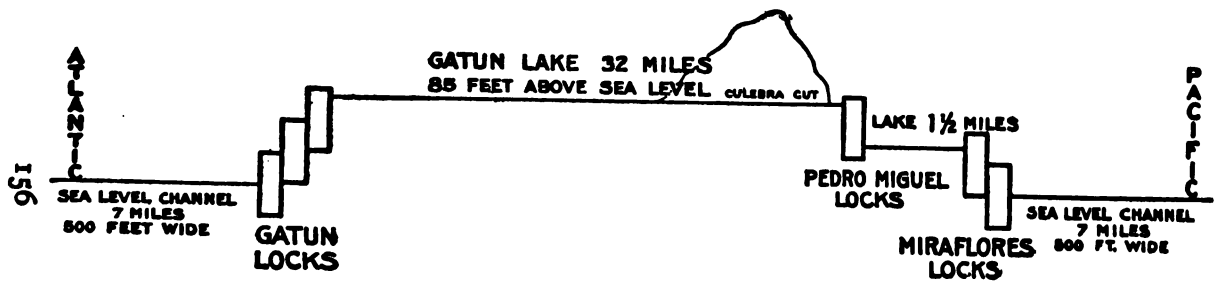
THE AMERICANS IN PANAMA

sense of justice. This writer knows of no higher tribute that can be paid to him than the statement that in five months in the Canal Zone he never heard anyone speak slurringly of the Chief Engineer. Col. Goethals has been no respecter of persons. In 1912, two officials drawing \$300 a month salary each, were discharged as summarily as any common laborer would have been, for breaches of the rules. It has been his practice to give his Sunday mornings to hearing grievances from employees, and those without just grounds of complaint are sent about their business peremptorily, while those who have been wronged are given justice, no matter how high the official who is in error. The man's admirable poise is shown in the just way he has exercised the absolute power of a Czar, for when he sets his pen to paper a new law is made in the Canal Zone. Those who cannot square their conduct with his fiat, go out on the next steamer, whether an individual or a labor union *en masse*.

As Admiral Schley said of the controversy over the battle of Santiago, "there is honor enough for us all," so with regard to the Panama Canal. Col. Goethals, as the star of the last six years, gets the curtain calls, but even if we assign Messrs. Stevens and Wallace to the rôles of villains, they, too, did their parts well. And the whole company of Americans, composing the chorus or supernumeraries, have contributed vitally to the success of the play. After all, it is no one man, but the Spirit of Americanism, indomitable and triumphant, that we admire in Panama. Future generations will see in Col. Goethals the outward head

GOETHALS

of this national characteristic, but the final verdict of approval will be much broader and more just than that, even to the admission that all praise belongs to the Americans in Panama.



PROFILE MAP OF THE PANAMA CANAL.

CHAPTER XIV

LOCKS AND DAMS

AN elevator system for ships is being installed at Panama at a cost of \$58,000,000. These elevators, known as locks, will raise ships to and lower them from the great artificial, inland lake which is 85 feet above sea-level.

In a sea-level canal, such as Suez, ships steam through a dug-out channel from one ocean to another. But at Panama, the plan adopted involves the lifting of ships over the Isthmus and the locks are the means whereby they are lifted. For this physical operation there are six locks on the Atlantic side and six on the Pacific side, at each end of the Gatun Lake.

A ship arriving at Colon from New York, on its way to San Francisco, enters the sea-level channel in Limon Bay and steams for seven miles through the canal, which is 500 feet wide and 41 feet deep, to Gatun. Here its way is barred by a massive pile of masonry with impressive steel gates and towering 85 feet above the ship is the surface of the Gatun Lake. To the West of the ship runs the man-made mountain, the Gatun dam, which holds the lake in bounds. The problem is to lift the ship to this lake.

As if by magic, the gates swing open and an electric locomotive, which has run out on a guide wall and fastened to the ship, tows it into the first lock. The

