The Panama Canal

AN ARMY'S ENTERPRISE

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Center of Military History
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Cover: Cucaracha Slide *by Jonas Lie, West Point Museum Art Collection. Steam shovels and train engines belch smoke as they attack the Cucaracha slide in 1913. This artistic view captures the scale of the Culebra Cut and the bustle of activity that occurred there daily for years.*

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Introduction

Throughout its history, the U.S. Army has been intimately involved with the development of the nation. Alongside its more better-known efforts to secure the country's independence, preserve the union, and defeat foreign adversaries on a global scale are a host of equally remarkable achievements conducted far from any battlefield or foreign foe. Included are its role in exploring and mapping the American West; maintaining the nation's ports and waterways; leading the technological revolution in manufacturing, civil engineering, electronic communications, aviation, and the medical sciences; and even establishing the national parks and other major conservation projects. But perhaps the Army's most singular achievement is its role in the construction of the Panama Canal.

In 1907, after so many other would-be builders, foreign and domestic, had failed, Army leaders undertook what seemed to be an impossible mission—uniting the Atlantic and Pacific Oceans through a series of gigantic canals, locks, and waterways in a primitive land whose climate and geography created instant hardships. This pamphlet describes the critical role of those Army officers who defied the odds and saw this immense project through to completion. They included Col. William C. Gorgas, who supervised the medical effort that saved countless lives and made it possible for the labor force to do its job; Col. George W. Goethals, who oversaw the final design of the canal and its construction and, equally important, motivated his workers to complete the herculean task ahead of schedule; and many other officers who headed up the project's subordinate construction commands and rebuilt the Panama railroad, a key component of the venture. In the surprisingly short period of seven years, these soldiers, thousands of fellow Americans, and tens of thousands of workers from around the world turned the dream of an isthmian canal into reality. Their success immediately ranked among the greatest peacetime feats of the Army and the nation, and it remains so to this day.

The canal project was the object of intense public interest at the time and became the subject of numerous books then and since. Many of those volumes provide greater detail on the construction process, the medical aspects, and the lives of the people involved, but this pamphlet marks the first attempt to focus on the U.S. Army's

role and to carry the narrative forward to cover the defense of the canal in the following decades. The authors—Jon T. Hoffman, Michael J. Brodhead, Carol R. Byerly, and Glenn F. Williams—have done a commendable job summarizing a well-known story, but also bringing to light new information. Their work is a fitting commemoration of this signal accomplishment that marked the beginning of America's global prestige and power.

JEFFREY J. CLARKE
Chief of Military History

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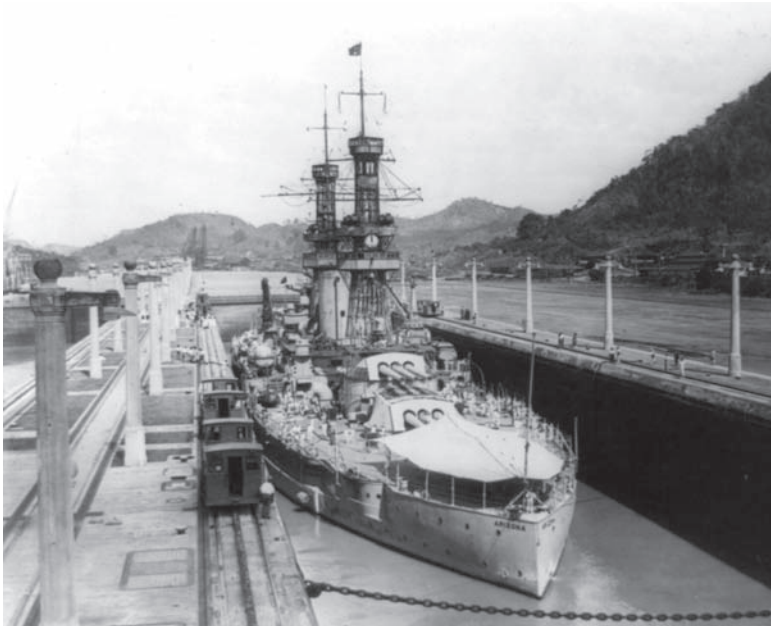
The Panama Canal
An Army's Enterprise

Almost from the moment of the European discovery of the Americas, the search for a shortcut between the Atlantic and Pacific Oceans became a fixation for rulers, entrepreneurs, and adventurers. The list of explorers who sought it includes such memorable pathfinders as Jacques Cartier, Sir Francis Drake, Henry Hudson, Capt. James Cook, Meriwether Lewis and William Clark, and Sir John Franklin. The drive to expand the United States from sea to sea during the nineteenth century added impetus to the effort, as did the discovery of gold in California in 1848. When it became clear that the arduous and dangerous journey around South America's Cape Horn was the only water route available, planners began contemplating the construction of an interoceanic canal across Nicaragua or at Central America's narrowest point, the Isthmus of Panama. A passage of that sort would shorten the 13,000-mile trip around the horn from New York to San Francisco by several weeks and 8,000 miles.

While commercial and political concerns remained major driving forces for a canal, the Spanish-American War validated a new rationale. Naval theorist Alfred Thayer Mahan had argued in his 1890 book, *The Influence of Sea Power upon History*, that a Central American canal was an integral part of American national defense. Eight years later, the highly publicized voyage of the USS *Oregon* dramatically illustrated the point. One of the newest and strongest battleships in the fleet, it was stationed on the Pacific coast, far from the expected scene of action around Cuba as conflict threatened between the United States and Spain. The Atlantic Squadron needed the additional fighting power, so the warship departed San Francisco on 18 March 1898. Sixty-seven days later, following an epic voyage around Cape Horn that kept the American public spellbound, the *Oregon* finally arrived off Florida in time to help defeat the Spanish fleet in the critical Battle of Santiago. The end of hostilities brought the Philippines and other Pacific possessions under the control of the United States, reinforcing the requirement that American soldiers and ships be able to shift rapidly from one side of the globe to the other. It was now obvious to all that national strategy dictated the need for a canal.

The U.S. Army played a critical role in the development of the canal. By the time the work was done and the first ship had transited the canal in 1914, the project had not only become the most expensive public work ever built, it had also set the bar for a new epoch in the advance of technology and medical discovery that was just beginning. Even more, completion of the canal put the world on notice that it now had to reckon with the United States as a global power.



The USS Arizona *makes its way through a lock. One of the driving forces behind construction of the Panama Canal was the requirement to move the military might of the United States rapidly from one side of the world to the other.*

Charting the Path

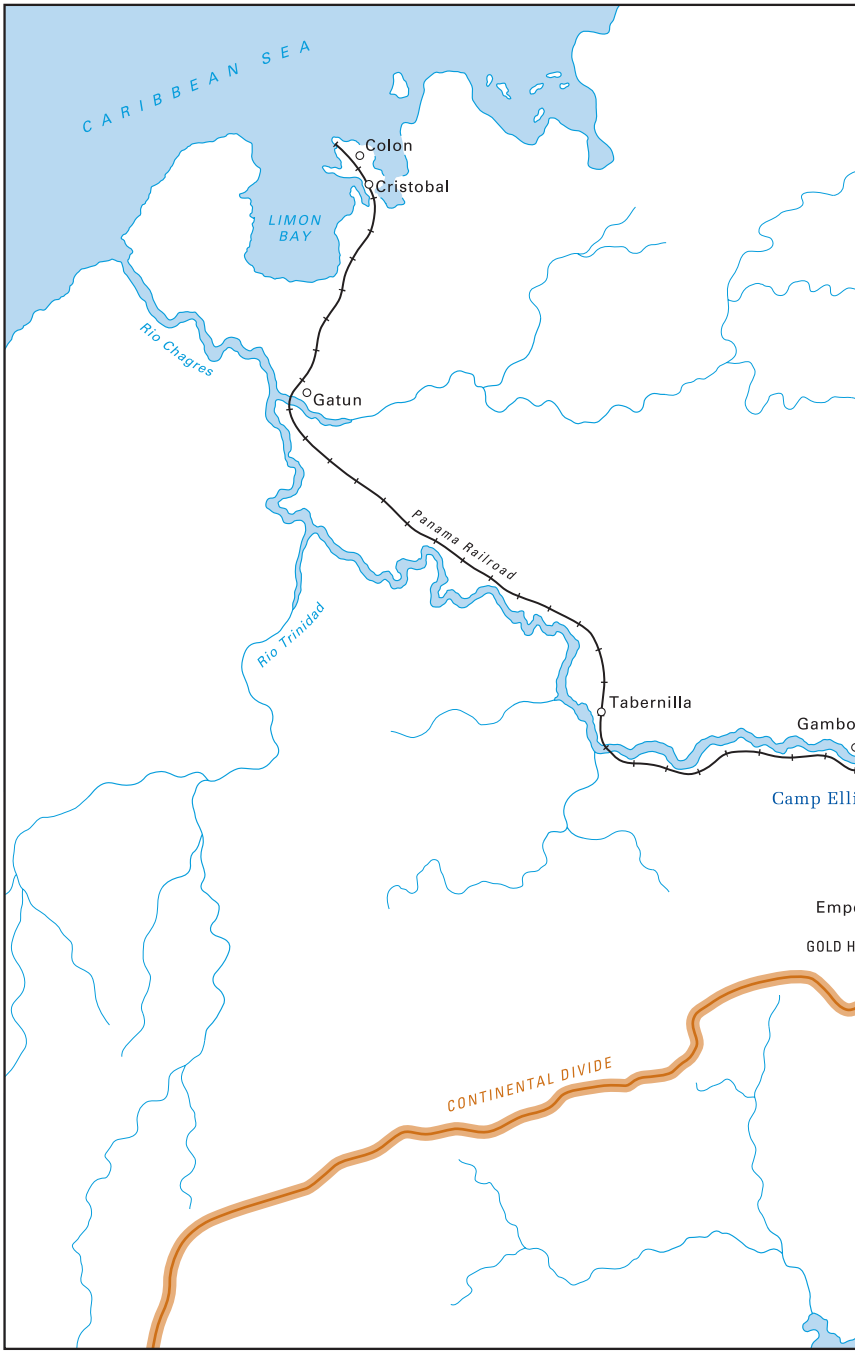
Army engineers had been involved in the effort from its beginning, usually in response to the interest of Congress or the president in the latest idea for connecting the two oceans. In 1839, the chief of the Army's Corps of Topographical Engineers,

