The Panama Canal: Uniting the World for Seventy-Six Years

The background, planning and construction of an outstanding engineering achievement presents lessons that are still worth knowing in a high-tech age.

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On August 15, 1914, the steamer Ancon made the first passage through the Panama Canal from the Atlantic Ocean to the Pacific Ocean. Following the ship through the Canal was Colonel George Goethals, the Chief Engineer of the Panama Canal project. The canal worked flawlessly on that day and has worked day-in and day-out for the past seventy-six years. No project built to that date, and possibly since then, has been of that magnitude and has been constructed under such unfavorable environmental conditions.

The Isthmus

The Isthmus of Panama runs primarily in an east to west orientation at a latitude of approximately 10° north (see Figure 1). The location of the canal is approximately at the same longitude as Buffalo, New York. The isthmus is as narrow as 35 miles at Darien and is approximately 50 miles wide at the canal site. The northern slopes of the isthmus are drained primarily by the Chagres River which can range between the extremes of being a docile stream to a raging torrent that can rise over 40 feet in a twenty-four hour period. The rugged Cordilleras that hug the Pacific side of the isthmus range from an elevation of 278 feet at Culebra to over 1,000 feet at other locations east and west of Culebra.

There are two seasons in Panama: rainy and dry. The dry season is concurrent with winter in the United States and has been described as being as close as anyone could ever come to paradise. The rainy season, however, is as close, for anyone who is working with soil and rock excavation, to the worst possible weather that could ever be imagined. It rains every day and at an intensity that has to be experienced in order to be appreciated. The isthmus had been called a pest hole, with diseases such as yellow fever and malaria being as common as measles and mumps were at that time in the United States.

Panama was discovered by western man in 1502 when a Spanish explorer by the name of Rodrigo de Bastidas sailed northward and

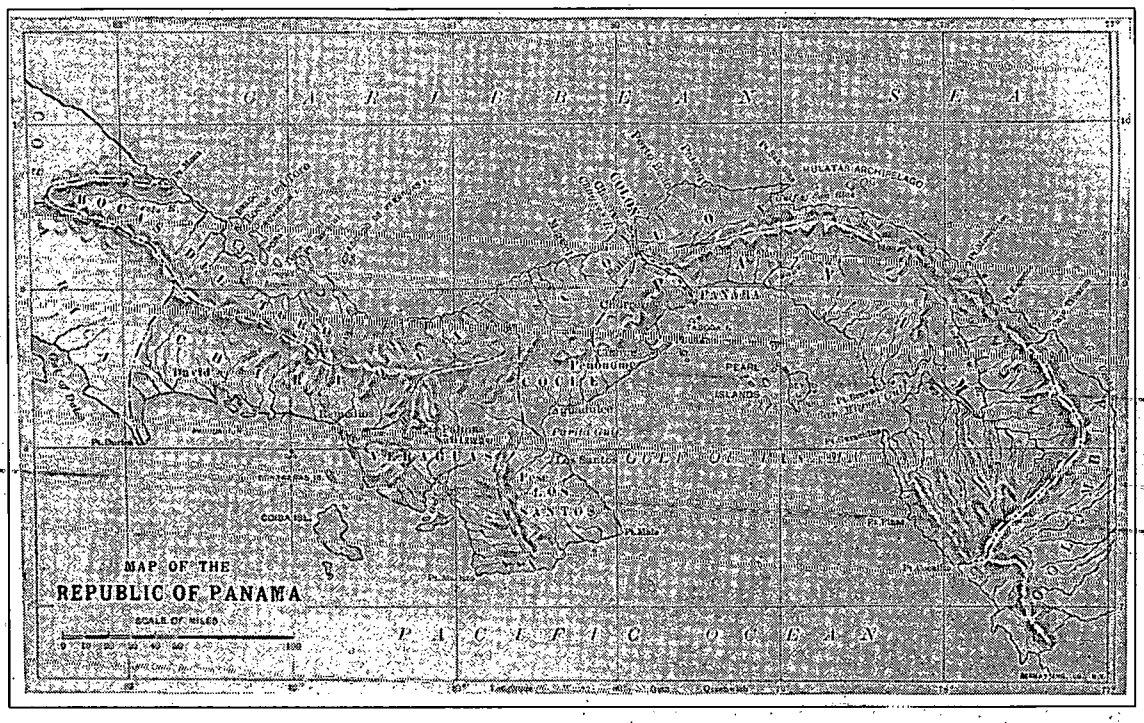

FIGURE 1. Map of Panama.

westward along the isthmus. The following year Christopher Columbus, the Admiral of the Seas, sailed southward and eastward from the Yucatan Peninsula to present day Panama. He, in fact, spent the Christmas of 1503 anchored in the Bay of Limon, the location of the northern end of the canal. This voyage, the fourth by Columbus to the new world in his search for a strait to the west, was like his others — a failure. The strait to the west would have to wait for twentieth century man.

In 1513 Balboa mounted a hill on the isthmus and saw the Pacific Ocean, what the native Indians called the "South Sea." This discovery, and subsequent pillaging and plundering expeditions by the Spanish Conquistadors such as Pizzaro and Cortez, made it necessary to find an easy way to move the rewards of their rape of the Indians back to Spain. As early as 1560 the Spaniards built a road, *El Camino Reale* (the King's Highway), across the isthmus from the area around Panama City to several different cities near the present northerly end of the canal, first Porto Bello and later Nombre de Dios, both towns named by Columbus in his 1503 trip. After the pillaging stopped, Panama went into a 200-year sleep as far as exploration and development was concerned.

Initial Plans for a Canal

A canal across the isthmus had been discussed almost from the beginning by the kings of Spain, but other than some crude mapping expeditions little was done until the middle of the nineteenth century to bring the dreams of many to reality. In 1846, the United States signed the Bidlack Treaty with Colombia, of which Panama was then a part, giving the United States the right to build and maintain a transportation system across the isthmus by any means then known or that would be known in the future in exchange for certain trading privileges. The Senate ratified the treaty and President James Polk signed it, but they had little appreciation of the future significance it would have.

All this changed in 1848 when gold was discovered at Sutter's Mill in California. The forty-niners wanted to go west by the fastest means possible before the gold was all gone and they had missed their chance to become instant millionaires. They had three routes

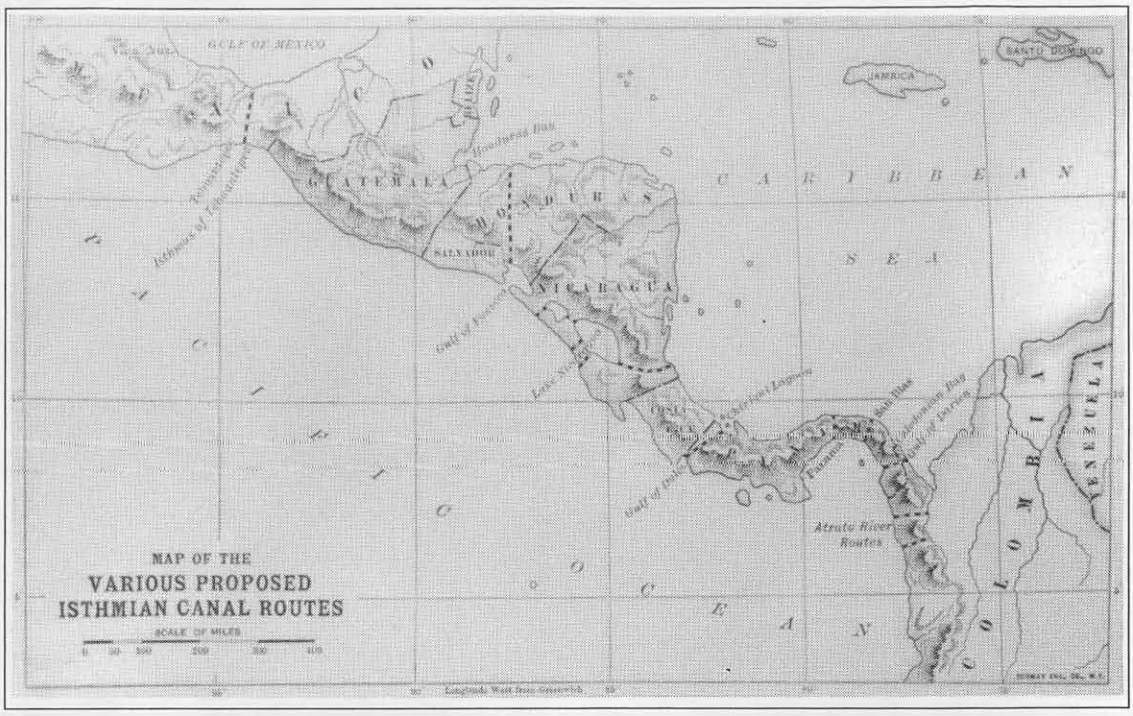

FIGURE 2. Survey of routes by the United States.

open to them at the time:

- Cross the plains and mountains of the still wild west (it took two months to travel those 3,000 miles);
- Sail or steam around Cape Horn (it took two months to travel 9,000 miles); or,
- Take a steamer to Panama, take a raft which was poled up the Chagres River by a native who would discharge the traveler at Gamboa, then be guided across the Cordilleras on foot, and arrive at Panama City to take a steamer or sailing ship to California (it took one month and covered 4,000 miles, a good deal of which would be under high risk of attack from bandits in Panama).