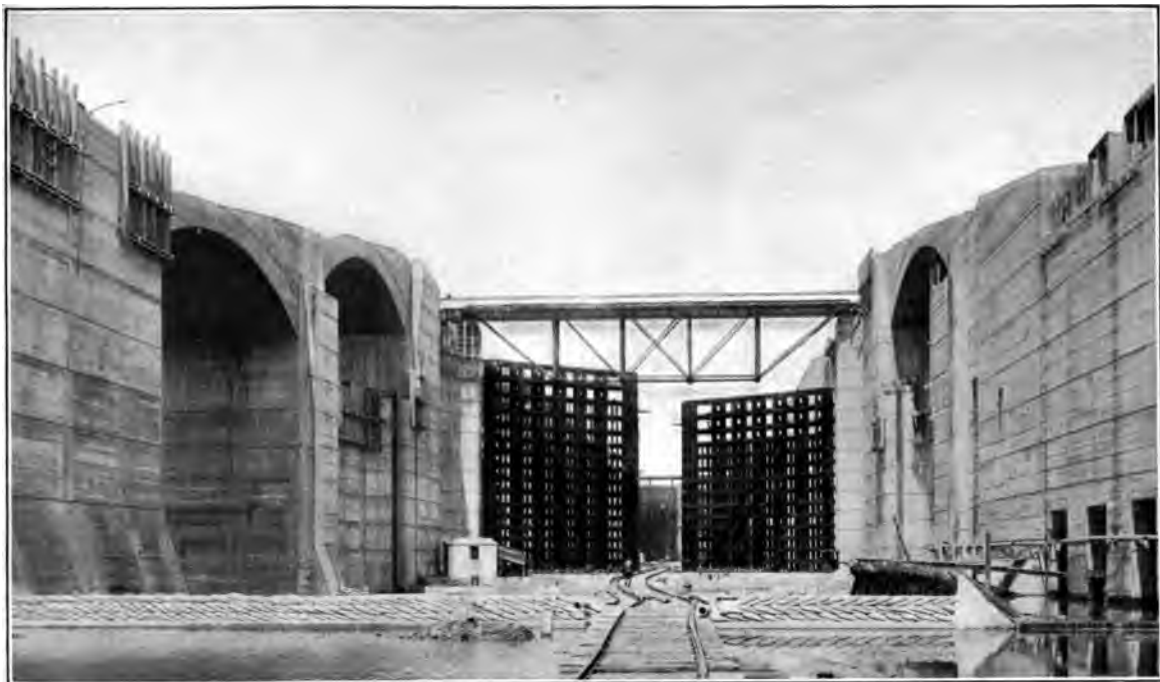
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gates swing together and the ship is imprisoned in a chamber 1,000 feet long and 110 feet wide and built of concrete. In a moment the water in this chamber begins to rise, being supplied through holes in the bottom, and the ship rises with the water.

Fifteen minutes after entering the lock, the ship has risen with the water for $27\frac{1}{2}$ feet. If the full capacity for filling the lock should be used the ship would rise that height in eight minutes. Another set of gates swing open in front of the ship, and the locomotives tow it into the second lock, a concrete chamber of the same dimensions. The gates having closed behind, this chamber begins filling with water until the ship is raised again for $27\frac{1}{2}$ feet. A third set of gates open and the ship is towed into the final lock where the operation is repeated with a raise of 30 feet, or a total lift for the three locks of 85 feet. When the gates in front swing open the ship steams out into the Gatun Lake. The time spent in climbing 85 feet was an hour and a half.

For sixteen miles through this lake the ship steams in a channel 1,000 feet wide; for four miles in a channel 800 feet wide, and for three miles in a channel 500 feet wide, or twenty-three miles in all. Then it enters the famous Culebra cut, which is 300 feet wide through the continental mountain divide, and nine miles long. At the end of the Cut is the Pedro Miguel lock, thirty-two miles from Gatun.

After entering this lock, which essentially is the same as the ones on the Atlantic side, the ship goes through the reverse of the process at Gatun. The



Photograph, Underwood & Underwood, N. Y.

ENTRANCE TO A LOCK—GATES UNDER CONSTRUCTION.

LOCKS AND DAMS

water in the concrete chamber begins falling, taking the ship down with it. When it has fallen 30 feet the gates in front open and the ship goes out into another artificial lake, a mile and a half long, at the end of which are the Miraflores locks. These two locks lower the ship $27\frac{1}{2}$ feet each, or a total for the three locks of 85 feet, which was the height the ship was raised on the other side. The ship then steams through a sea-level channel for seven miles to the Pacific, having made the whole journey from deep water in the Atlantic to deep water in the Pacific, fifty miles, in ten hours.

Thus it will be seen that the Atlantic and Pacific oceans are still separated by thirty-two miles of land at Panama, on which is a fresh-water lake 85 feet above sea-level. The locks simply are so many stair-steps up to and down from this lake. At both ends the locks are built in pairs, or twins, so that ships going in opposite directions may pass through them simultaneously. A wall 60 feet thick separates the locks, and if one set should become disabled, the adjoining set still would be available for passage. The time required for a ship to mount the three locks on one side and descend the three locks on the other side is three hours.