Col. John J. Abert, directed one of his officers, 1st Lt. Thomas J. Lee, to estimate the amount of material that would have to be excavated in order to build a canal through Nicaragua. Lee, who appears never to have gone to Nicaragua, acknowledged that his "very imperfect" estimate could "barely serve to give an idea of the magnitude of the work." A decade later, when a company proposing to build a railroad across Panama applied to Congress for financial aid, the House of Representatives solicited Abert's views.

In 1849, the American promoters of the Panama Railroad secured the services of an Army topographical engineer, Brevet Lt. Col. George W. Hughes, to survey a roadbed across the Isthmus of Panama, which was then a province of Colombia. He presented the company with plans, profiles, and maps and authored an optimistic report that minimized the many difficulties of building such a line. Between 1850 and 1855, a U.S. corporation completed the Panama Railroad. The resulting savings in time and distance proved extremely attractive to travelers and shippers, making the venture an instantaneous commercial success. Even so, most cargo—and all warships—still had to go round Cape Horn, so the need for a canal remained ever-present. *(Map 1)*

From 1857 to 1860, a joint Army-Navy party surveyed a potential canal route from the Gulf of Darien, located on present-day Panama's border with Colombia, to the Pacific. Heading its topographical unit was another of Abert's officers, 1st Lt. Nathaniel Michler, who produced an impressive 461-page report. In 1860, another Corps of Engineers officer, 1st Lt. James St. Clair Morton, served as the head of the topographical division in a U.S. Navy investigation of the Isthmus of Chiriquí, located on Panama's border with Costa Rica.

The U.S. government gave even more serious consideration to establishing a maritime link between the two oceans in the 1870s, during the administration of President Ulysses S. Grant. In 1852, Grant had crossed the isthmus as a junior officer with the 4th Infantry regiment and had seen the necessity for an easier route himself. The railroad was only partially completed at the time, so it carried the troops only halfway. They had to finish the trip on foot and mule and in native canoes. The regiment suffered some one hundred and fifty deaths from disease among the troops and their families during the trek—one-seventh of those making the


CARIBBEAN SEA
Colon
Cristobal
LIMON BAY
Rio Chagres
Gatun
Panama Railroad
Rio Trinidad
Tabernilla
Gambo
Camp Elli
Empe
GOLD H
CONTINENTAL DIVIDE

Map 1


ISTHMUS OF PANAMA
Pre-Canal
0
10 Miles
0
10 Kilometers
Rio Chagres
CONTINENTAL DIVIDE
Bas Obispo
Culebra
Pedro Miguel
Rio Grande
Miraflores
CONTRACTORS HILL
Ancon
La Boca
PANAMA CITY
Naos Island
BAY OF PANAMA

passage. "The horrors of the road, in the rainy season," Grant wrote his wife, "are beyond description." From 1872 on, the president prodded Congress to create a succession of boards, associations, and commissions to study and recommend feasible routes.

Most of those who approached the issue favored a route to the north across Nicaragua. While that country was much wider than Panama, a canal there could connect rivers and Lake Nicaragua and potentially require much less digging. The highest terrain to be crossed also appeared to be much closer to sea level than in Panama. In 1880, a group of U.S. investors formed a corporation and obtained an agreement from Nicaragua for the use of a right-of-way, but nothing came of it. In 1887, the nation granted a second concession to a different U.S. corporation, but that organization ceased operation in 1893 for lack of funds. The vice president and general manager of the company during its final years was Capt. George W. Davis, a self-trained engineer and infantry veteran of the Civil War who was on leave from active duty.

While the Americans studied and surveyed and sought financial backing for their effort in Nicaragua, the French began to build a canal of their own in Panama that promised to beat all competitors. The famous builder of the Suez Canal, Count Ferdinand de Lesseps, had charge. Starting in 1880, he planned to repeat his success in Central America by constructing a lockless, sea-level waterway in just twelve years at an estimated cost of $132 million. By 1888, however, the project had consumed twice that amount, covered only one-third of the required distance, and had resulted in the deaths of an estimated 16,500 workers (the vast majority succumbing to various diseases common in the region, such as yellow fever). In that year, de Lesseps grudgingly converted his design into a lock canal, which vastly decreased the amount of digging required. By that point, however, financial resources had begun to dry up and he made little further progress. With accusations of mismanagement, alarm about high disease rates, and large cost overruns mounting, the project came to a halt in 1889.

In 1894, the French formed another company to finish what de Lesseps had started. American Henry L. Abbot served on its technical committee. Commissioned in the topographical engineers in 1854, he had earned a brevet promotion to captain for gallantry at the First Battle of Bull Run, had risen to the rank

of brevet major general of volunteers by the end of the Civil War, and had recently retired from the Regular Army as a colonel after a distinguished career in the Corps of Engineers. Abbot championed the new corporation and its plans for a lock and dam system in articles in U.S. magazines. He urged his countrymen to think no more about a route through Nicaragua, arguing that a canal across the Isthmus of Panama was clearly the right choice. What difficulties there were, he contended, mainly involved cutting through the Continental Divide, regulating the Chagres River, and operating in the region's tropical climate with its enervating heat and deadly diseases. None of these, he believed, was of enough consequence to prevent the successful completion of the project. Abbot's arguments notwithstanding, the new company made little more progress than its predecessor, serving mainly to hold the ground until someone stepped forward to buy its assets.

Throughout the French effort, Americans continued to debate the best location for a canal. Since de Lesseps' failure in Panama seemed to provide ample evidence of that route's unsuitability, Nicaragua remained the lead candidate in the eyes of most interested parties. In 1895, the U.S. government created the Nicaragua Canal Board, also known as the Ludlow Commission after the board's chairman, Lt. Col. William Ludlow of the Corps of Engineers, to study the viability of that alternative. During his service with the group, Ludlow personally examined the Suez, Kiel, and Corinth Canals, as well as waterways in the Netherlands. All three members of the board visited Nicaragua, but they felt they had too little time and money to make any firm recommendation.

Congress chartered a new group in 1897, the Nicaragua Canal Commission headed by Admiral John G. Walker. The group's other members were a serving Army engineer, Col. Peter C. Hains, and a former Army engineer, Professor Lewis M. Haupt. After two years of work, the commission produced a 325-page report, which concluded that a Nicaraguan canal was feasible but fraught with construction challenges.

In 1899, with the French effort in Panama winding down, President William McKinley appointed Admiral Walker to head a new group to restudy the options. Known as the Isthmian Canal Commission, the association's nine members included three Corps of Engineers officers, Haupt, Hains, and Lt. Col. Oswald H. Ernst.

Although Nicaragua remained the likely spot in the minds of most Americans, the new board's name indicated that receptivity had grown to the idea of a canal located elsewhere in Central America. This interest became even more evident when the entire commission traveled to Paris to review information on the French work in Panama. The commissioners conferred at length with Philippe Bunau-Varilla, a former French Army officer who had been the chief engineer of de Lesseps' operation. Bunau-Varilla was a tireless champion of a canal across Panama.

The commission ultimately recommended a waterway across Nicaragua, but that was mainly because the French canal company was asking $109 million for its holdings in Panama, which the Americans valued at only $40 million. In addition, much of the work the French had done seemed of limited value to the project the group had in mind, and much of the equipment de Lesseps had left behind was too small or outdated to be of much use in the new effort. Overall, nonetheless, it was clear that the commissioners largely favored Panama from a practical standpoint. A canal across the isthmus would be one-third the length of its Nicaraguan competitor, require fewer locks, and be easier to navigate and cheaper to operate. Panama also boasted better harbors on both coasts.