It was just prior to this time that two Americans, George Law and William H. Aspinwall, received concessions to provide steamship and mail connections from the east coast of the United States to the mouth of the Chagres River and from the west coast to Panama City. Next, they proposed the construction of a railroad across the isthmus and contracted with two of the premier civil engineers of the time, Colonel Joseph Totten and John C. Trautwine, to undertake such a project.

Starting construction in some of the worst possible conditions in a disease-ridden country must have been a sobering experience even for men with the background of Totten and Trautwine. After five years of dealing with yellow fever, malaria, cholera and serious financial problems, sufficient progress was made and with help from the forty-niners who would pay almost anything to speed up their passage across the isthmus, they completed the railroad in 1855. It was not much of a railroad when it opened, but it did, on its single track, provide a connection between the Atlantic and Pacific Oceans, making it the first transcontinental railroad.

The United States was never very far away from planning for the construction of a canal. Almost every President from James Polk on either commissioned studies or surveys to determine the best route across the isthmus. The Senate in 1866 had a comprehensive study made of all the routes that had been considered in the past. This report, replete with beautiful

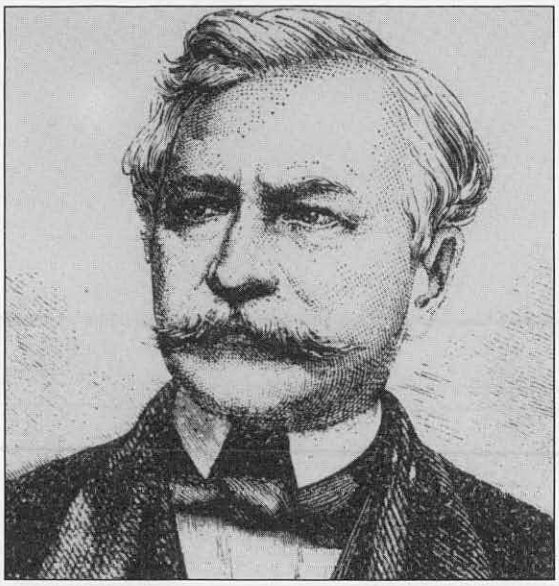

FIGURE 3. Ferdinand de Lesseps.

FIGURE 4. Lucien Napoleon Bonaparte Wyse.

maps, shaped the United States' planning for several years until President Grant restated the country's position on any future canal: any such canal would have to be under the control of the United States. He sent out many survey teams to determine, using the best surveying techniques available, the most desirable route for a canal. On the basis of these surveys, the Nicaragua Route (see Figure 2) became the United States' choice. A private company in fact did start the construction of a canal on this route in the early 1870s but ran out of funds after a very short time.

The French Plan

It was into this period of attempting to realize continually mulled dreams that Ferdinand de Lesseps (see Figure 3), the famed builder of the Suez Canal, became interested in the challenge of crossing another isthmus with a canal. After the opening of the Suez Canal in 1869 his status as an entrepreneur made him one of the most well known and respected Frenchmen of his time. Even though he was not an engineer, he was justifiably known as *Le Grand Français* due to his having succeeded in instances where most of his contemporaries were sure that he would fail, either through lack of money or through lack of technical expertise. He would, when people asked him what his business was, answer "Isthmuses."

De Lesseps commissioned, along with a group of movers and shakers interested in geography, Lucien Napoleon Bonaparte Wyse (see Figure 4) to make a trip to the Panama region and make a survey of a route or routes that could be considered for a French canal. After a minimal effort at actual surveying, Wyse made a little side trip to Colombia and received a concession from the government permitting him to build a canal anywhere east of the existing Panama Railroad. On his way home, he traveled to Washington in order to see if he could obtain copies of the American surveys that had been commissioned by Grant, but he was unsuccessful in his attempts.

Back in France, Wyse made his results known to de Lesseps and an investment-development group headed by Istvan Turr. They sent him back to Panama to do some more surveying, and then they went to work setting up an "International Symposium on an Isthmanian Canal" to be held in Paris in the spring of 1879. The purpose of this symposium was to bring together all of the experts from around the world to discuss which route across the isthmus would be most advantageous. The symposium included the involvement of engineers, entrepreneurs, politicians, shipping experts

and bankers.

The Americans came fully prepared to state the case for the Nicaragua route as well as to describe some of the other routes that they had considered. Wyse presented the French plan which was really not a plan at all, since it was based more on faith than fact. When the vote on a sea level route at Panama was being taken, de Lesseps with his usual flair for the dramatic, voted yes and made a triumphal boast that he would lead the effort.

A review of the voting, however, showed that it was not the engineers who supported this route. Instead, support for the sea level canal came from individuals who were under the spell of de Lesseps. Those that were in a position to know said that the jungle, disease, and the Chagres River made it highly improbable that the kind of canal that de Lesseps wanted to build could be built. One forward-looking Frenchman, Godin DeLepinay, had instead proposed an "Artificial Nicaragua" which would be accomplished by building a lock canal with an artificial lake that would store the waters of the Chagres River, thereby making it an ally rather than an enemy in the construction and maintenance of the canal. De Lesseps, attempting to repeat his success at Suez, was blind to these suggestions and was obsessed with his ability to accomplish the impossible, just like he had done at Suez.

The story of the initial financing of the canal by de Lesseps is a fascinating one, but it would require a book to fully relate all of its details. Suffice to say that the bankers and financiers, newspaper editors and politicians, as well as the average person on the street who invested his or her life's savings, wanted to get their hands into the very large pie that de Lesseps was proposing. After a false start that raised little money, he and his son Charles went along and played the game the way the money men wanted and raised enough to start the canal. The cost of doing business in this way, however, proved to be one of the main reasons for the eventual failure of the French effort.

De Lesseps then made a symbolic journey to Panama to break ground on January 1, 1880. This trip was made during the dry season and was de Lesseps's first time in Panama. Reports of his excursion are filled with statements about his charm and vitality, even though he was in his late 70s. They portray him as a "rainmaker" type of individual who had supreme confidence in his ability and the inevitable technological fixes that would develop at the time that he needed them — just like what happened at Suez. He was not to visit Panama again until 1886 when things were falling apart for his company and then only to try and salvage his effort to raise more money through the sale of lottery bonds.

The story of the French failure that appears in most historical accounts centers around de Lesseps, money, corruption, greed, disease, earthquakes and even a revolution. From the vantage point of the typical civil engineer on the project, it was a constant struggle against bureaucracy, unrealistic expectations, insufficient funds, inflexible leadership and finally a struggle against the three natural enemies: disease, the Chagres River and the jungle.

De Lesseps originally planned to have contractors build his canal and, true to form, contracted with Couvreux Hersent, the same firm that he had used at Suez to do the job. The company prepared for the massive project during 1880 and 1881. The best civil engineers in France were ready and eager to be part of this glorious triumph and many graduates from L'Ecole Polytechnique, the premier engineering college in the country made the trip to Panama.

What these engineers found was something altogether different from what they had bargained for. Almost from the beginning Paris started calling the shots from afar, thus depriving the engineers of the necessary control. One of the first examples of this distant bureaucratic control came when Gaston Blanchet, the contractor's chief engineer, wanted to clear a path 400 feet wide across the entire isthmus for purposes of doing, for the first time, a professional survey in order to provide the engineers with a good look at actual ground conditions. The response from Paris was to cut only a 40-foot wide corridor.