On the Atlantic side, the locks at Gatun are connected and constitute one solid piece of masonry. On the Pacific side the lock at Pedro Miguel is separated from two locks at Miraflores by a small lake a mile and a half long. This lake, like the great Gatun Lake, is formed by damming rivers. A dam at the Pedro

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Miguel lock, which is the first lock encountered going toward the Pacific, holds the waters of Gatun Lake from spilling down the Pacific slope.

Chief Engineer Stevens began the excavations in the Gatun and Pedro Miguel lock sites in 1906, shortly after the decision was made for a lock-type canal, but most of the excavation and all of the concrete laying has been done under Col. Goethals. It was necessary to remove about 5,000,000 cubic yards of rock and earth from the site of the three locks at Gatun to prepare a foundation for the tremendously heavy structure. Careful borings had been made to ascertain if a suitable foundation could be found there.

On August 24, 1909, the first concrete was laid in the Gatun lock site. Rock of a desirable kind for use in making the concrete, as well as sand, could not be found in the Canal Zone, and experiments along the coast showed that at Porto Bello, twenty miles East of Colon, good rock could be quarried, and sand was discovered in suitable quantities and quality at Nombre de Dios, forty miles East of Colon. These two places are the oldest on the Isthmus, Columbus having been there in 1502.

Rock crushing began at Porto Bello on March 2, 1909. If all the rock and sand removed from Porto Bello and Nombre de Dios was placed in barges separated by the usual distances in a tow, they would reach from Colon to New Orleans, or 1,500 miles. This material was towed to Colon and thence through the old French canal to Gatun. Here it was unloaded

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by machinery and stored conveniently for the concrete mixing plant.

All the machinery and equipment for building the locks was designed on a scale commensurate with the unprecedented size of the structures. Eight giant mixers were fed with rock, sand, and cement by cars operated by electricity, the finished product coming from each of the mixers at the rate of 64 cubic feet for each complete operation.

To get the concrete into place, four cableways, suspended across the lock site on towers 85 feet high, were installed. Electrically operated cars brought the concrete to these towers where great buckets were filled. These buckets then were run up to the cables, and out on the cables to a given point, where they were lowered and the concrete dumped into the proper position.

After the floors of the locks had been laid, the walls were built in the usual manner of erecting steel forms, which were removed when the concrete had hardened. At Gatun the walls of the locks were built in sections 36 feet long, and joined together, on the idea that such construction would have less tendency to settle and crack than if it was built in one solid, continuous wall. This may be appreciated when it is understood that at Gatun the locks form a concrete wall about 3,500 feet long, or considerably more than half a mile. The usable part of each lock is 1,000 feet long and there are three in flight. The twin locks have an outside wall 52 feet wide, an inside measurement 110 feet wide, a separating wall 60 feet wide, another inside

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measurement of 110 feet, and a final outside wall 52 feet wide, or a total width for both locks lying side by side, from outer wall to outer wall, of 384 feet.

In each of the outside walls and in the center wall tunnels 18 feet in diameter were constructed for use in filling and emptying the locks with water during the processes of raising and lowering ships. Smaller tunnels run out from these main longitudinal tunnels, under the floors of the locks with openings through which the water is turned into or withdrawn from the lock chambers by gravitation. Valves operated by electricity regulate the flow of the water. The water for operating the locks starts from the Gatun Lake and flows through the tunnels downgrade, through the three locks, until it finally is used in the lowest lock when it is spilled into the sea-level channel.

The first concrete for the Pacific side locks was laid at Pedro Miguel on September 1, 1909, seven days after the beginning of operations at Gatun. It was in February, 1910, that concrete work was started in the two locks at Miraflores, which, in 1912, were the most backward feature of canal construction. For all twelve locks, 4,302,563 cubic yards of concrete is required. Three years after beginning the concrete work, or in August, 1912, the locks were more than 90 per cent completed, the one at Pedro Miguel being the nearest done with 98 per cent of the estimated concrete in place. The three locks at Gatun then had about 95 per cent in place and the two at Miraflores about 80 per cent.

For the three locks at Gatun, 2,000,000 cubic yards

LOCKS AND DAMS

of concrete was required; for the one lock at Pedro Miguel, 889,827 cubic yards; and for the two locks at Miraflores, 1,412,736 cubic yards. A contract was awarded the Atlas Portland Cement Co. for 4,500,000 barrels of cement, with the privilege of increasing this order by 15 per cent, and in 1912 another 1,000,000 barrels were bought to complete the canal. The stability of the locks depends upon the quality of cement used, hence the Government inspectors have watched this factor jealously.