Strong sentiment favoring Nicaragua remained in Congress and elsewhere in Washington, but Bunau-Varilla and a New York attorney who represented French interests, William Nelson Cromwell, eventually convinced President Theodore Roosevelt of the advantages of the Panama route. When the French company agreed to sell its assets and the Panama Railroad for $40 million, the commission reversed its ruling and recommended Panama. The eruption of Mount Pelée in Martinique on 25 April 1902 and subsequent earthquake and volcanic activity in Nicaragua all but ratified the move. Two months later, in June 1902, both Houses of Congress passed what became known as the Spooner Act, which authorized work on a canal across Panama. Roosevelt signed it into law right away.

Before construction could resume, however, the United States had to negotiate an agreement with Colombia ceding a right-of-way across the nation's territory. Representatives of both countries signed the Hay-Herrán Treaty of 1903, which offered Colombia an initial $10 million in gold upon ratification and annual payments of $250,000 beginning nine years thereafter. The U.S. Senate

approved the pact, but the Colombian Congress rejected it. The Colombians wanted two changes—a stipulation that the French company should give Colombia $10 million in exchange for the right to transfer its concession and an increase in the initial U.S. payment to $15 million. Secretary of State John M. Hay refused to entertain the proposal.

Many in the U.S. government believed that the Panamanian people disliked being citizens of Colombia. They had good reason to think so, for there had been revolts or riots in Panama against Colombian rule fifty-three times over the previous fifty-seven years. Panama's representatives in the Colombian Congress, moreover, had already served notice that the province would revolt if the Congress rejected the treaty. True to course, on 3 November 1903, spurred on by Bunau-Varilla and Cromwell, Dr. Manuel Amador Guerrero and a group of prominent Panamanians declared independence.

Although the United States had guaranteed Columbian sovereignty over Panama in the Bidlack-Mallarino Treaty of 1846, President Roosevelt supported the revolution. Indeed, on the day before it occurred, the USS *Nashville* arrived off the harbor of Colon to discourage Colombian reinforcements from interfering. Then, on 5 November, a battalion of U.S. Marines under the command of Maj. John A. Lejeune went ashore to give added heft to Roosevelt's "big stick" diplomacy. That same day, in recognition of the indispensable American role in the rebellion, the Panamanians gave the honor of raising their new flag for the first time to Maj. William M. Black, who was serving in the country as part of the Isthmian Canal Commission. The United States recognized the new republic the next day.

Although the Spooner Act required the United States to reconsider the Nicaraguan route if a political crisis occurred in Panama, Bunau-Varilla, acting as the Panamanian minister to the United States, effectively nullified that provision by drafting the Hay-Bunau-Varilla Treaty of 1903. In return for guaranteeing Panamanian independence, the pact gave the United States authority to build a canal and to use it in perpetuity. Its terms were essentially those of the agreement with Colombia, but they expanded the Canal Zone from six to ten miles wide and gave the United States virtual sovereign power and authority in that area. The document also granted the United States the right to enforce public health ordinances in the towns of Colon

and Panama City, which were not part of the zone's territory, and to intervene anywhere in the country to maintain order. Both nations approved the treaty, but the Panamanians did so reluctantly and only because they needed U.S. military power to safeguard their new autonomy. The United States could not have asked for more.

A short ceremony in Panama City on 4 May 1904 symbolized the transfer of the French canal company's property to the United States. Second Lt. Mark Brooke of the Corps of Engineers received the keys to the company's storehouses and a hospital at Ancon in central Panama. He then read a short proclamation, shook hands with Panamanian and French dignitaries, and raised the American flag on top of the company's office building. With that, the Panama Canal became an official American project.

The original draft of the Spooner Act had given the Army Corps of Engineers responsibility for building the canal, but the final form of the legislation dropped that provision. The law did provide for a governor and a seven-member Isthmian Canal Commission to oversee the project and the Canal Zone, with the condition that the Army and Navy were each to have at least one representative in the group. President Roosevelt decided that the board would report to the secretary of war. This seemed to be an odd chain of command since the Corps of Engineers no longer had a big role to play, but Roosevelt explained that the War Department "has always supervised the construction of the great civil works and . . . been charged with the supervision of the government of all the island possessions of the United States."

The commission, which Roosevelt appointed in 1904, included no Army engineers except for now-retired Maj. Gen. George W. Davis, who was also the new governor of the Canal Zone. Beyond his service as a vice president of the failed Nicaraguan canal project in the1890s, Davis' own experience as an engineer consisted of supervising the erection of small buildings at western outposts in the 1870s and as an assistant engineer in the completion of the Washington Monument in the early 1880s. Working under the leadership of Admiral Walker in Washington, D.C., the other commissioners were even less qualified. Although the entire board had to approve all plans and actions, none of its members had a background in running

a massive construction effort. Their lack of expertise and the group-decision-making structure they adhered to rendered the body cumbersome and ineffective.

A year later, Roosevelt dissolved the board and replaced it with the Second Isthmian Canal Commission. Still obliged by the Spooner Act to appoint seven members, he circumvented the requirement by naming three of its members to serve as an executive council that would wield the real power. The chief engineer and the governor of the Canal Zone, both in Panama, filled two of those posts. A civilian, Charles E. Magoon, replaced Davis in the latter job. Brig. Gen. Peter Hains and Col. Oswald Ernst received appointments to the reconstituted commission, serving primarily in technical advisory capacities.

On 29 April 1904, President Roosevelt announced the appointment of John F. Wallace as the commission's chief engineer. Wallace concentrated initially on providing water and sewer systems and building better housing for workers. Replacing much of the equipment left by the French with sturdier, more efficient American models, he then ordered the resumption of digging and the continuation of a survey to determine the center line of the canal. Exasperated by the red tape the commission required, fearing for his health, and lured by a higher-paying position elsewhere, Wallace resigned in June 1905.

His successor was John F. Stevens, a capable, energetic, and self-educated engineer and former general manager of the Great Northern Railroad. Under this new management, the pace of construction increased dramatically. Stevens' first priority was to establish the necessary infrastructure to support effective work on the mammoth project. Arriving at Colon in July 1905, he set about revamping the sadly deteriorated Panama Railroad and reorganizing the engineering and construction bureaus. Stevens made substantial headway in surveying the canal's route; conducting soil borings at projected lock sites; acquiring better equipment; and building the necessary docks, warehouses, and workshops. He moved the project's headquarters from Panama City to Culebra, where he could directly observe work on one of the greatest challenges he faced—digging through the highest point on the canal route. He expanded Wallace's programs for municipal improvements and worker housing at Panama City, Colon, and other communities in the zone. He also created commissary and hotel systems and provided

wholesome food at reasonable cost and recreational facilities for the labor force. Meanwhile, Governor Magoon established a police department, schools, a court system, churches, and post offices.

Army Engineers Take the Lead

For reasons never entirely clear, Stevens submitted a letter of resignation on 30 January 1907. Having seen his first two chief engineers walk off the job, President Roosevelt resolved to fill the vacancy with an Army engineer who would remain at his post until ordered to do otherwise. His decision proved wise, as well, in terms of skill and experience. Both Stevens and Wallace had been railroad men, and so, too, had most of the staff they had chosen to fill key positions. The group had established a highly efficient rail system in support of the excavation, but the construction of locks and dams required individuals more thoroughly versed in hydraulics and the use of concrete. With the founding of the U.S. Military Academy at West Point in 1802, the Army had established one of the nation's premier educational institutions for engineers, and its top graduates generally went into the Corps of Engineers. Beginning in 1824, Congress charged the corps with the mission of improving the nation's navigable waterways, a job that evolved over time to include the construction of dams, locks, reservoirs, and levees. Thus, no body of professionals in the United States had more training and experience in those fields than the U.S. Army Corps of Engineers. In addition, Roosevelt had decided to protect the canal by building fortifications, a job for which Army engineers were also well suited.

On 4 March 1907, Roosevelt appointed 48-year-old Maj. George W. Goethals as a member of the Isthmian Canal Commission. An engineer with close to three decades of experience, Goethals had worked on several water projects and had visited the isthmus with Secretary of War William H. Taft in 1905. One month after making the appointment, the president restructured the organization in Panama yet again. Abolishing the position of governor, he made Goethals chairman and chief engineer of the canal commission and president of the Panama Railroad Com-

pany. By so doing, he placed all the authority for the project in the hands of one man and turned the commission into a rubber stamp for his decisions.

Maj. Gen. George W. Goethals

Goethals, *by Brig. Gen. Chester Harding. Harding, a fellow Army engineer who worked on the Panama Canal project, painted this portrait in 1930.*

The son of Belgian immigrant parents with a distinguished heritage, George Washington Goethals was born in Brooklyn, New York, in 1858. He graduated second in the West Point class of 1880 and went on to further training at the Engineer School of Application at Washington Barracks in Washington, D.C. His first independent mission as an officer involved the construction of a bridge over the Spokane River in Washington State to replace one swept away in a storm. It was "the hardest job I ever tackled," he would later recall, even including the Panama Canal, because he had "never built a bridge"

and had to figure out how to do it while meeting a compressed time schedule. In 1884, he married Effie Rodman, with whom he had two sons.