The definitive plan for the canal was also under development at this time, but there was no question that it was to be a sea level canal and the engineers had to develop plans to make this type of canal work. Keep in mind that

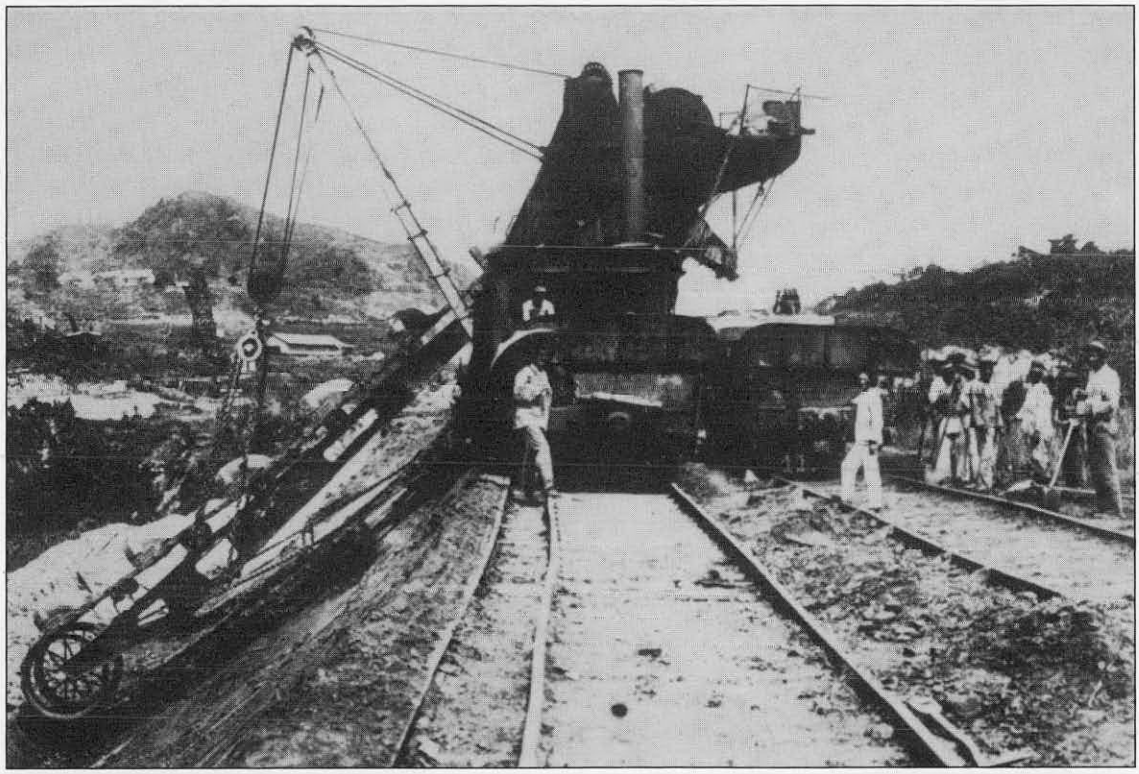

FIGURE 5. French ladder excavator.

many engineers, French and American alike, had told de Lesseps that the Chagres River would not permit the construction of a sea level canal. In spite of this knowledge, the French engineers on the site were instructed to find a way to make it work. By this time, disease (mainly yellow fever and malaria) was starting to take its toll on the visitors from Europe. The natives who were still alive were immune to yellow fever since most had survived earlier cases of the dread disease. At this time, it was commonly thought that the disease came from some mysterious germ from the swamps called *miasma*.

Excavating soil and rock during the rainy season proved extremely difficult. Under pressure to show some progress while they were working on a plan to harness the Chagres River, the engineers started dredging from both oceans inland using primarily American-built dredges. Progress for this type of excavation was good; in fact, if they were building a 100-foot wide canal, their efforts would have been of value. The French equipment, however, was unable to discharge the excavated material far enough away from the banks to prevent much of the excavated materials from sliding back into the already excavated canal. The ladder dredges (see Figure 5), despite excellent workmanship, were just too small to do the job. The railroad rolling stock that was employed was the best available in the early 1880s, but it was insufficient for the job.

What the engineers did not seem to realize, based on the evidence, is that the task of excavation was only a relatively minor part of the overall challenge. The main difficulty was how to transport the excavated materials from the Culebra Cut to the spoil areas and, once there, how to quickly unload the soil and rock in order to get the cars back to the excavators. The French constantly found that their dirt trains got bogged down in their own previously dumped material. In short, they never had a system in place that could guarantee that the excavators would always be excavating and not sitting around waiting for the dirt trains to return.

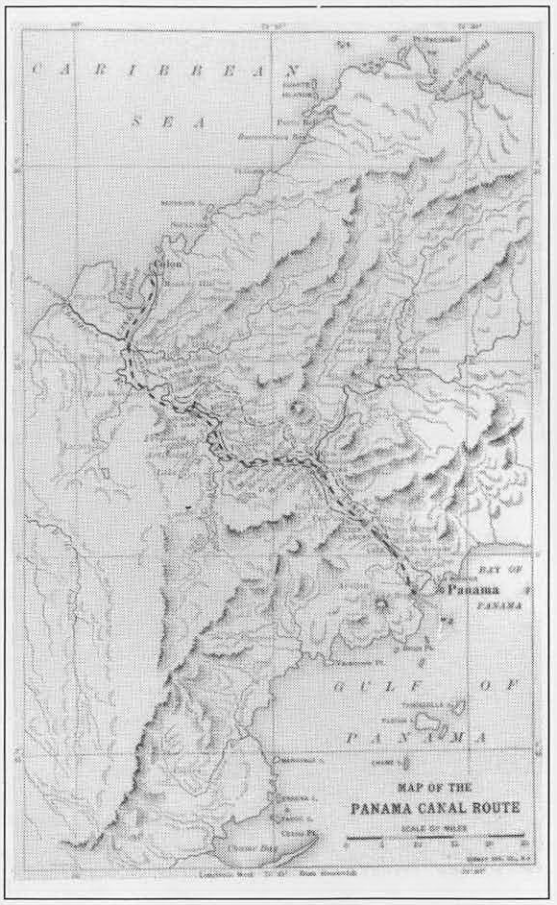

FIGURE 6. Map of the proposed canal route.

Failure of the Sea Level Design

The major problem, however, regarding what to do with the Chagres River remained unsolved by the French, perhaps because it virtually precluded any solution. The elevation of the Chagres River at the point where it was to make its first contact, near Gamboa, with the line of the sea level canal was approximately 45 feet above sea level and about 32 miles from the Atlantic Ocean (see Figure 6). The Chagres River drains a large and steep watershed and, as a result, is subject to rapid transition from stream to raging torrent. To prevent it from flooding the excavation, the French proposed to dam it upstream and dig a diversion channel in order to separate the river waters from the ocean waters. This project, however, required a major effort in and of itself, and it was for this reason that it was finally deemed to be totally impractical.

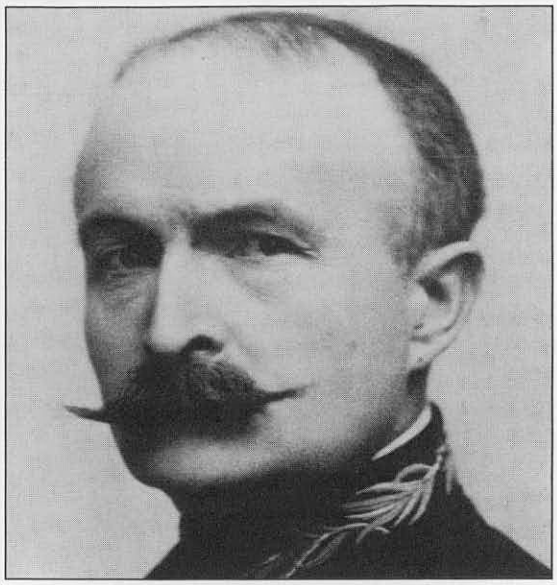

FIGURE 7. Phillippe Bunau-Varilla.

One French engineer, however, distinguished himself for his vision in trying to solve many of the problems mentioned above. He was Phillippe Bunau-Varilla (see Figure 7), a graduate of L'Ecole Polytechnique, and a believer in de Lesseps and the ability of French technology to accomplish the task. He came to the isthmus to work for the company after the contractors were excused from their contract, and was given a responsible position immediately working for Jules Dingler, Director General and a well-known French engineer. At this time, yellow fever was rampant and even though the French built the best hospitals and provided excellent nursing care, the chances of surviving the fever were exceedingly small. Dingler's wife and children died of the disease as did many other Frenchmen. Bunau-Varilla himself was infected, but he was one of the few who managed to survive.

After Dingler left the isthmus in late 1885, Bunau-Varilla found himself at the age of twenty-seven in charge as Director General of the largest construction project in the history of man until such time as another, more senior engineer could be sent over from France. During his stay as Director General, he made many recommendations that, if followed, might have saved the day for de Lesseps.