Rock for the Pacific locks has been obtained at a quarry opened in Ancon hill, at the Pacific entrance of the canal. The sand has been brought from Chame, about 23 miles up the coast from Panama. The Pacific division has been at much less expense in obtaining materials than the Atlantic division, accounting for the difference in the cost of construction in the two divisions. The Pacific division was at one disadvantage in that the three locks were not together, as on the Atlantic side, necessitating practically two separate jobs. The amount of excavation at Pedro Miguel to secure a foundation was 770,000 cubic yards and at Miraflores, 2,247,600 cubic yards, a total for the three locks of 3,017,600 yards, which is nearly 2,000,000 yards less than had to be excavated in the site of the three Atlantic locks.

All twelve locks were half done as regards the concrete work, about May 1, 1911. The best month's record for laying concrete was made in April, 1912, in the Pacific division, when 97,735 cubic yards were laid. The concrete is all of reënforced construc-

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tion, and an unusual feature has been the placing of rocks weighing many tons throughout the walls. The lock walls at Pedro Miguel were not built in sections as at Gatun, but as one solid piece of masonry more than 1,000 feet long. At Miraflores the two locks were built in sections, as at Gatun.

The gates for the locks were contracted for, in 1910, to cost \$5,374,474.82. Their construction and erection are by the McClintic-Marshall Construction Company, of Pittsburgh, under the inspection of the Commission. This concern, in 1912, had more than 1,000 men at work and were rushing the construction to meet the dates agreed upon for their completion. Under the contract this company had until January 1, 1914, to finish the work, but estimated that this time could be beaten by six months. The date for finishing the gates at Pedro Miguel lock was May 1, 1912, but the contractor was behind on this program; at Gatun the gates were to be erected by February 1, 1913; and at Miraflores by June 1, 1913. Work was rushed on the gates at the lake end of the Gatun locks, in the summer of 1912, to hold out the rising water. On July 1, 1912, out of a total of 58,000 tons of steel required in all the gates, 19,631 tons had been erected, or 34 per cent, leaving to be erected before September, 1913, when the first ship is scheduled to go through, 38,369 tons.

There are 46 gates in all twelve locks, with two leaves to the gate, or 92 leaves. The gates are from 47 to 79 feet high, are 7 feet thick, and weigh from 300 to 600 tons each leaf. They are constructed with



Photograph, Underwood & Underwood, N. Y.

INTERIOR OF A LOCK—CAPACITY, TWO SHIPS AN HOUR.

LOCKS AND DAMS

interior cells, which at the bottom will be air chambers to assist in their manipulation, and at the top, water chambers, to increase their weight as the water rises in the locks. The sheathing is with steel plates riveted on heavy girders. These gates will be opened and shut, to permit the entrance or egress of ships, by electrical apparatus.

As 95 per cent of the vessels in the world are less than 600 feet long, it would be a great waste of water and time to use the full 1,000-foot lock in each passage. So intermediate gates are being constructed which will permit the use of only 400 or 600 feet as the particular vessel may require. There are recesses in the lock walls which allow the gates to be opened and still leave a clear width of 110 feet. At the entrance of the locks, a chain, with links three inches in diameter, stretches from one side to the other to stop vessels which might not obey the signals. In case the first gates should be rammed and broken, a second set of gates especially provided for emergencies have been constructed behind the first set. If both sets of gates should be demolished, the water would rush through with a fearful velocity, but provision has been made against this contingency by having in readiness emergency dams, which would be swung out over the lock and forced down through the in-rushing water. This dam, built of steel, is open at the bottom and steel plates are then shoved down it, gradually closing the openings until the flow is stopped. A floating caisson would then be placed in position and sunk, completely shutting out water from

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the lock, the emergency dam would be raised, and repairs begun.

It is to prevent such accidents that the plan of towing vessels through the locks with electric locomotives was adopted, as then no misunderstanding of signals from the captain to the engineer of a ship could result. The tracks for these locomotives are on each side wall of the locks, and two will fasten to the rear and two to the front of a ship to effect a passage. If all twelve locks were joined end to end they would make a canyon nearly three miles long, 110 feet wide and 80 feet deep.

THE GATUN DAM

The natural topography of the Isthmus at Panama permitted the Chagres River to escape into the Caribbean Sea through a break in the mountains at Gatun. Engineers logically considered that this was the point at which a dam should be thrown across the Chagres River. Two valleys were formed at Gatun by a hill which rose in the center to an elevation of 110 feet, and the dam that was designed runs from the Gatun locks to this hill and from this hill to the mountains, a total distance of 7,500 feet, or a mile and a half.