As a captain, he received charge in 1891 of the completion of the Muscle Shoals Canal on the Tennessee River in Alabama. Setting to work, he persuaded his superiors that a lock capable of lifting a boat or barge to the unprecedented height of 26 feet would be best suited for the project. When completed, the lock set a world record. Goethals also built a short railroad as part of the process. Both experiences would prove invaluable in Panama.

At the beginning of the Spanish-American War, Goethals helped construct a camp in Georgia. Then he took charge of engineer operations for the force seizing Puerto Rico. During the landing on that island, he had to construct a wharf quickly. Over the protests of senior Navy officers at the scene, he confiscated barges they had just captured and sank them off the beach to form his dock. This was clearly a no-nonsense officer who could get a job done.

In 1903, a board of generals selected Goethals to be one of the first forty-two officers to serve on the Army's new General Staff in Washington. There he made a strong impression on Secretary Taft, who recommended him for a job as one of Stevens' chief assistants on the canal. The railroad man was not interested; but two years later, the Army major stepped in to take over the entire project. Initiated by a late evening telephone call requesting that he come to the White House to meet the president, the assignment came as a complete surprise to the engineer. It also brought with it immediate promotion to lieutenant colonel.

Goethals later would say that he left nearly all of the engineering aspects of the project to the capable men who worked under him and focused, instead, on supervising the overall effort, particularly the aspect that he knew was most critical—what he termed "the human element." He was not out to curry favor with those who worked under him, but he understood their need to know that their superiors cared about them and their well-being. In return, he expected unwavering devotion to duty. As one canal man remarked: "You've got your work and you'll do it; you've got your rights and you'll get 'em, every time."

Another trait that stood Goethals in good stead was his incorruptibility. "Nothing could disturb or cloud his perception of right and wrong," an attorney general of the United States observed. "A thing was true or false; there was with him none of that deceptive middle

region in which so many lose their way and fool themselves into unworthy compromises." The officer's distant manner and unbending high standards made few friends among those who worked directly with him, but he generally inspired at least grudging respect. Farther down the line, those who saw only the results of his policies almost universally admired him.

With the completion of the Panama Canal in 1914, Colonel Goethals received the thanks of Congress and a promotion to major general. World famous, he hoped to be appointed chief of engineers. Instead, President Woodrow Wilson named him to the newly re-created position of governor of the Canal Zone. He resigned the governorship and retired from the Army in 1916.

With America's entry into World War I, Goethals returned to duty as the acting quartermaster general. The following year, he took charge of the War Department's Division of Purchase, Storage, and Traffic. Given the free hand he had wielded in Panama, he rapidly reformed a system overwhelmed by the demands of a major conflict. A civilian once again in 1919, he enjoyed success as a consulting engineer. Undeniably one of America's greatest builders, he died in New York City in 1928.

The appointment of Goethals did not make the Panama Canal a U.S. Army Corps of Engineers project. Goethals served on detached duty, receiving a civilian salary and reporting to the secretary of war rather than to the chief of engineers. Even so, he filled many of the key positions on his staff with engineer officers on loan from the corps. In fact, the Panama Canal project had the largest number of Corps of Engineer officers on duty in one location outside of Washington, D.C. Working in concert with their civilian counterparts, they would provide the drive, organizing skills, and experience necessary to propel the project to completion.

Soon after assuming his duties, Goethals made changes in the administrative structure of the workforce he inherited. Where Stevens had organized the project by activity, such as excavation and dredging, Goethals split it into three geographical divisions. The chiefs of each sector were to be in charge of almost all activities within their areas. The Atlantic Division reached from Limon Bay to the locks and dam at Gatun. (The actual body of water north

of Panama was the Caribbean Sea, but the project officially dubbed that the Atlantic end of the canal.) The Pacific Division embraced the area from the sea-level entrance at Panama Bay to the Pedro Miguel Locks. The Central Division covered the bulk of the route, encompassing Lake Gatun and the massive Culebra Cut. The new organization was fully in place by July 1908.

Maj. David D. Gaillard was Goethals' choice to head the Central Division. His was probably the most demanding and daunting engineering responsibility of the entire project, as it would literally involve moving a mountain of rock and dirt under conditions complicated by climate, topography, and geology. Gaillard, who was soon promoted to lieutenant colonel, was a native of South Carolina and an 1884 graduate of West Point. He came to the task with a rich background that included resurveying the border with Mexico; service on the Army's General Staff; command of engineer troops during the Spanish-American War; and work on a number of civil water projects in Florida, Washington, and Alaska, and around Lake Superior. In addition to his construction experience, Gaillard had authored a respected work on the effects of wave action. His assistant in running the Central Division was a civilian, Louis K. Rourke.

Gaillard's West Point classmate and roommate, Maj. William L. Sibert, was already on the project. A member of the canal commission and the head of both the Department of Lock and Dam Construction and the Division of Hydraulics and Meteorology, he took charge of the Atlantic Division as part of the reorganization. Following three years of study at the Engineer School of Application, Sibert had worked at the Sault Ste. Marie Canal in the Great Lakes and had directed river and harbor improvements at Cincinnati, Little Rock, and Pittsburgh. Besides constructing numerous locks, he had commanded engineer troops in the Philippines and had also served as general manager of the Manila-Dagupan Railway. His combination of rail and waterway experience made him ideal for this assignment. His primary assistants in running the division on the Panama project were also Army engineers. Maj. Chester Harding directed work on the Gatun Locks, while Majs. Edgar Jadwin, James P. Jervey, and George M. Hoffman, and Capt. Horton W. Stickle served as resident engineers.

One of Goethals first acts had been to lure Sydney B. Williamson to Panama. The two had worked together at Muscle Shoals and had built the famous locks there. Goethals had been

most impressed then by his subordinate's leadership, demonstrated when Williamson had gone down into a deep hole perilously close to collapse and had wielded a shovel alongside laborers who had refused to work in the dangerous location until he led the way. Goethals selected him to direct the Pacific Division. Although a civilian at the time, Williamson was an 1884 graduate of the Virginia Military Institute who had served as a captain in a volunteer engineer regiment during the Spanish-American War. In 1903, he had left government service to work for engineering firms in New York and Baltimore, where he studied the use of reinforced concrete. A combination of concrete poured around a framework of steel rods, this building method provided a much stronger structure than concrete alone. It was just coming into significant use, but its heavy employment on the Panama Canal would dwarf any type of reinforced concrete project for the next couple of decades.

Williamson's staff had no military personnel. Goethals had guessed, correctly as it turned out, that his reliance on geographic rather than functional divisions and the civilian-military mix would result in energetic competition as each group sought to outshine the other.

Another engineer officer detailed to duty in Panama was Lt. Col. Harry F. Hodges. An 1881 graduate of West Point, Hodges had initially served in Washington as a member of and purchasing officer for the canal commission. In that role, he had overseen a vast web of contracts for the acquisition of equipment and supplies. In 1907, he moved to Panama, where he served as the project's assistant chief engineer and as acting chief engineer whenever Goethals was absent from the zone. He also supervised the design of locks, dams, and regulating works. Without Hodges, Goethals believed, the canal could never have been built. Army engineer Capt. Frank C. Boggs replaced Hodges in Washington as the commission's purchasing officer.

Beginning in 1909 and for several years thereafter, the Corps of Engineers sent newly commissioned officers to the canal, where they could gain valuable experience in water projects. One of them was Goethals' son, 2d Lt. George R. Goethals. Immediately after graduating from West Point in 1908, the young officer had served under his father in relocating the Panama rail line. Later, he worked in the railroad's transportation and operations departments. Becoming the assistant engineer of the Pacific Division after that, he helped direct the construction of locks and dams at

Balboa and Miraflores. As his last task, he oversaw the fortification of the Canal Zone.

Officers from outside of the Corps of Engineers also filled significant roles in the project. Maj. Carrol A. Devol of the Quartermaster Department became chief quartermaster of the Canal Zone. Capt. Robert E. Wood, a cavalry officer, served as his assistant. Lt. Col. Eugene T. Wilson, a coast artillery officer, was in charge of feeding the huge workforce and running the commissaries. Maj. Tracy C. Dickson, an ordnance officer, served as the inspector of shops. First Lt. Frederick Mears, another cavalryman, handled the task of relocating the Panama Railroad. Personnel from the Army Medical Department, led by Col. William C. Gorgas, would prove indispensable to the successful completion of the canal. Navy Cdr. Harry H. Rousseau, in charge of terminal construction, had responsibility for designing and building warehouses, machine shops, wharves, docks, and coaling stations at both ends of the canal.

That so many of the senior leaders of the project had a common background in the Corps of Engineers and the Army did little to foster harmony within the group. The relations between Goethals (who was promoted to colonel in 1909) and some of his principal subordinates were strained from the outset. Sibert frequently disagreed with his chief's engineering decisions while Goethals found his subordinate "cantankerous and hard to hold." At one point, the colonel considered replacing Sibert. The two officers spoke to each other only when necessary, but Sibert stayed with the project until its completion.