If de Lesseps had been more directly involved with the project, he would have realized that the technological fix he always counted on resided in the mind and abilities of Bunau-Varilla. The young engineer had proposed, among other things, that all excavation for the canal be performed in the wet by creating artificial lakes with locks at either end of the lakes. This construction method would enable the canal to be used as a lock canal during the excavation process. Thus, within this system, excavation could be continued in order to deepen the lakes until such time as it would be possible to remove the lock gates of the highest lake so that the highest level lake would now be at the level of the lower lake. In time, the canal could eventually become a sea level canal, with the tolls collected in the meantime applied to the cost of completing the canal, thus minimizing the amount of capital that had to be raised by selling bonds. He also proposed and implemented erecting large wooden railroad trestles in the dump areas in order to eliminate the problems of the dirt trains being bogged down in the mud.

In 1886 Bunau-Varilla resigned as an employee of the project development company and went into partnership with others and became a contractor on the canal. By this time, however, money was running out and word was getting back to France that all was not well and that one of the greatest financial disasters in history was about to occur. De Lesseps had gone back to the citizens of France on several occasions for more support, always with glowing reports about the progress being made on the canal. He was able to obtain more money to carry on, but at progressively higher rates of interest which is usually the case when lenders question the safety and quality of their loans.

The government, in order to check the exact extent of the progress being made on the canal, sent an investigator, Armand Rousseau, to obtain first-hand information and to report back on his findings. De Lesseps realized that his last chance to salvage the canal was at hand, and made his second trip to Panama to urge on his workers in late 1885, during the dry season of course. Based on what he saw during this trip, he decided to change the design of the canal (the conclusion reached by Bunau-Varilla, Armand Rousseau and his own new Director General Leon Boyer) to a lock canal and to bring into the project leading French civil engineers such as Gustave Eiffel.

After making these changes in 1887, de Lesseps again asked for authorization from the national Chamber of Deputies for the sale of lottery bonds. The Chamber of Deputies finally approved the sale of the bonds in June of 1888, but de Lesseps, despite frantic appeals to the French people, failed in raising the amount needed. It was shortly after this failed attempt to raise new monies that the company he headed was placed into receivership. Not too long after that, in February 1889, a liquidator was appointed to salvage what he could for the original shareholders.

Restructuring for a Second Try

The New Panama Canal Company was formed by the liquidator in 1894. Many financiers and contractors who had made small fortunes through their original involvement with de Lesseps on the canal, including Bunau-Varilla, were forced to invest in the new company under threat of prosecution and jail. Their primary task was to see that work proceeded on the canal at such a rate that the concession with Colombia could be maintained and extended. The real purpose of the new company was, in the opinion of many, to keep the company going long enough in order to sell its assets to someone else, most probably the United States.

Investigations conducted in 1893 into the de Lesseps company revealed that fraud, bribery and greed were prevalent in the financial circles and newspapers of France. Much of the money raised through the sale of bonds had gone into the pockets of individuals who did not contribute to the construction of the canal.

It should not be forgotten, however, that the French engineers made significant progress on the construction of the canal. They excavated over 50,000,000 cubic yards of soil and rock; they built hospitals, villages, harbors and piers; and they left vast amounts of equipment that could be used by anyone who wanted to come in to pick up the pieces and translate de Lesseps' dream into reality.

The fact that they had spent in excess of

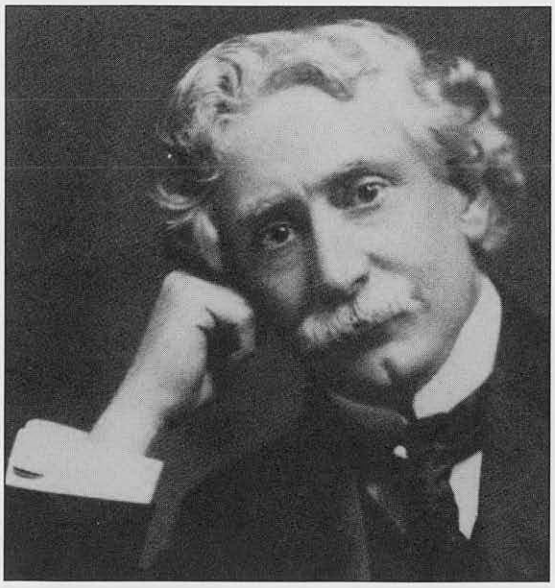

FIGURE 8. William Nelson Cromwell.

FIGURE 9. Theodore Roosevelt.

$287,000,000 would, however, detract from the work the French engineers had performed and leave the impression in the minds of many that they had not accomplished anything.

From an engineering standpoint, the French engineers had made excellent surveys, measured the flow in the streams and rivers and had begun to develop a plan to perform the excavation of Culebra by following some of the suggestions of Bunau-Varilla. They also proved that western man could come into the tropics and build an isthmanian canal thousands of miles away from civilization. If the French had started the canal twenty years later when equipment of much larger size and capacity was available, and the source of yellow fever and malaria was known, there is not much doubt that, even with corruption on the home front, they could have built a lock canal at Panama.

The Panama Canal

How the United States got involved in the construction of a canal at Panama is told in great detail in *The Path Between the Seas*, by David McCullough,[1] and by Phillippe Bunau-Varilla in his fascinating book, *Panama: The Creation, Destruction, and Resurrection.*[2] The United States from 1899 to 1902 was strong in its belief that when a canal was built it would be built by the United States and it would be a lock canal through Nicaragua. Largely through the efforts of Bunau-Varilla, William Nelson Cromwell (see Figure 8), lawyer for the New Panama Canal Company, George Morison, a civil engineer and member of the Isthmanian Canal Commission, Senator Mark Hanna and finally Theodore Roosevelt (see Figure 9), the new President of the United States, this sentiment was changed to Panama. As a result of their efforts, the Spooner Act was passed by Congress which gave the President the authority to negotiate with both Colombia and the New Panama Canal Company for the purpose of arriving at a treaty with Colombia and at an acceptable purchase price for the French company. If these negotiations were unsuccessful, the President was authorized to initiate the process required to construct a canal through Nicaragua.

The Senate ratified the Hay-Herran Treaty with Colombia and all was apparently set for a smooth beginning of construction by the United States. All, that is, except for ratification of the treaty by Colombia. After some bitter words back and forth between the United States and Colombia, the treaty was rejected by Colombia. The Colombians apparently wanted more than the $10,000,000 the United States was offering them and felt that the some of the

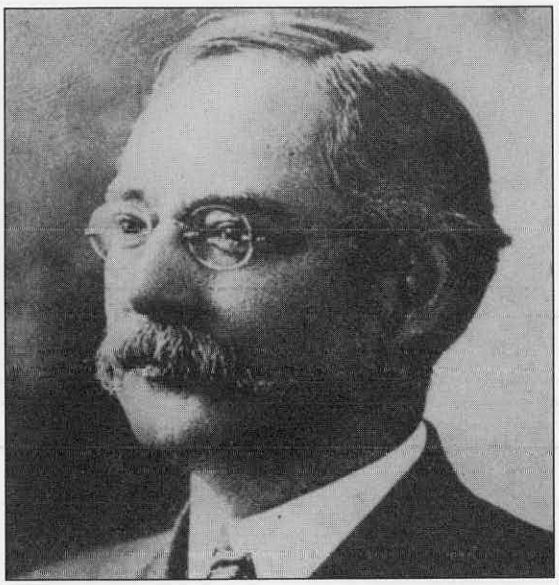

FIGURE 10. John Finley Wallace, first Chief Engineer.

$40,000,000 that was to be paid to the New Panama Canal Company should come to them. They also had some concerns about sovereignty over the land on which the canal was to be built. To say that Theodore Roosevelt was unhappy with what he referred to as those "Bandits in Bogota" or "that Bogota lot of jack rabbits" would be vastly understating the case.

In November of 1903, a group of Panamanian locals unhappy with Colombia's rejection of the treaty revolted and took control of what is now Panama. This uprising was planned in part by Bunau-Varilla, William Nelson Cromwell and a handful of Panamanians. In order to ensure its success, the revolution needed and, from a Colombian viewpoint, was granted the support of the United States and its gunboats.

What happened behind closed doors in Washington is not entirely known. Some say that Theodore Roosevelt was fully aware of everything going on and that he approved of the dispatch of gunboats to Panama and the subsequent actions of United States forces taken to protect passage on the Panama Railroad. However involved Washington was involved with the "revolution," Roosevelt recognized the new country of Panama two days after the revolution, which was fast even by his own standards. Roosevelt was to state later in his autobiography that his foreign policy was based on:

> "the exercise of intelligent forethought and of decisive actions sufficiently far in advance of any likely crisis."