As the Chagres River every year discharges enough water to fill the lake, some means of disposing of the surplus water had to be provided. The plan adopted called for a spillway to be constructed in this hill, about third-way in the dam site. This spillway is of concrete, requiring 225,000 cubic yards to complete.

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On July 1, 1912, it was more than 90 per cent completed.

The floor of the spillway is 10 feet above sea-level, and 300 feet wide through the hill, which involved excavation through rock for a depth of 100 feet at the highest point of the hill. A concrete dam was built on this floor to a height of 69 feet above sea-level and in shape like a semicircle. On top of the concrete dam, piers were built with an arrangement for steel gates. These steel gates will be electrically operated and regulate the flow of water out of the lake. As much as 140,000 cubic feet of water per second may escape through the spillway when the gates are open.

There will not be a complete loss of this water, as on the east side of the spillway a power plant of the hydro-electric type will be operated. A drop of 75 feet by the water will operate turbine engines which in turn will operate the electric machinery that will generate all the power and illuminating current needed from one end of the canal to the other. But an additional power plant will be maintained at Miraflores for emergencies. The power to operate the lock gates will come from the spillway plant.

The Gatun dam is so stupendous that it almost seems to be a continuation of the hills that enclose the lake. It in fact does complete the natural mountain chains that form the barriers of the Chagres River. It is 105 feet high, or 20 feet above the ordinary level of the lake at 85 feet elevation. The plan of construction has been to build parallel mounds, for the mile and a half, 1,200 feet apart. Between

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these mounds, built of rock and earth, a core for the dam has been constructed by pumping mud and sand from the bed of the Chagres River. About 20 per cent of the material pumped is solid matter, and when it has deposited the water is pumped off. This operation has been repeated until an impervious heart has been made in the dam. Even if water from the lake penetrated the outside walls of rock and earth, it would find this core water-tight. The dam is nearly half a mile thick at the base, 398 feet thick where the water surface strikes it at 85 feet, and is 100 feet wide at the top. The outer coverings of rock and earth on the dam close over the hydraulic core at the crest. For about 500 feet the dam will be subjected to the full pressure of 85 feet of water, at other points to a less severe pressure.

Engineers consider the dam excessively safe and the layman has no difficulty in appreciating its strength. This feature was subjected to a storm of criticism throughout the early days of the canal because some engineers believed the earth would not support so heavy a structure, but the present Chief Engineer never has doubted its stability. About half of the material required, 21,994,111 cubic yards, has been brought from the Culebra cut. On July 1, 1912, the dam was more than 90 per cent completed, leaving less than 10 per cent to be done before the passage of the first ship.

On the Pacific side, the first dam encountered is at Pedro Miguel and serves to hold the waters of Gatun Lake at its southern end. It is 1,400 feet long and

LOCKS AND DAMS

forty feet wide at the top. The maximum height of the water against this dam will be 40 feet. The plan of construction is much the same as at Gatun, but only about 1,000,000 cubic yards will be required.

After a ship is lowered 30 feet by the Pedro Miguel lock, it finds itself in an artificial lake a mile and a half long. This lake is formed by two dams, the one to the west being 2,300 feet long, and 40 feet wide at the top, holding a maximum head of water of 40 feet. It is constructed with a hydraulic core like the Gatun dam. On the east a concrete dam 500 feet long, and provided with a spillway, as at Gatun, and capable of discharging 7,500 cubic feet of water per second, will hold the small lake in control. The Cocoli River is the principal feeder of this lake.

Records kept by the French, and by the Americans since 1904, show conclusively that enough water always will be available to keep the Gatun Lake and the tiny Miraflores Lake adequately supplied with water. No trouble at all can develop during the eight months of rainy season, and in the dry season of four months enough water will have been stored in the lake by means of the regulating works in the Gatun dam spillway to allow for all losses through evaporation, seepage, power consumption, and loss through the locks. During the wet season the lake will be raised from elevation 85 for two feet, to elevation 87, over an area of 164 square miles. This water could be used until the lake falls to about 82 feet, or five feet over the 164 square miles. In an average dry season this would permit 58 complete transits of the canal

LOCKS AND DAMS

Colon, seven miles away, or pass through the old bed of the Chagres River harmlessly into the Caribbean Sea. While the pressure on the dam will be terrific, no such catastrophe is considered probable.

CHAPTER XV

THE CULEBRA CUT

POPULAR interest always has centered chiefly in the excavation phase of canal construction, losing sight of the fact that the locks, dams, and breakwaters call for an expenditure of \$85,643,000. The Culebra cut has been exploited more than any other feature of the canal, yet it was estimated to cost \$80,481,000, or five million dollars less than the features just enumerated. Even the dredging of fifteen miles of sea-level channel has received little publicity, and this was to cost no less than \$30,906,000.