Gaillard, Sibert, and Gorgas, all southerners, felt that Goethals had a sectional bias against those from the south that made service under him almost unbearable. From the chief engineer's perspective, "everybody down here seems to develop a large crop of corns and it is difficult to step without treading upon one." Others ascribed the frequent irritability of Americans in Panama to the climate, with one medical officer asserting that "the effect of constant heat and moisture, without change of season, is to induce a condition of nervous and physical depression."

Some of Goethals senior subordinates did get along well with their boss. Hodges, his chief assistant, was a primary example. The relationship between Goethals and Williamson was not only productive but also close, despite Williamson's status as a southerner

from Virginia against whom Goethals was allegedly prejudiced. Goethals, for his part, never allowed personal discord to affect his professional relationships. When a leading engineering journal of the day criticized Sibert's management of the construction effort at the Gatun Locks, he strongly defended his subordinate in a letter to the editor and took personal responsibility for the decisions in question. Sibert was less generous. He mentioned Goethals in the introduction to a history of the project he published in 1915 and then never referred to him again by name.

The chilly relationship between the chief engineer and some of his principal lieutenants was only one of many challenges military and civilian leaders had to address before the project could succeed. About the only thing set in concrete after three years of American effort was the overall plan for the canal. By the fall of 1905, it had become necessary to settle the argument between advocates of a lock canal and a sea-level canal. To that end, President Roosevelt created a Board of Consulting Engineers to determine the best approach. Its chairman was retired General Davis. Also sitting on the board was Brevet Major General Abbot. Capt. John C. Oakes, Corps of Engineers, served as secretary. Of the thirteen members, five were foreigners. Joined by Davis and two other Americans, they formed a majority that issued a report recommending a sea-level canal. The minority report of the remaining five Americans, including General Abbot, favored locks and dams. Roosevelt, Secretary Taft, the Isthmian Canal Commission, and Stevens agreed with the minority, as did Congress, which passed an act on 29 June 1906 officially choosing a lock system.

The deciding factor in the decision was the wild and unpredictable Chagres River, which could rapidly surge into an enormous flood when torrential rains fell in its mountainous watershed. Many planners believed it was too unmanageable to serve a useful purpose and had initially sought ways to divert it away from the canal. General Abbot emphatically disagreed. After conducting a careful study, he concluded that the river's power, when harnessed, would be a great asset.

The final plan routed the canal along the valley of the Chagres River on the Atlantic side of Panama and along that of the Rio Grande River on the Pacific. From Limon Bay on the Atlantic, a man-made seven-mile sea-level channel would lead to Gatun. At that point, a dam would put the Chagres River to use, generating

hydroelectric power and creating a huge artificial lake known as Lake Gatun that would form a substantial portion of the canal's waterway. A single flight of three locks at Gatun, relying on gravity to move the water, would raise ships up to the lake or lower them from it. To facilitate two-way traffic, each of the locks throughout the system was to have two chambers. After entering the lake, ships would have ample room for a safe and rapid transit for twenty-three miles. *(Map 2)*

Arriving at the other end of the lake, vessels would reach the Culebra Cut, a narrow, nine-mile stretch slicing through the Continental Divide. At the southern end of the cut at Pedro Miguel, there would be a smaller dam with one lock, which would lower ships to another man-made lake contained by a dam at La Boca. After crossing that, ships would enter two more locks that would lower them into a sea-level channel leading to Panama Bay, the Pacific terminus of the canal. The route required the relocation of the Panama Railroad farther to the east since the lakes would submerge much of the old right-of-way.

The overall plan for the locks and lakes of the Panama Canal closely approximated a scheme advocated by Frenchman Adolphe Godin de Lépinay in 1879 that de Lesseps had rejected. The design for the locks themselves roughly duplicated the one for those of the Sault Ste. Marie Canal, which had by then linked Lakes Superior and Huron for fifty years. Operated by the Corps of Engineers since 1881, the canal was small (1.5 miles long) but it carried far more traffic than the Suez Canal. Goethals and other engineer officers in Panama had earlier served tours of duty at Sault Ste. Marie. Shortly before his departure, Stevens assigned the task of designing the Gatun Locks to Joseph Ripley, chief engineer of the Sault Ste Marie Canal. Ripley would depart the project in 1908, to be replaced by Colonel Hodges, who would do the major share of the work.

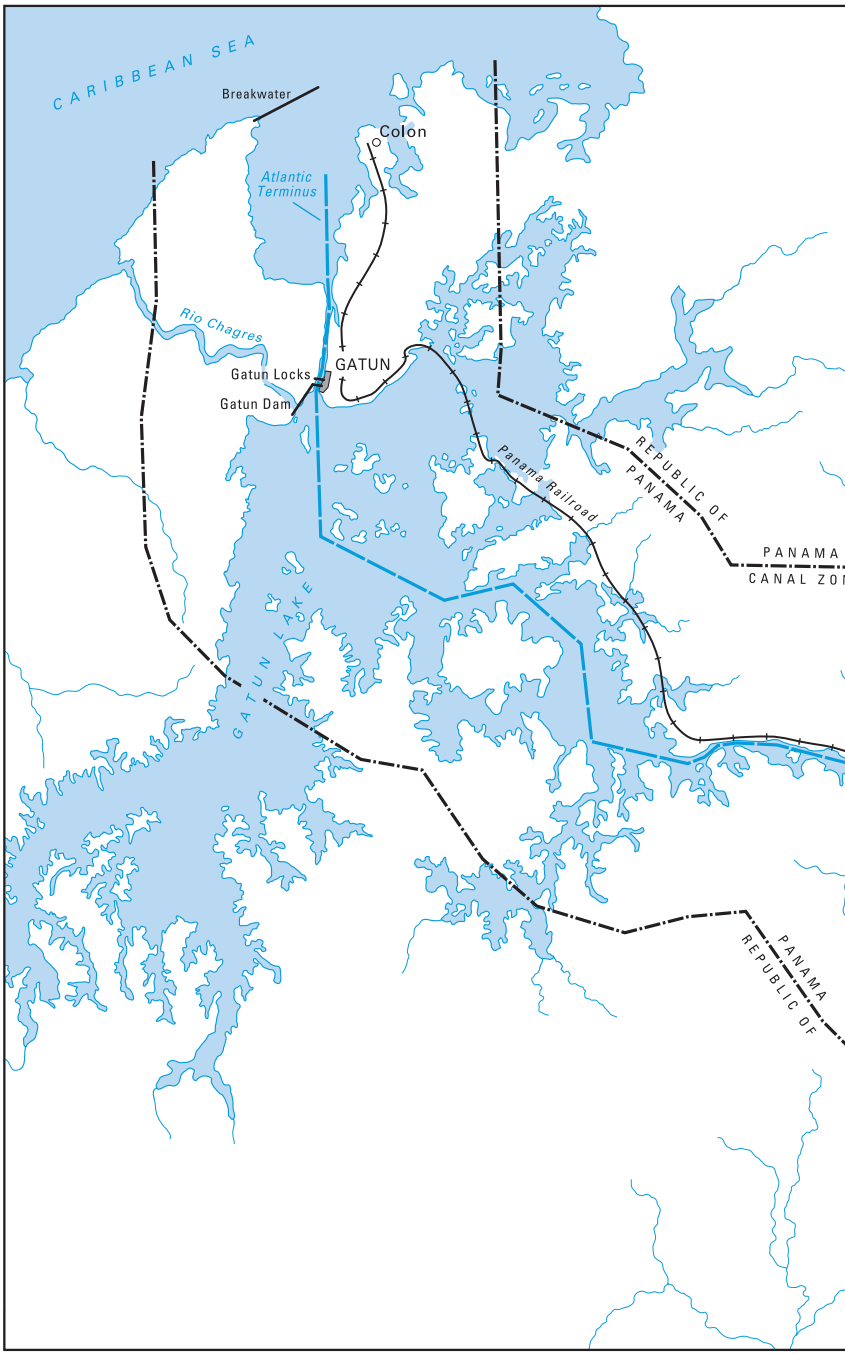
With debate over the design of the canal completed, the actual work of turning the plan into a reality presented huge challenges. Not the least of which were Panama's climate and terrain. After the French gave up their effort, jungle growth had reclaimed large swaths of the construction area. The torrential rains that fell eight months out of the year in the region left abandoned equipment such as steam shovels and dredges rusting and mired in the mud. The rains also were partly responsible for another big problem—landslides (known simply

as slides in Panama because of their frequency). The many that occurred, particularly in the Culebra Cut, brought frustration and heartbreak throughout the years of canal building. Slides and all manner of accidents caused injuries and fatalities. Temperatures that ranged over 100˚F meanwhile posed a constant risk of illness and even death from heat prostration. A wide variety of insects and poisonous reptiles also made life miserable and sometimes dangerous.