He further stated that:

> "From the beginning to the end our course was straight-forward and in absolute accord with the highest standards of international morality. Criticism of it can come only from misinformation, or else from a sentimentality which represents both; mental weakness and a moral twist."

So, in Roosevelt's mind, what he did was a measured response to the situation that he faced and one in which he had predetermined all of his possible courses of action under a variety of eventualities.

As noted, we may never know the exact story behind the uprising. On November 18, 1903, two weeks after the revolution, Secretary of State, John Hay, signed a treaty with Panama that had been drafted by none other than Phillippe Bunau-Varilla, Envoy Extraordinary and Minister Plenipotentiary to the government of the United States of America. The Senate viewed this new treaty as an improvement over the Hay-Herran Treaty and it was ratified on December 2, 1903. The Hay-Bunau-Varilla Treaty was somewhat reluctantly ratified by the Panamanians on February 23, 1904, as the first order of business of the new government. On November 4, 1904, the United States flag flew over the newly acquired territory — the Canal Zone — for which it was, by treaty, to act as if it were sovereign in perpetuity.

At that moment the dreams of Americans from Bidlack to Roosevelt seemed about to come true, but no less perhaps than the man with the greatest commitment to the canal in terms of time and passion — Phillippe Bunau-Varilla — would realize his dreams as well. He had been involved with the Canal since 1884, a period of over twenty years. Bunau-Varilla was to write in his book:

> "I have fulfilled my mission . . . I had

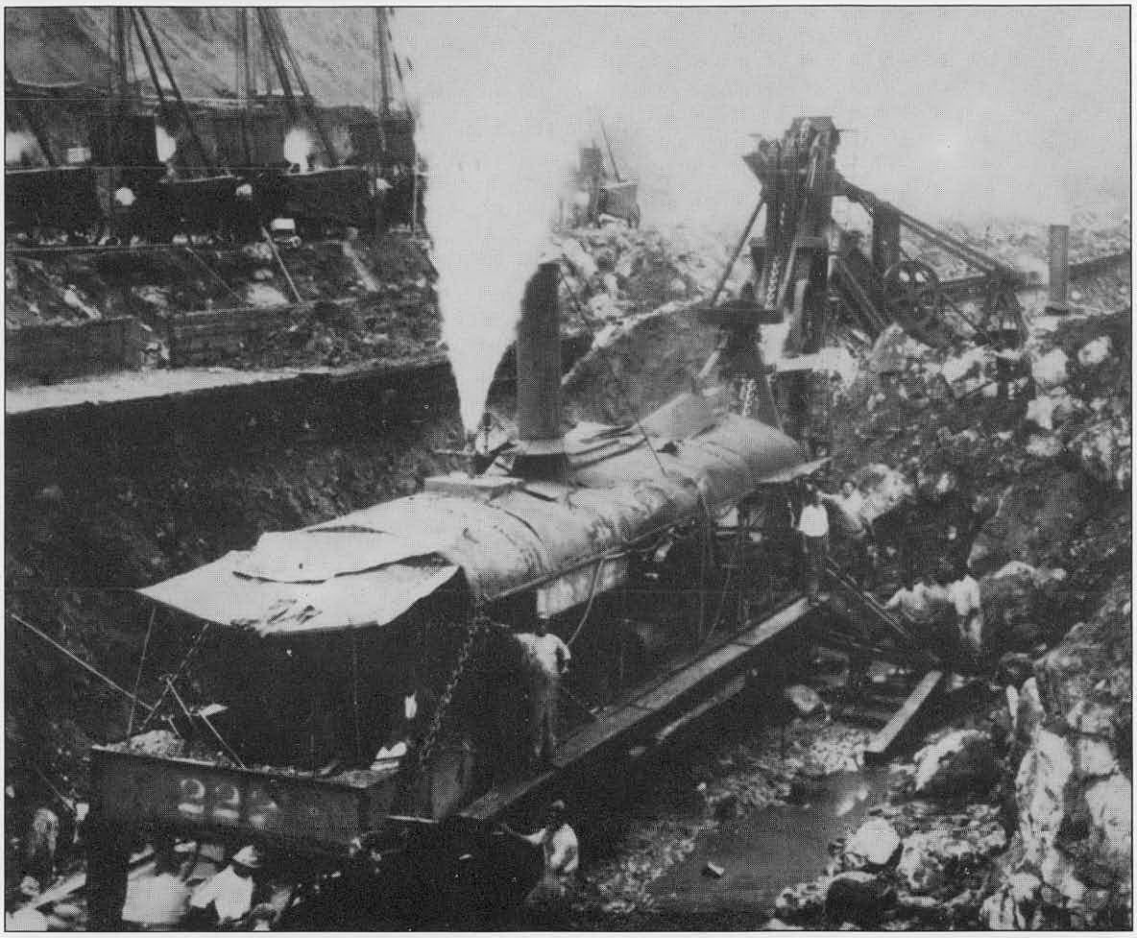

FIGURE 11. Bucyrus steam shovel.

safeguarded the work of the French genius, I had avenged its honor: I had served France."

He might have gone on to say that his company was to receive $453,200 of the $40,000,000 paid to the New Panama Canal Company. Perhaps he did what he did for the glory of France and French genius; or, perhaps he did what he did in order to salvage a bad investment. The actual motivations for his actions will never be known, but this may be one situation where the interpretation that puts him in the best light might be the most accurate one.

It was now time for the United States to go in and pick up the pieces left by France and show the French how American know-how and determination would make the "dirt fly." Such was not the case, however, since the first year of the American effort made the French actually look good. The problem was not a lack of money but a lack of leadership and a circuitous decision-making organization.

John Finley Wallace (see Figure 10), one of the top construction engineers in the United States and President of the American Society of Civil Engineers (ASCE) in 1900, was selected by President Roosevelt to be Chief Engineer. Unfortunately, the Spooner Act prescribed that the project be overseen by a seven-man Isthmanian Canal Commission without explicitly defining what were the lines of authority within the project. In addition, most of the commission was located in Washington, D.C., far away from the work. Given the failure of the French, there was substantial pressure on the chief engineer to produce results quickly. Wallace succumbed to this pressure and was seemingly obsessed

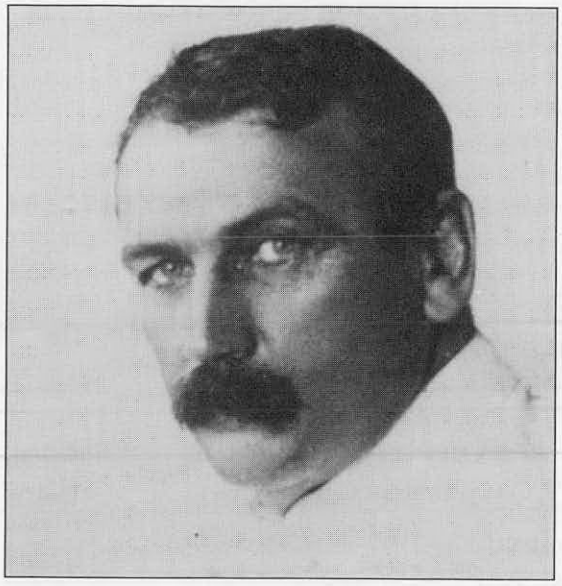

FIGURE 12. John Stevens, second Chief Engineer.

with making the "dirt fly" and, as a result, never really was able to share his plan, if he had one, with his men.

Wallace's staff was also graced with the addition of the noted physician, Dr. William Gorgas, to control the effects of disease on the project staff and workers. Gorgas had been selected for his post because of his experience in clearing Havana of yellow fever in a very short period of time. What he had learned and accomplished there, Gorgas had been assigned to repeat in Panama. However, Wallace did not believe that mosquitoes spread yellow fever and malaria, and, as a result, did not support Gorgas's efforts.

The layout of the area to be cleared of the *Stegomyia* and *Anopheles* mosquitoes was different from Havana, but the procedures to be followed were the same. Gorgas knew that *Stegomyia*, the yellow fever mosquito, would be easiest to eradicate, since he knew their breeding habits, places where they laid their eggs, their range of movement and life cycle. He also knew the importance of keeping these mosquitoes away from infected people. The *Anopheles* mosquito, the carrier of malaria, posed a much greater problem, but at least he knew how to attack them and minimize their effect.

Wallace and the poor organizational structure, however, did not supply Gorgas with the men and materials needed to accomplish his task. As a result, yellow fever returned to the isthmus. Even though the outbreak of the disease was much less severe than in the time of the French efforts, panic set in and many Americans abandoned the project. Morale was poor, output was poor, planning was not evident, corruption flourished, and all Wallace did was keep on digging with the equipment the French had left behind.