The physical aspects of the dry excavation doubtless account for this singling out of one feature by the public mind. However stupendous the laying of concrete might be in the locks, or the sucking up of mud by the dredges, they are not as impressive as cutting through a mountain chain. They are prosaic operations compared with the picturesque attempt to change geological conditions. In the Culebra cut, Man was wrestling with Nature, whereas, in lock-building, he merely is playing the rôle of mason.

One finds in government work that the chief aim seems to be to plant two employees where only one worked before, and the canal organization is the least overworked set of employees in the world, but in the excavation phase of the government work the organ-



Photograph, Underwood & Underwood, N. Y.

THE CULEBRA CUT, LOOKING TOWARD THE PACIFIC.

THE CULEBRA CUT

ization has attained as great efficiency as any private contractor could have attained, under the conditions adopted in the Canal Zone. World records for steam shovel performances have been broken by government employees in Panama under adverse circumstances.

The Culebra cut is nine miles long with a curve for nearly every mile. At these curves, the cut is widened to permit the ships to pass easily. Always the chief problem has been one of transportation, or how to keep empty cars in front of the steam shovels constantly, in a canyon only three hundred feet wide. In a working day of eight hours it has been found possible to keep the steam shovels working only about six hours, because of this circumscribed field of operations.

Naturally the 75 miles of track in the Culebra cut must be shifted constantly as the excavation work carries the levels down. This keeps the track shifters and hundreds of men at work day and night. During the maximum operations in the Cut, 6,000 men were employed in the daytime, while at night 400 men worked to keep the steam shovels in repair, to replenish their coal bins, blast more material for the shovels, and otherwise to get the Cut in shape for the next day's activities.

About 100,000,000 cubic yards were to be removed to complete this part of the canal, or practically half the total excavation. On July 1, 1912, the beginning of the last year of work, there were 7,399,615 yards left to be removed, which would have been out by January 1, 1913, at the rate of excavation, if it had

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not been for the slides. To this had to be added 6,000,000 yards from that source, or more than 14,000,000 yards to be removed in order to get the Cut in shape for the passage of the first ship. It was decided then to keep the 38 steam shovels at work and operations at full blast until July, 1913.

For the whole length of the Cut, the average depth from the surface to the proposed bottom of the canal was about 120 feet, the highest point on the center line of the canal being at Culebra between Gold and Contractor's hills where excavation has gone down 272 feet. After the soil had been removed for a short depth, solid rock was struck and to January 1, 1913, 54,504,150 pounds of dynamite were used in blasting, or the staggering total of 27,252 tons. The lay mind thinks of a pound of dynamite as impressive, but its use in the canal work has been bewilderingly heavy.

The following table shows the amount of dynamite used for the nine years of American operations:

1904 and 1905	500,000 lbs.
1906	1,400,000 "
1907	5,087,000 "
1908	6,822,000 "
1909	8,270,000 "
1910	10,403,000 "
1911	9,501,850 "
1912	8,533,000 "
1913	3,986,500 "

THE CULEBRA CUT

Most of the explosive has been used in the Culebra cut. It is estimated that a pound of dynamite will break up 2.14 cubic yards of rock and earth, and as much as 26 tons has been set off in one blast in the canal. Stringent rules have prevailed to prevent accidents, and while deaths from this cause have run into the hundreds the handling of this amount of dynamite has been distinguished for the small number of fatalities. In September, 1908, a steam shovel dug up a bushel of dynamite left by the French in 1887, but it had lost its potency. The largest single shipment of dynamite to Panama was 846 tons received on June 27, 1911, without an accident in loading or unloading from the steamer.

All through the day drills, operated by compressed air, are boring into the rock in the Cut for 24 feet. A small charge of powder is set off at the bottom of these holes to enlarge them for the real charge of as much as 200 pounds. Then after the men have quit for the noon hour, or after five o'clock in the afternoon, the charges are set off by electric current. It sounds like the steady booming of artillery in the Cut. Many persons have been killed by being struck by rocks hurled long distances in these blasts. The next morning the steam shovels find plenty of food for their hungry jaws, which bite off four or five cubic yards at a dip, swing around and drop the six or seven tons upon the cars. Frequently they lift rocks so heavy that the cars are broken.

From 150 to 175 trains a day loaded with excavated materials leave the Culebra cut for the dumps.