The task of obtaining workers to build the canal presented an issue. From the beginning of the project, there had been a debate over what sort of labor force would be best. General Hains, one of the early commissioners, had dealt largely in ethnic stereotypes. He dismissed the Panamanians as too lazy. As for the Chinese laborer, Hains asserted that he was inclined to open a store once he had earned a little money. The West Indian black was "fairly industrious" and "not deficient in intelligence" but drove a hard bargain, demanded too many holidays, and was overly conscious of his rights as a British subject. Hains recommended the hiring of blacks from the American South because he felt they were accustomed to hot weather, spoke English, had temperate habits, demonstrated resistance to disease, and were "intelligent, industrious, and ambitious." The commission adopted advice Hains offered that the government hire personnel and manage the work itself rather than rely on contractors. Otherwise, his opinions carried little weight.

In the end, the question of who should build the canal seems to have settled itself. People came from everywhere. By the time Goethals took control, about 24,000 were employed in the zone, a number that grew to more than 40,000 before the project ended. Ninety-seven countries were represented, with a majority of the unskilled coming from Barbados and other Caribbean islands. Some 10,000 Spaniards, Italians, and Greeks also signed on.

In the initial years of the American effort, many workers returned home because of insufficient pay, inadequate housing, unsatisfactory food, poor sanitation, and fear of disease. Stevens initiated dramatic improvements in some of these areas, but they applied unevenly across the workforce. Contrary to the view of Hains, Stevens thought poorly of the Caribbean blacks, citing what he considered the "natural indolence of these people." In a system not unlike the Jim Crow segregation in effect in the American South, he and the canal commission divided the workers into two


CARIBBEAN SEA
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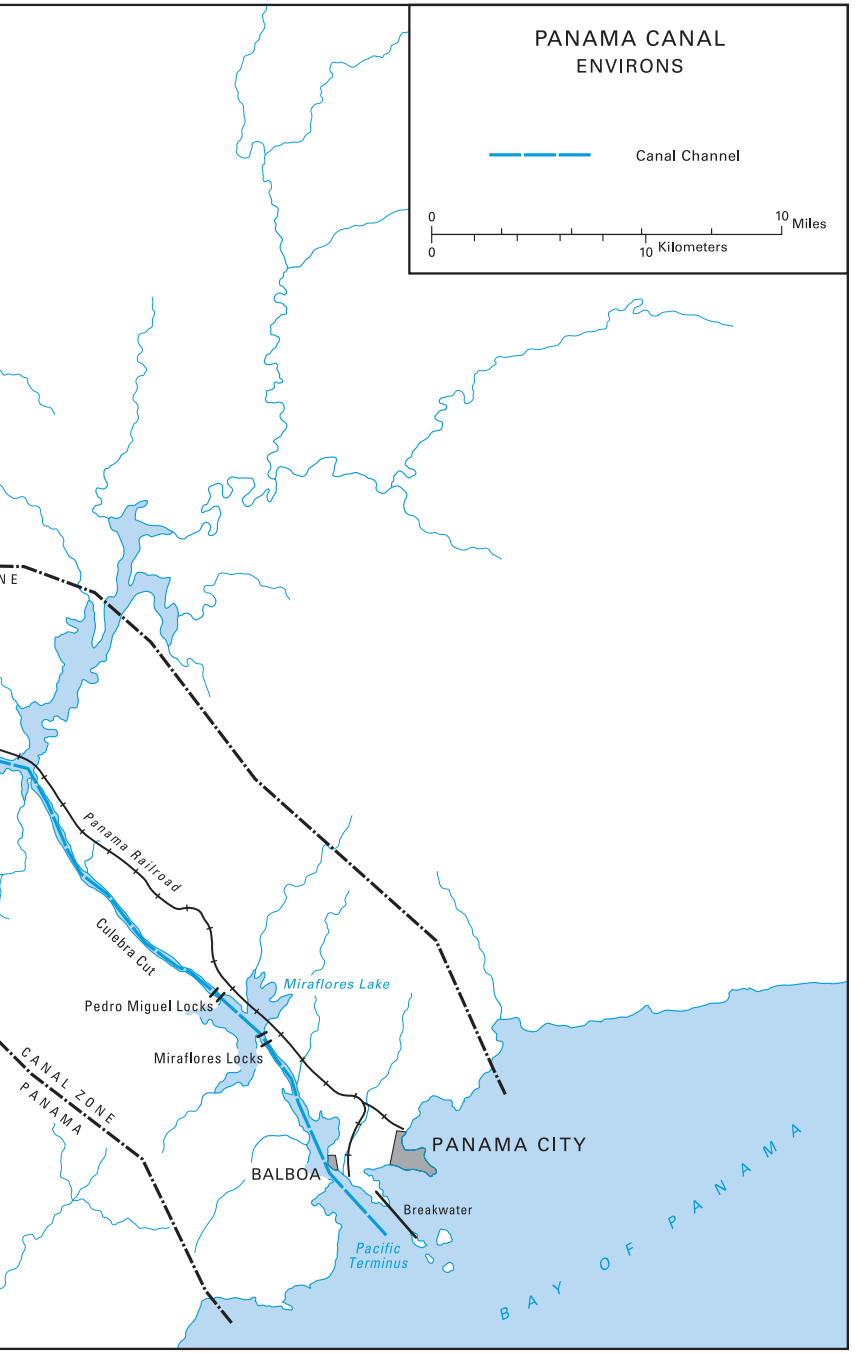
Map 2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Miraflores Locks
CANAL ZONE
PANAMA
PANAMA CITY
BALBOA
Breakwater
Pacific Terminus
BAY OF PANAMA

classes. The skilled employees, fewer than 10,000 primarily white Americans with a smattering of American blacks, local Panamanians, and other nationalities, received their salaries in U.S. gold coins. Some 30,000 semiskilled and general laborers, all foreign, initially received less-valuable Panamanian silver. Although that disparity in pay changed eventually, with everyone earning American dollars, workers in the two classes continued to be known as either gold roll or silver roll employees. A major likened the distinction to the one that existed between the commissioned and noncommissioned officers of an army and its junior enlisted personnel, but the division in this case was based on race and nationality more than rank. As time passed, the project's hiring process increasingly excluded black Americans and foreigners from gold roll jobs.

Living quarters for those on the silver roll in the Canal Zone.The class distinctions between the skilled (primarily American gold roll employees) and the largely unskilled (foreign silver roll workers) went beyond pay into housing, schools, and other amenities.

Those on the gold roll benefited the most from improvements in Canal Zone living conditions. They resided in housing and neighborhoods separate from those of the silver roll, frequented different stores and shops, and sent their children to segregated schools. The public health department even categorized hospital

patients according to their employment status and treated them in separate wards when possible. Although all canal employees received free medical care, family members had to pay a daily rate for any stay in the hospital, a heavy burden for lower-paid married workers. For those who were single, even food service went by class. Bachelor Americans ate in restaurants for thirty cents a meal, and Europeans had their own mess halls for forty cents a day. West Indians could get food from separate kitchens for thirty cents a day, but this was a large sum for unskilled laborers who sometimes earned as little as ten cents an hour. Many Caribbean blacks graduated over time to higher-paying work as carpenters, masons, painters, and even foremen, but they still received less than their gold roll counterparts.

Goethals never changed this system, but he did seek to improve the attitude of his employees. When he first arrived, many feared that an Army man would subject civilians to military discipline. One newspaper cartoon depicted battalions of uniformed workers wielding picks and shovels in ordered columns. Greeted with "cold silence" at an initial gathering with gold roll personnel, Goethals sought to allay that concern by vowing that he would look after their interests as if they were his own and that "every man who does his duty will never have any cause to complain on account of militarism."

The first labor issue he had to deal with was a strike by well-paid steam-shovel operators that arose immediately after he joined the project. The workers wanted a nearly 50 percent increase in salary. When the government offered longevity pay but no immediate raise, many of the highly skilled workers walked off the job. Goethals responded by telling everyone to return to work and threatening to hire replacements for those who did not. Within a few weeks, he had all the equipment operating again at full capacity, sometimes with new workers. No more strikes occurred.

The chief engineer's willingness to make good on his pledges, positive or negative, gained the respect of his employees. So did his policy of encouraging workers to come to him with any grievance—a major change from the previous administration, which tended to respond to complaints by telling the aggrieved they could always quit and go home. He opened his office every Sunday morning to anyone who wanted to register a complaint or concern. He received everyone, regardless of race or station,

on the same footing and listened patiently to their problems before rendering a verdict or launching an investigation. He also started a weekly newspaper to keep workers informed about the project and its progress. Among other items, it published statistics on the performance of excavation crews, leading to fierce competition to set new records and a substantial increase in productivity.

Perhaps the most important personnel issue for both supervisors and the workers was the state of the workers' health. In addition to the sometimes dangerous work, tropical Panama presented the continual threat of a wide range of deadly illnesses, a scourge that had played no small part in defeating de Lesseps' attempt to build a canal. In this, the Army engineers were ably supported by Army medicine and Colonel Gorgas, but several years of hard work, innovation, and sheer determination lay ahead.