Observers would later say that Wallace never had his heart in the job and feared for his life. This evaluation may very well have been true, and the Canal Commission might have been partly to blame for the dismal state of affairs in Panama, but the man at the top must have a vision for a project of this magnitude to succeed in this type of inhospitable environment. The project director must be able to instill confidence and enthusiasm for the task in those engineers that work for him.

Wallace surely should have been up to this challenge considering his background in the United States. The fact that his salary of $25,000 was higher than that of any government official except the President was an indication of how much was thought of him and how much was expected of him. As is often the case when a project is floundering, the man in charge does not measure up to the task.

Wallace's inability to lead was covered up by his constant complaining to the Secretary of War, William Howard Taft, about his problems in getting the supplies he needed. He also brought up again for discussion the old issue of whether the United States should be building a sea level canal or the lock canal that had been recommended by the Canal Commission.

Perhaps his greatest contribution to the canal project was the decision to use the Bucyrus 95-ton steam shovel as the primary excavation machine (see Figure 11). Realizing the sad state of organizational affairs, he asked for more authority and was about to get it when he suddenly resigned (or was fired depending on whose account is to be believed) in June of 1905, less than one year after he accepted the leadership of the greatest construction project ever attempted by the United States. In his own words written ten years later he stated:

"The foundations of all great structures are hidden from sight, and only the architectural effect of an imposing building resting thereon appreciated. Nevertheless without the foundations the final structure could not be erected, and without any expectation of public appreciation either at present or in the future, I felt in my own conscience that my compensation would consist in the personal feeling that during the strenuous period of preparation at least a foundation of ideas in organization and plans had been made, and that the misunderstandings which I may have had with the administration and those above me at least made the way easier for my successors."[3]

It is hard to find anyone connected with the enterprise who agreed with Wallace's appraisal of the foundation that he believed that he had placed or of the plans he had developed. John Stevens (see Figure 12), the second Chief Engineer for the project and Wallace's successor, revealed:

"When I reached the zone, conditions could have been worse, but they were bad enough. No real start at any effective work on the canal project had been made, no organization worthy of the name had been effected, sanitary reforms were really just beginning, little new plant had been provided, and little that was absolutely needed had been ordered . . . In such organization as existed, no cooperation was apparent — exactly the opposite — and no systematic plan, as far as could be discovered, had been formulated toward carrying out the work along lines promising any degree of success."[4]

Stevens also remarked that Wallace had what appeared to be a "thorough case of fright." He was also to note shortly after he began to work that:

"[T]here are three diseases in Panama, they are yellow fever, malaria, and cold feet and the greatest of these is cold feet."

Stevens, a railroad builder of national repu-

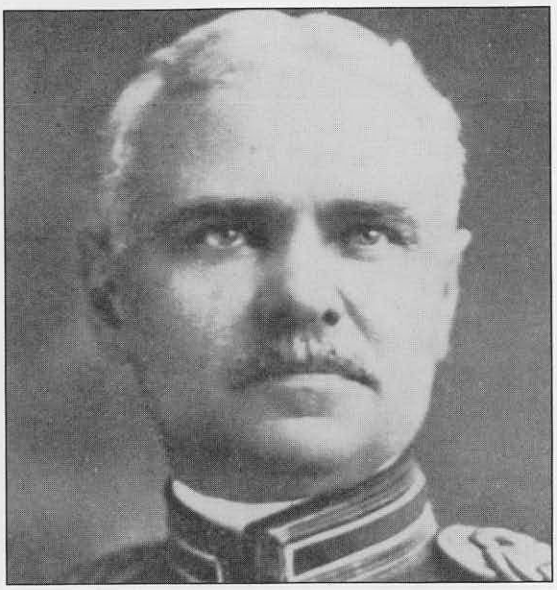

FIGURE 13. George Washington Goethals, third Chief Engineer.

tation, was a self-made man who made his career on the frontier working for James Hill in the layout and construction of the Great Northern Railroad. He was a "can-do" man who believed that hard work was the key to success in any venture. When he arrived at Panama in the summer of 1905, he found that the place, as noted above, was in as bad shape as President Roosevelt led him to believe it was. He saw at once that there was no coordination between groups that should have been cooperating, and that the Panama Railroad, which was the key to success, was in terrible condition. He also observed that the men were not being properly fed, housed and cared for. He found that:

"[W]orse than all, over and above in the diseased imaginations of the disjointed force of white employees, hovered the Angel of Death in the shape of yellow fever."[4]

His first major decision was to suspend all digging until he had determined that the project was in such a state that digging could be efficiently and wisely undertaken. As part of these preparations, he furnished Gorgas with all the resources he needed under the proviso that Gorgas control outbreaks of yellow fever on the isthmus in four months.

While the disease eradication efforts were going on Stevens had additional housing constructed; he arranged to have recreational facilities erected; he brought in food and ice; and he built bakeries for the workers. He then ordered the latest and highest capacity locomotives and dirt cars, upgraded the track, and employing the Bucyrus shovels, which had been ordered by Wallace, laid out a railroad network that would move the dirt efficiently from Culebra and other cuts to the spoil areas. He was everywhere along the route and the workers finally could see that they had a leader who shared with them his vision, enthusiasm and plan. In short, he was everything that Wallace was not.

Stevens also requested more authority than had been given to Wallace. Roosevelt modified the commission to give him what Wallace had requested. This level of authority later proved to be insufficient. Nevertheless, in less than six months Stevens had turned the entire project around and was ready to begin digging.

One of the main problems Stevens faced was that some of the engineers still thought the United States should be building a sea level canal. Wallace had urged Taft and Roosevelt to build a sea level canal before he was replaced. In fact, a commission formed by President Roosevelt with well-known civil engineers making up most of the membership, recommended by a majority vote that a sea level canal 150 feet wide should be constructed. A Senate committee also voted in favor of a sea level canal. On the other hand, Stevens overwhelmingly supported a lock canal. This canal's primary design feature was a major dam at Gatun to store the waters of the Chagres River. The canal as proposed was in fact very much like that described by Godin DeLepinay in 1879 in Paris. Roosevelt, however, listened to Stevens who had seen the Chagres River in flood and decided to approve the lock canal design as supported by Stevens. With that issue finally out of the way, excavation began in earnest and the United States embarked on the years of work necessary to accomplish the task.

Stevens had fabricated a well-oiled machine that offered the promise of success. Things were looking so good that President Roosevelt made a trip to Panama to see for himself what was going on. In one way, his visit was reminiscent of de Lesseps's trips, since he seemed to be everywhere and seeing everything. However, unlike de Lesseps, he came in the rainy season and the workers were amazed to see the President of the United States slogging through the mud. He was to report back to Congress that the "Army of Panama" was at work on this project, the most important construction job in the history of the country.

Suddenly, early in 1907, Stevens began to disturb Roosevelt and Taft with the tenor of some of his statements and attitudes. Shortly thereafter Stevens either resigned, or was fired, once again depending on a subjective interpretation of the events and personalities involved. So, less than two years after he began as chief engineer, he left his post in a most curious manner. In three years the project had had two chief officers. However, the main difference this time from Wallace's vacating the post was that conditions on the isthmus were in far better shape. Stevens later reflected that:

> "We handed over to the army engineers a well-planned and built machine, one that was running fairly smoothly, with perhaps a squeak or a hot bearing here and there, as is always inevitable with new machinery. Improvements in detail could be made, as would have been the case no matter who had been the engineer. But the fact remains that no radical change was made in any of its component parts, and that it proved such a success was no surprise whatever to me."[4]

Roosevelt was beside himself and decided that:

> "[T]he only way to carry forward the great project was to put at the head of the organization a man who would be compelled, under the rigor of military law, to remain at his post of duty."

This man turned out to be Major George Washington Goethals of the U.S. Army Corps of Engineers (see Figure 13). Goethals was the son of Belgian immigrants who settled in Brooklyn in 1848, the year that gold was discovered in Sutter's Creek in California. He attended the

City College of New York for almost four years but did not graduate since he had received an appointment to the United States Military Academy at West Point in April of 1876, the year of the Centennial of the Nation. Graduating in 1880 near the top of his class, he was commissioned as a Second Lieutenant in the Engineers Corps on June 12th.

His assignments prior to his service on the canal included several years of teaching at the Engineer School of Application and at the Academy. He also worked for Colonel William Merrill on the construction of locks and dams on the Ohio River, and as assistant in the design of locks and dams on the Cumberland and Tennessee Rivers. For that project, he had major responsibility for maintaining the river in navigable condition while keeping in operation the Mussel Shoals Canal.