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A great deal has gone to build the mighty Gatun dam; much has been used in reclaiming nearly 400 acres from the ocean at Balboa, the Pacific terminal; the new Panama Railroad has required millions of yards in making fills; and the breakwater at Balboa also has taken a considerable amount. What could not be usefully employed has been wasted on dumps. The average haul from the Cut has been twelve miles, but as much as thirty miles must be traveled by some of the dirt trains. Twenty flat cars constitute a train and one car can be loaded by a shovel in two and a half minutes, or with seven scoopsful of earth and rock. When the trains get to the dumps, an unloading plow is drawn by a steel cable over the flat cars, sweeping the material off the side which is open. Then spreaders are pushed over the track to shove the material to one side and down the embankment. Track shifters later come along and move the track over to the edge of the fill. Between 1,000,000 and 1,500,000 yards have gone out of the Culebra cut every month, except one, since December, 1907.

The employees are carried from the various towns to their work in the Cut, or on the locks and dams, by labor trains. The largest labor train in the world was operated out of Panama to Pedro Miguel until July, 1912, when it was divided into two sections. These trains bring them to their homes, or the hotels, for the noon meal, consuming from ten minutes to half an hour in the journey. But as the rest period at noon is for two hours in the Canal Zone, ample time for eating is allowed. Tourists go through the

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Cut on a special train that costs the government a great deal of money because of the disarrangement of dirt train schedules, every minute a shovel is kept idle thereby costing Uncle Sam a pretty penny and making the men swear because they may be sweating for a record day's work.

In the month of March, 1909, more dirt was taken out than in the first twenty-two months of operations. The excavation in one month usually exceeds an amount equal to the Pyramid of Cheops, which is 750 feet square and 451 feet high. The canal force of 1909-1910-1911 would have dug and finished the Suez Canal. March, 1911, retains the record for the greatest excavation in the Cut, when 1,728,748 yards were removed, and this also is the record month for excavation for the whole canal, with a total removal of 3,327,443 yards. The average daily output of steam shovels rose from 500 yards in 1905, when only dirt was handled, to 1,500 yards in 1911, when rock predominated. The cost in the Central division has ranged from 10 cents a yard to 91 cents a yard, with an average of 91 cents, from 1904 to 1909, and fell to 51 cents in 1911-12.

Rains interfere with the excavation work in the Cut, reducing the output in the rainy season several hundred thousand yards a month. During the downpours, operations must be suspended, but the Cut has been dug at a slant on both sides of the mountain system, so that water is drained out of it by gravity, running out at both ends. Rivers which crossed the line of

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the canal have been diverted by digging new channels for them.

The precise date when the canal was half dug, in the year 1910, cannot be fixed until the water is turned into the Cut and dredges begin handling the slides, after ships are using the canal, but on a basis of 221,000,000 yards excavation, it was half done about July 1, 1910. Slides make a revision of the estimates almost a monthly task for the Chief Engineer. The Culebra cut was half finished about July 1, 1910.

Almost at the wind-up of operations the canal diggers made the highest records for excavation. On April 11, 1912, forty-four steam shovels took out 68,505 yards in the Cut, which is the record for one day in that division. Steam shovel No. 257 working at Gatun took out 5,554 yards in one day, the highest record in the Canal Zone for one shovel, the date being May 2, 1912, and in August, 1912, the same shovel made a record by removing 86,844 yards in 26 working days.

That part of the Central division which is little mentioned, extends from the Gatun locks to the entrance of the Culebra cut, about twenty-three miles. Only about 12,400,000 yards had to be excavated to complete this channel as it follows the Chagres River valley from about sea-level to Bohio, then the level rises until it reaches 48 feet above sea-level at the Cut. From Gatun to Obispo the Chagres River crossed the line of the canal twenty-three times. In the same distance the Chagres River has 26 tributaries, the more

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important ones being the Gatun and Trinidad rivers. All contribute to the great Gatun Lake.

The slides, which have been accurately and inaccurately exploited in the press, represent the steep sides of the Culebra cut breaking off and falling down into the excavated part. Even where the Cut has been sunk through solid rock these slides occur, as the rock formations of the Isthmus are brittle and dissolve to dust after exposure to the atmosphere. An attempt was made to prevent slides by plastering the sides of the Cut with concrete, but the experiments were futile. There are between fifteen and twenty important slides on both sides of the nine-mile Cut, the largest being on the West side of the canal near the town of Culebra, and embracing 63 acres. Around the towns of Culebra and Empire are many smaller slides that have given much trouble to the engineers. Steam shovels, locomotives, and flat cars have been caught in these slides, but, singularly, few lives have been lost.