Conquering Yellow Fever

By the end of the nineteenth century, most American cities had been able to control diseases such as typhoid, plague, cholera, and dysentery with improved sanitation. Meanwhile, in the southern states, malarial regions were diminishing and yellow fever was becoming increasingly rare. When Americans entered new overseas territories during and following the Spanish-American War, however, the nation acquired fresh medical problems, both familiar and exotic. The arrival of large numbers of outsiders in these places tended to induce epidemics among the visitors, who were not as well adapted as the indigenous populations to the local pathogens—the bacteria and viruses that cause illnesses.

This situation was particularly the case in Panama, long considered one of the unhealthiest places on earth because it harbored such deadly diseases as yellow fever, malaria, bubonic plague, and typhoid. Thousands of canal workers also fell victim to pneumonia, and accidental explosions and railroad wrecks killed hundreds more. Gorgas and his Army medical officers thus fought sickness and injury on a number of fronts. Their experience with trauma on the battlefield and tropical medicine during campaigns and occupations would serve them

well in this environment. Similar to their mission in wartime, they had to keep as many men as possible healthy and effective in order to win the fight.

Yellow fever was one of the most intimidating tropical diseases. Although outbreaks were infrequent, they were terrifying. Symptoms included high fever, chills, headache, jaundice (hence the name yellow fever), and at times hemorrhaging into the stomach and intestinal tract, causing the horrifying "black vomit." Mortality rates ranged from 10 to 60 percent of those infected, and death typically occurred between the seventh and tenth day of the illness. An attack could be mild, however, and would induce lifetime immunity to the disease. Because frost killed the mosquitoes that carried yellow fever, it was not endemic in the United States and usually arrived in U.S. ports from tropical areas where it persisted year-round. The most extensive yellow fever epidemic in America struck in 1878, beginning in New Orleans and moving up the Mississippi River, causing more than 100,000 cases and killing from 13,000 to 20,000 people.

In addition to the toll on health, large-scale outbreaks could devastate the economy. Gorgas, a veteran of many yellow fever epidemics, observed: "When this disease was announced in a town, everybody left who could. The sick were frequently left without care, and often a great deal of cruelty and cowardice was shown." People who became ill were treated like lepers and "all business is entirely paralyzed, the quarantines not allowing any communication between the affected districts and those not affected." In regions where yellow fever was endemic, such as Panama, it was rare among adults, since the vast majority had immunity from surviving a bout with it as a child. Extensive outbreaks occurred only when "non-immunes" arrived in an area—such as when the Americans came to construct the canal.

Gorgas, one of the first Americans to go to Panama in 1904, was an expert in this disease. He had acquired prominence following the Spanish-American War, when the surgeon general sent him to Cuba to run a yellow fever camp. He stayed on in Havana, developing a program to implement the Reed Commission's historic findings that the *Aedes aegypti* mosquito transmitted yellow fever. His efforts succeeded in a matter of months in eliminating the disease from the city and also greatly reducing malaria.

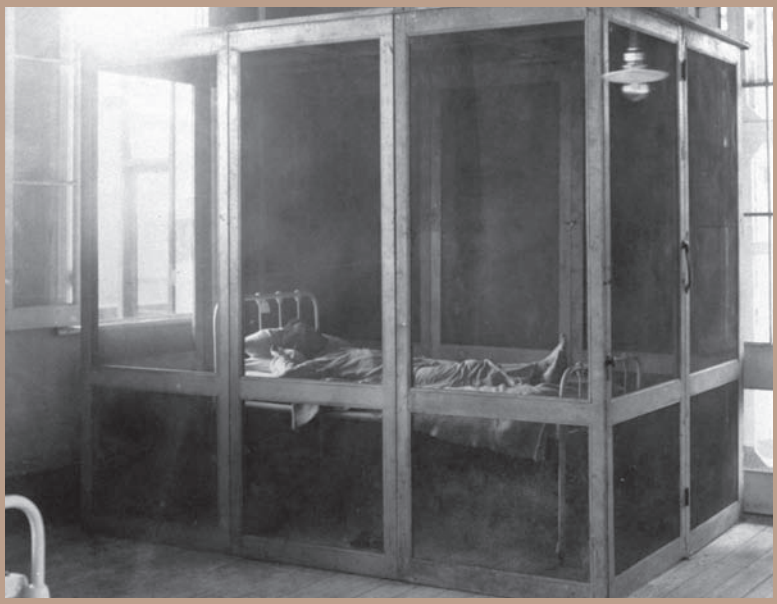
Yellow Fever Work in Cuba

The names of two Army medical officers are linked forever by their fight against yellow fever—Walter Reed and William C. Gorgas. Reed led the effort that unlocked the key to yellow fever; Gorgas put the new knowledge to practical effect. The story began when the United States occupied Cuba in 1898 and had to deal with Havana, a city of 250,000 long considered a source of epidemic outbreaks. At the time, medical experts believed that filth caused many diseases, so when yellow fever persisted even after the city had been scrubbed, Army Surgeon General George M. Sternberg appointed a commission to investigate the cause of the scourge and how to prevent it. Headed by Army bacteriologist Reed, the group included three other specialists in infectious disease, James Carroll, Aristides Agramonte, and Jesse W. Lazear. The three were serving with the Army as contract doctors, but Carroll had begun his career as an infantryman in 1874, become a hospital steward in 1883, earned a degree in medicine in 1891, and would finally receive a commission in the Medical Corps in 1902.

In a dramatic series of experiments beginning in June 1900, the commission proved that yellow fever was spread not by filth, but by female *Aedes aegypti* mosquitoes, which carried the virus from person to person with their bites. To achieve this breakthrough, the commission first disproved a hypothesis that bacteria caused yellow fever, and then tested several theories regarding the role of mosquitoes. For almost twenty years, Cuban physician Carlos Juan Finlay had argued that the *Aedes aegypti* transmitted yellow fever to humans, but he had never been able to demonstrate this in laboratory conditions. In 1898, during a yellow fever outbreak in Mississippi, Public Health Service scientist Henry R. Carter was able to show that a period of ten to fourteen days elapsed between the appearance of the first case of yellow fever and subsequent cases. This, he theorized, was due to some sort of external incubator. Now working in Cuba, Carter told commission members of his findings and they turned to mosquitoes as the culprit. They contacted Finlay, who gave them eggs of the type of mosquito he believed carried yellow fever.

While Reed took leave back in the States, Lazear and Carroll conducted initial experiments in August and September 1900. They hatched Finlay's eggs, let them feed on yellow fever patients, and then had them bite a handful of volunteers. Carroll and one soldier both came down with the disease but recovered. Lazear, however, was also bitten—whether accidentally or intentionally is uncertain—and contracted yellow fever. His case, however, was so severe that he died 25 September 1900. When Reed returned to Cuba soon after, he set up a camp in the jungle to continue the commission's work and christened it in honor of Lazear. He and his team set about systematically demonstrating that mosquitoes only picked up the yellow fever virus if they fed on a person during the first three days of infection, and the insects then had to incubate it for a period of days before they could pass it on to another human via a bite. Most dramatically, the commission finally exploded the filth theory when brave volunteers slept for twenty nights in pajamas and bed linens soiled by yellow fever patients' vomit and diarrhea and did not develop the disease.

Now the challenge went to Gorgas, recently appointed the chief sanitary officer of Havana. In December 1900, the military governor of Cuba, Maj. Gen. Leonard Wood (a physician and combat leader), authorized Gorgas to implement the commission's findings. Theorizing that an intentional inoculation via a bite from an infected mosquito would induce mild cases of yellow fever that would deliver lifetime immunity, he first tried to use the insects to vaccinate people against the disease. Sixteen volunteers allowed themselves to be bitten and eight developed yellow fever. Three of them died, however, including a young nurse, Clara Maass, and Gorgas had to abandon the vaccination program. Now, the only solution he saw was to rid Havana of mosquitoes. Gorgas went to work. He first enclosed yellow fever patients in screens to prevent mosquitoes from picking up the disease and spreading it to others. He then ordered the fumigation of every building in Havana to kill adult mosquitoes. Gorgas' team also identified collections of water where mosquitoes might breed, and either screened or drained them, or spread oil on the surface. Results appeared within months. Yellow fever in Havana fell from 1,400 cases in 1900, to 37 in 1901, and none in 1902. Malaria deaths decreased as well.



A yellow fever patient is isolated in a screened enclosure in the hospital. The disease was only transmitted by a mosquito that had fed on an infected person, so preventing the insects from getting such a meal helped contain the spread of the illness.

Reed and Gorgas were thrilled. Gorgas likened Reed's discovery to the development of the smallpox vaccine, and told him: "I am very happy to shine in the more humble role of being the first to put your discovery to extensive, practical application." Gratified that Gorgas had so convincingly proven his scientific work, Reed replied in kind: "I was simply delighted by your annual report. What a glorious record! . . . It made my heart beat faster, as I read it." Tragically, however, Walter Reed did not long enjoy his success, as he died of infection after an appendectomy in November 1902. Eighteen months later, when Gorgas traveled to Panama, he had Reed's science, but not his friendship, to support him.