It was on this particular assignment that he rounded out the experience that he would need to succeed at Panama, since he built and operated a 14-mile long railroad that served as a supplement for the construction and operation of the canal. Later, he was to design and build locks at Colbert Shoals that had a vertical lift of 26 feet. This lock represented a remarkable achievement, since up until that time a lift of 14 feet was considered to be a large lift.

After a stint as Assistant to the Chief of Engineers in the Spanish-American War, he returned to teach at West Point. He was subsequently appointed to the National Coast Defense Board, which was also called the Taft Fortification Board. It was in this capacity that he came into close contact with William Howard Taft, Secretary of War to President Roosevelt. He toured extensively with Secretary Taft and made a visit to Panama with him in 1905 during Wallace's year as Chief Engineer. Taft later urged John Stevens to appoint Goethals as Assistant Engineer. Stevens declined this recommendation, since he was looking for a "railroad man" and not a specialist in locks.

With Stevens's resignation, Goethals's time had arrived. It was as if his entire career had pointed him toward this moment and project. He had experience with the design and construction of locks, railroads, and major excavation projects. He also had experience in the management of large numbers of men and demonstrated an ability to work with the bureaucracy and Congress. In addition, he had the support of Secretary Taft and, therefore, of President Roosevelt.

On February 26, 1907, Goethals was appointed Chief Engineer and arrived in Panama in March to take over from John Stevens. Realizing that the civilians at work on the canal were apprehensive about working for a military man who would have other military personnel as his assistants, Goethals stated early on that:

> "I am no longer a commander in the United States Army. I am commanding the Army of Panama, the enemy is Culebra Cut and the locks and dam."

He further told them that the organization would be no more military than in the past, except in the precision of its work, and that no person who did his duty, whatever the person's rank or station, need have any fear of the incoming administration.[5]

Goethals, upon his appointment, possessed complete control of everything that occurred at Panama since Roosevelt had found another way to get around the Spooner Act. The President simply made all of Goethals's assistant engineers members of the canal commission that was called for in the act. In addition, the engineers would all reside on the isthmus and report directly to Goethals. Roosevelt had supposedly informed the new members of the commission that:

> "[I]f at any time you do not agree with his [Goethals's] policies, do not bother to tell me about it — your disagreement with him will constitute your resignation."[5]

The commission consisted of George Goethals, William Gorgas, William Sibert, David Gaillard, Harry Rousseau, Joseph Blackburn and Harry Hodges. All of them were military men except for Blackburn who was a former Senator from Kentucky and who had little responsibility and no authority.

So when Goethals took the reins, the organizational problems were over, a lock canal had been decided on with a dam at Gatun, the

FIGURE 14. Gatun Locks.

railroad had been upgraded and a system for transporting the spoil had been put into place by Stevens. Gorgas had rid the zone of yellow fever and was working on malaria. Housing, food supplies and recreational facilities were provided for the workers and their families. In short, the United States was sparing no expense in order to provide everything needed to ensure the project's success.

Many people who have written about the canal have implied that all Goethals had to do was to oversee the continued functioning of the system that had been established by Stevens. Nothing could be further from the truth:

- Nothing had been done on Gatun Dam other than the taking of borings;
- Nothing had been done on the detailed design of the locks;
- Final plans for harnessing the Chagres River had not been drafted; and,
- No one had developed a plan to stop or minimize landslides.

While evidently not an inspirational leader like Stevens, Goethals gave the impression that he was "one of the guys," and he did gain the respect and admiration of the workers. According to the workers, Stevens was referred to as "Big Smoke," while Goethals was referred to as the "white haired Colonel," the "old man" or "the Colonel." Most, if not all, of the workers on the isthmus would speak highly of Goethals years after the completion of the canal. He always praised the workers and their dedication to the task. He was, however, quick to send home anyone whom he felt was not doing his job.

As an engineer, he completed the plans for the Gatun Dam, the largest earth fill dam ever built. The dam was built in spite of some bad press back in the United States that held that it would never be safe due to excess settlement or that it would never hold water due to "underground rivers."

Goethals also modified the arrangement of the locks on the Pacific side by moving one set of locks back from Sosa Hill to Miraflores because of poor soil conditions encountered at the original site. This solution was also justified from a military standpoint, since Miraflores

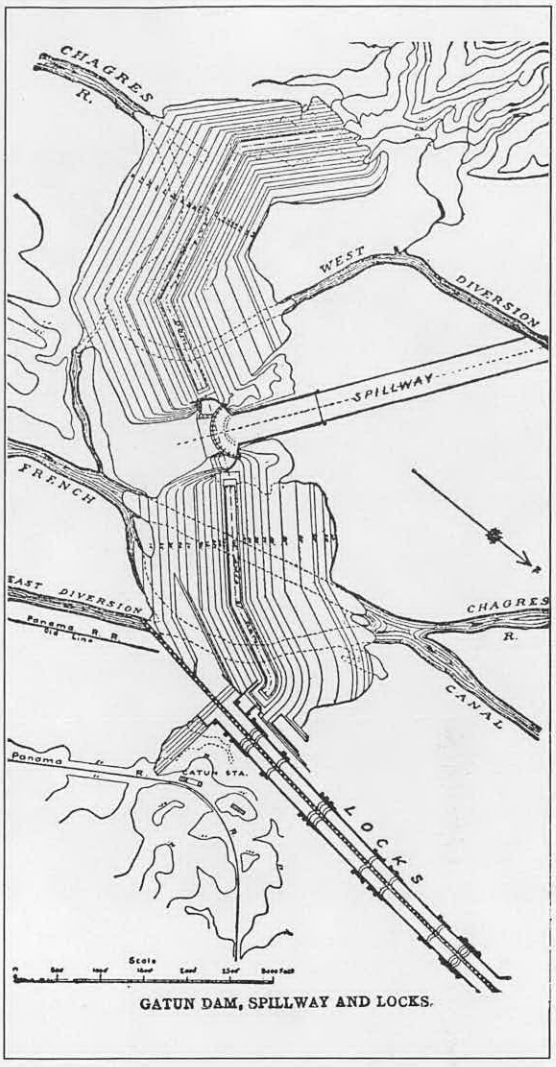

FIGURE 15. Gatun Dam.

was safer from bombardment by ships lying off the southerly end of the canal.

The construction of the dam and locks at Gatun was placed in the hands of Colonel Sibert who had worked on the famous Poe Lock on the Soo Canal and had other experience in building locks and dams around Pittsburgh (see Figures 14 and 15). His relations with Goethals were strained, but they never reached the breaking point. He did, however, get his licks in when he collaborated with John Stevens in a book entitled, *The Construction of the Panama Canal,*[6] in 1915.

The design of the gates for the locks and the maze of tunnels with their huge gate valves