Sometimes the pressure on the sides of the canal operate to make the earth bulge up in the bottom of the Cut. Division Engineer Gaillard devised the plan of terracing the sides of the Cut to relieve this pressure with the result that much extraneous material has been prevented from sliding into the Cut. Engineers who formerly stood stanchly for the sea-level type of canal, after seeing the slides of the present 85-foot level lock type, are forced to admit that the attempt to sink a cut through the Isthmus for a sea-level channel would be attended by such prodigious

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earth movements, necessitating such an inestimable additional excavation, as to make it well nigh impossible. For a sea-level canal the Culebra cut would have to go 85 feet deeper than in the present plan, which would require both a wider bottom and indefinitely wider surface opening, and then the slides would be immeasurably greater than at present. The best year's work in the Culebra cut was 16,586,891 yards. Slides first and last have added more than that amount to the total estimate of excavation for the division. Yet the increase in efficiency of the organization has enabled the workers to handle the extra amount within the time and cost estimated for taking out the original yardage.

Three methods of excavation have been employed in digging the seven miles of sea-level channel on the Atlantic side and the eight miles of similar channel on the Pacific side. Steam shovels dug down on the Atlantic side to forty feet below sea-level, with great dikes to hold out the water, and dredges have done the remainder of the excavating. On the Pacific side, in addition to dredges and shovels the hydraulic method has been used. This method consists of playing a powerful stream of water on the earth and draining the water with the soil in a fluid state to a selected dump which has been boarded, the water being drained off when the mud has deposited. The Atlantic entrance required an excavation of 47,523,000 cubic yards and the Pacific entrance 58,287,000 yards. On July 1, 1912, the former lacked 8,592,773 yards of



THE DEEPEST PART OF THE CULEBRA CUT.

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1904	243,472 cu. yds.	
1905	914,254	“
1906	2,702,991	“
1907	9,177,130	“
1908	13,912,453	“
1909	14,557,034	“
1910	15,398,599	“
1911	16,596,891	“
1912	15,314,978	“
1913	9,200,000	“

99,015,217 cu. yds.

For the whole canal, the excavation year by year since 1904 was as follows:

May 4 to December 31, 1904.....	243,472 cu. yds.	
January 1 to “ 1905.....	1,799,227	“
“ “ 1906.....	4,948,497	“
“ “ 1907.....	15,765,290	“
“ “ 1908.....	37,116,735	“
“ “ 1909.....	35,096,166	“
“ “ 1910.....	31,437,677	“
“ “ 1911.....	31,603,899	“
“ “ 1912.....	29,258,852	“
“ to August 31, 1913.....	13,653,564	“

205,933,379 cu. yds.

The above table estimates the excavation by the time the first ship is scheduled to pass through the

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canal. Terminal works at Balboa requiring more than 8,000,000 yards excavation, and finishing details of the canal channel proper, will bring the total excavation, by January 1, 1914, when the canal is expected to be in regular commercial use, to 221,000,000 cubic yards.

It will be noted that the calendar year 1908 marks the highest record for annual excavation since the Americans began, overtopping the nearest year's record by more than two million yards. It also represents the amazing increase of two and a half times the output of the year 1907, just preceding it, the explanation of which is found in the fact that the long period of preparation has been passed in 1907 and the great canal organization, built up by Mr. Stevens, struck its stride and plunged dynamically at the natural obstacles.

The year 1908 recorded the greatest annual excavation in the Atlantic division, the year 1909 the maximum excavation in the Central division, and for the Pacific division the highest annual excavation was in 1910.

In the late spring of 1912, the press in the United States exploited the discovery of volcanic formations in the bottom of the Culebra cut. The engineers have not been alarmed by these vaporous emissions, which, in July, had about stopped, and were caused, according to the Commission geologist, by the warm atmospheric effect upon pyrite material. A great variety of colored stones are found in the blasted material in the Cut, and when cut and polished make attractive ring

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settings and other souvenirs. One crystal-like stone has been found hard enough to cut glass. No coal or other usable minerals have been struck in the excavations.

In the first plans for relocating the Panama Railroad, it was designed to run the tracks on the edge of the Cut at an elevation of 10 feet above the water level, but the slides made this impossible. The new line was placed well back from the Cut away from the probability of slides. An observation tower used by thousands of tourists, back of the town of Culebra, for viewing operations in the Cut, was removed in June, 1912, just in time to prevent its sliding into the cut, and in August two slides near Empire threw 1,200,000 yards into the Cut, or more than a month's work.

It will be a time of mingled emotions when the canal employees stand on the side of the Cut, in 1913, and watch the waters of Gatun Lake creep up and cover the scene of nine years' work, and then to watch a ship pass in an interoceanic trip that has been the dream of four centuries.