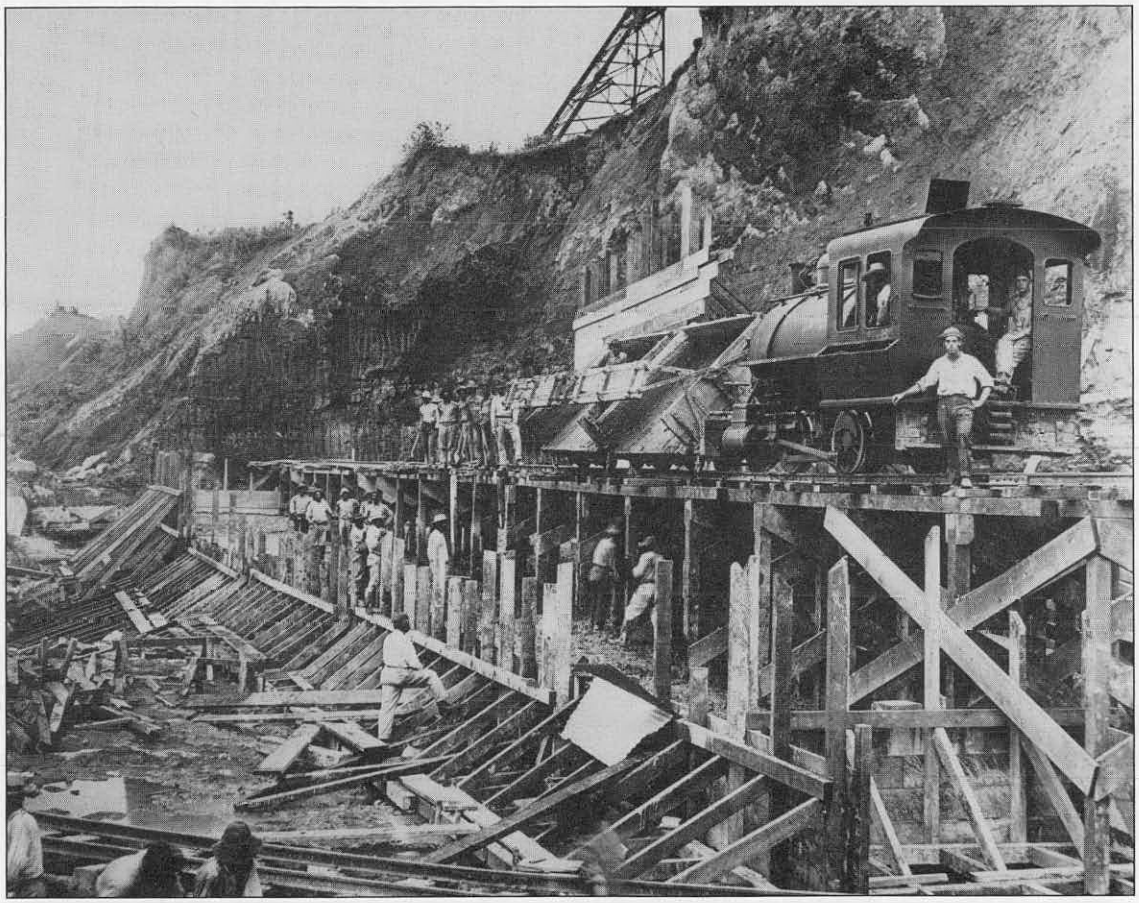

FIGURE 16. Concrete work on the locks.

went to Colonel Harry Hodges. Construction of the locks began in 1907 and was completed in 1913 (see Figure 16). A total of over 5,000,000 cubic yards of concrete was used for the project, with all of the cement and sand having to be shipped to the isthmus. Never had such a quantity of concrete been placed on one project before.

Efficiency was the order of the day and the cost accounting system set up by Goethals was able to track costs accurately and, in many cases, able to challenge the workers to perform better.

But all of these tasks, major though they were, could not measure up in magnitude to the excavation required at Culebra that Goethals had assigned to Colonel Gaillard. When Goethals took over, he estimated that he would have to excavate approximately 54,000,000 cubic yards from the Culebra Cut. Before this part of the project was completed, a total of more than 100,000,000 cubic yards had been excavated. Part of this increase was due to the fact that Goethals had widened the canal to a minimum of 300 feet, but most of it resulted from slides that had began in 1907 and continued throughout the construction of the canal and for many years after it opened. It is hard for an engineer even today to appreciate the fact that slides containing over 7,000,000 cubic yards of material do occur, but that is exactly what happened time and time again. Names like the Cucaracha (famous for its slides) became almost like household words on the pages of *Engineering News Record* and still are found in the soil mechanics books of today.

All Goethals could do when these slides occurred was to tell Gaillard to dig them out. He knew that eventually the slides would stop and the slopes would stabilize. Before the Culebra

Cut was completed, the top width of the cut had increased from a planned width of 670 feet to over 1,800 feet. In many places, the slopes were as flat as 1 to 5. Goethals's system of drill, blast, dig, haul and do it over again day after day, week after week and year after year had apparently succeeded. When he directed that work begin to pull all of the tracks out of the cut in 1913, another Cucaracha slide filled the bottom of the excavation once again. After attempting to dig the slide material out in the dry, he decided to pull up all of the track, flood the excavation and dig using dredges.

Since everything was being completed on schedule and under budget, it became clear to every one connected with the canal that it would be opened in the summer of 1914. Morale was high and, as a result, production was also at a high level. George Goethals was the man of the hour. He had proved himself worthy of the trust that Secretary Taft, President Roosevelt and finally President Woodrow Wilson had placed in him. This military man, this engineer, had become an inspirational leader by example. He became judge and father confessor out of necessity. He was an early efficiency expert in his approach to cutting costs, and even played psychologist by including in the *Canal Record*, the weekly publication of the Canal Commission, details of the production of each shovel crew. This type of recognition created a spirit of competition between shovel crews that resulted in ever increasing volumes being excavated each period.

The canal, when completed, had cost over $630,000,000 with the United States's share being $352,000,000. A total of over 260,000,000 cubic yards of materials had been removed and over 5,000,000 cubic yards of concrete were poured. The world's largest earth fill dam had been constructed that impounded the world's largest man-made lake (see Figure 17) and a land that was considered to be a pest hole was now developed and free from the fear of disease. Cities had been built and made habitable, the railroad had been upgraded and Panama was an independent country with a canal.

When President Roosevelt visited the isthmus in 1906, he addressed the workers:

> "You, here, who do your work well in bringing to completion this great enterprise, will stand exactly as the soldiers of a few, and only a few of the most famous armies in all the nations stand in history. This is one of the great works of the world."

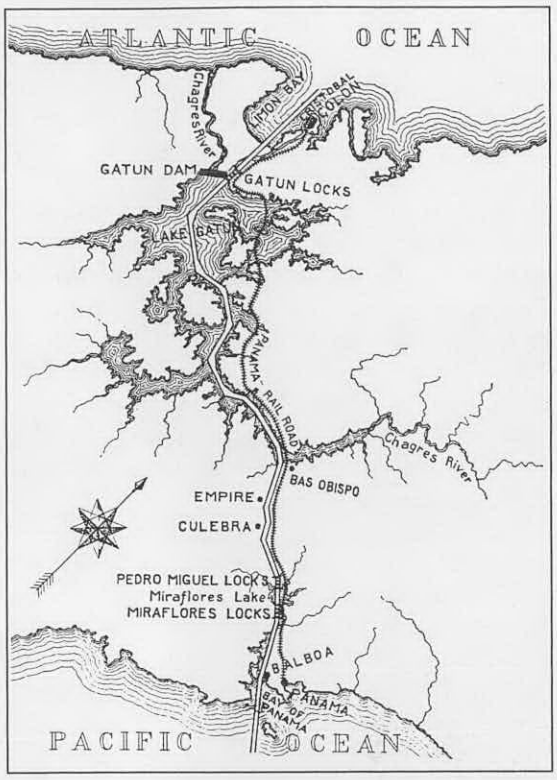

FIGURE 17. Plan of the completed canal and Gatun Lake.

The "Army of Panama" had done its job and they had earned the right to be going home.

Epilogue

De Lesseps died in 1894 a broken man who had been convicted of fraud and mismanagement. Bunau-Varilla returned to victoriously sail through the canal in order to preserve some measure France's honor and contribution to the canal's construction. He was later to lose his leg in the battle of Verdun in World War I. John Wallace would have a very successful career. John Stevens also returned to a very successful practice in civil engineering and ultimately became President of ASCE in 1927. George Goethals would be promoted to Major General and remain as Governor of the Canal Zone until

World War I when he was appointed Head of the Quartermaster Department. Theodore Roosevelt, after running for President again and losing in 1912, would always consider the canal as one of the major accomplishments of his administration. He never saw the completed canal. Eventually, William Howard Taft would become Professor of Law at Yale University after losing in his bid for a second term as President and later be appointed Chief Justice of the United States Supreme Court. Colonel Gaillard would die in 1913 shortly before the completion of the canal. Colonel Gorgas would become Surgeon General and be recognized the world over as the man who, as much as anyone, made the canal possible.

All of these persons in varying degrees, had accomplished what most had thought was impossible — they had *divided the land and united the world.* From that August day over seventy-five years ago, the canal has done what it was designed to do — move ships between two oceans. It is, undeniably, one of the marvels of the twentieth century.

The canal that the "Army of Panama" had built would be enlarged to a minimum width of 500 feet over the years. The Madden Dam would be built on the Chagres River further upstream from Gatun Lake to impound more water in order to meet the needs of traffic during the dry months. This dam, completed in 1936, ensures that the 12,000 transits a year will not deplete the waters in Gatun Lake and will permit a minimum navigable depth in the canal of 38 feet. The small locomotives used to haul the ships through the locks were changed in 1964 after a fifty-year life.

Other than the modifications listed above and some improvements to the canal's lighting and general maintenance systems, the canal was able, fifty years after its opening, to handle all but 103 ships. At an age of more than 75 years, it is still able to handle 93 percent of the ships currently in use. The super tankers, as a class of ship, are all too large to fit into the 110-foot by 1,000-foot locks.

In 1977, President Carter signed a treaty with Panama that resulted in the United States surrendering all rights it gained in the Hay-Bunau-Varilla Treaty of 1903 signed with the newly emerged state of Panama. The Senate, after much debate, ratified this new treaty in 1978. The treaty provides a twenty-year transitional period over which the management of the canal would gradually shift from an American operation to a fully Panamanian operation in 1999.

NOTE — *This article was based on a presentation at a meeting of the BSCES Committee on Younger Members at Merrimack College in November, 1989.*

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