Eager to apply the mosquito control methods he had developed in Cuba to the canal project, Gorgas had asked the

surgeon general to send him to Panama. Instead of fighting insects in a single city such as Havana, however, he now faced a battleground consisting of two small urban areas and the 500 square miles of an elongated zone of jungle and swamp that separated them. "While there was a considerable difference in the conditions and environment at Havana," he explained, "still I believed that the methods worked out at Havana could be so modified as to be applied successfully at the Isthmus." The Americans were well aware that several thousand workers had died in the 1850s while building the railroad across Panama, and Gorgas later estimated that 22,000 people died and one-third of the workers were sick annually when the French attempted to construct a canal. But Gorgas and his contemporaries believed that new scientific knowledge and techniques would enable them to succeed where de Lesseps had failed. As it turned out, the political opposition would prove to be more daunting than the mosquitoes.

The Panama Canal Treaty gave the United States the authority to manage public health measures in the cities of Panama and Colon and throughout the Canal Zone. Responsibilities included maintaining the health of the canal workforce, caring for the sick and injured, and implementing sanitation measures such as street cleaning and garbage collection. The medical department oversaw an extensive hospital system, which included two large, well-equipped facilities in Ancon and Colon, medium-sized buildings of twenty to one hundred beds in each of the public health districts, and smaller ones in forty villages throughout the zone. The Panama Railroad even had a special car to transport the seriously sick and injured to the two major hospitals.

Beyond these more typical medical responsibilities, Gorgas also believed that his duty required killing mosquitoes and he set out to learn more. He had begun preparations for the project in 1902, attending a tropical medicine conference in Cairo, traveling to the Suez Canal to consult with the British about mosquito control there, and going to Paris to discuss the health problems the French had encountered in the 1880s. Meanwhile, the American Medical Association had urged President Roosevelt to include a "medical sanitarian" such as Gorgas in the Isthmian Canal Commission. Roosevelt had declined, however, and Gorgas thus went to Panama as the chief public health

officer in an advisory capacity, reporting to the commission, but having little real authority.

When the United States took possession of the Canal Zone, Gorgas surveyed the region to determine what kinds of resources he would need to tackle yellow fever. He developed a million-dollar proposal for a program similar to the one he had executed in Havana. The plan laid out requirements for the professional staff of the hospitals and medical system; the labor required to screen and fumigate homes and barracks, drain swamps, eliminate mosquito propagation areas, and inspect the results; and supplies such as screening, lumber, and insecticides that the department needed to carry out the enormous task.

Admiral Walker, head of the canal commission, was concerned about costs and skeptical of the need to control mosquitoes, so he only authorized Gorgas a staff of seven and $50,000 for supplies. Marie Gorgas later wrote: "It is hardly an exaggeration to say . . . when they landed at Panama to engage in the mighty task of ridding this jungle of disease, [they] had little more than their own hands and their own determined spirit to work with." Her husband nevertheless took up the challenge: "In June, 1904, however, we all commenced work with a great deal of enthusiasm, determined to do the best we could under the circumstances."

Gorgas' team included several key individuals. Henry Carter, in addition to his valuable research on yellow fever, had worked with Gorgas in Cuba. Joseph A. Le Prince had overseen the teams that had destroyed mosquitoes in Havana. Marie Gorgas would refer to Le Prince as "one of Dr. Gorgas' most effective lieutenants at Havana and Panama." In the new campaign, Carter served as director of hospitals and chief quarantine officer, while Le Prince became the chief inspector. Mary E. Hibbard was chief nurse for the hospital system.

The public health department's first inspection found mosquito larvae in almost every house in Panama, revealing the need for an army of inspectors and a mountain of supplies. Whereas General Wood had supported Gorgas' work in Cuba, members of the canal commission thought Gorgas should be cleaning up filth in the cities, instead of chasing insects. The commission's view seemed justified when the first Americans arrived, because initially there was no yellow fever present. Gorgas, however, knew that yellow fever was a "strangers' disease" and that, with the addition of thousands of workers, an epidemic would occur. He also un-

derstood, as Marie Gorgas later wrote, "that all the blame for the outbreak of disease would be charged to his negligence." The first yellow fever case appeared on 21 November 1904, and six more developed in December, but no one died. In January, out of another six cases, two proved fatal.

Gorgas fought the disease by screening patients and killing mosquitoes, but did so with inadequate resources because the commission still repeatedly refused or ignored his requests for supplies and personnel. For example, fumigation involved clearing buildings of all people and pets, sealing them airtight with paper and wood framing, and then burning an insecticide such as pyrethrum or sulfur. But when Gorgas requisitioned tons of newspaper for this purpose, commissioners misunderstood and denied it, believing it was too much reading material for his department. When he asked for one hundred trained female nurses, the commission approved only forty. The senior leaders also rejected his requests for ambulances and laboratory equipment. Weeks went by without buildings being screened against mosquitoes. Le Prince told of a young architect, charged with designing structures for the canal project, who ridiculed the public health crew for their insistence on screening the doors and windows, until he himself got yellow fever and paid with his life for his erroneous view.

In January, Gorgas provided Army Surgeon General Robert M. O'Reilly with an upbeat assessment, noting that the quarantine and hospital departments were organized and working well. "We have accomplished everything which could have been accomplished with what has been allowed by the commission." He then proceeded to outline his problems obtaining staff and getting supplies and construction projects approved by other elements of the bureaucracy. While his efforts had decreased the mosquito population, he regretted that his goal to "free this Zone from malaria and yellow fever" would take some time, because, "what I hoped and wanted when I came down here was to bring this result about in six months rather than two or three years."

As yellow fever cases continued to appear, Secretary Taft sent his friend, Charles A. L. Reed (a physician and former American Medical Association president) to investigate. Reed toured Panama for fifteen days, reviewing health conditions and the public health department's work. Gorgas provided him with a memorandum dated 17 February 1905, describing the commission's failures to act on his requests for supplies, personnel, and authority to carry

out his program, and outlining recommendations for reform. His major complaint was that delays caused by layers of oversight prevented him from obtaining the materials he needed to fight mosquitoes. "The Chief Sanitary Officer," he wrote, "should report directly to the supreme authority."

Two weeks later, Reed submitted his report to Taft and it appeared in the *Journal of the American Medical Association* almost immediately. It was a bombshell. After praising Gorgas' public health program, Reed issued a scathing indictment of the commission's management of Gorgas' department. The author charged that the chief public health officer was subordinate to seven other layers of command, while the commission, "ignorant of his purpose," either disregarded or rejected his proposals or micromanaged the program. Reed decried the "commission's petty antagonisms to the sanitary department," and called the requisition process tortured. He saved his sharpest barbs for Commissioner Carl E. Grunsky, who so often had rejected Gorgas' requests for supplies. He recited, for example, a four-month-long process to procure a nursing bottle for a newborn infant. Reed concluded that President Roosevelt should "ask for the resignation of the commission."

Reed knew he was stirring up trouble. He sent a copy of his report to Gorgas, assuring him that "I had it explicitly understood with the Secretary of War before submitting any report to him, that you or any other source of information will be duly protected from the wrath of the commission." Even so, Gorgas wrote to his mother that he wished the report had been "written more temperately." Despite the seriousness of Reed's charges, they had little immediate impact. Roosevelt and the Congress, already frustrated with managerial problems dogging the canal project, had just finished an attempt to reform the system, reorganizing the canal commission with fresh faces and a three-man executive body to make the decisions. Since the new leaders came to power for other reasons and were equally ignorant of modern medical theory, they initially were no more inclined than their predecessors to support Gorgas and his program.

Yellow fever continued to spread through the vulnerable workforce. In April 1905, several high-ranking canal officials succumbed to the disease. In May, 63 people contracted yellow fever and 19, almost a third, died. Panic ensued. From April to June, five hundred American employees (three-fourths of the total) fled for home. Most alarming, the project's chief engineer, John Wallace, and his wife left precipitously. Newspapers carried stories about

yellow fever cases from Panama arriving in U.S. ports, causing fears that the epidemic might spread to the United States. To add to the alarm, in July an Italian in the town of La Boca in the Canal Zone died of bubonic plague. However, that same month the yellow fever epidemic began to subside with only forty-two cases, and opposition to Gorgas remained.

The new chairman of the canal commission, Theodore P. Shonts, and John Stevens, Wallace's successor as chief engineer, arrived in Panama at the end of July. While Stevens supported Gorgas' work, Shonts did not and he soon recommended removing the chief public health officer. Despite Charles Reed's report and praise for Gorgas' programs, Secretary Taft forwarded Shonts' proposal to Roosevelt. The president was inclined to accept the advice of his new commission head, but he decided to confer with physicians William H. Welch of Johns Hopkins and Alexander Lambert, a personal friend and hunting companion. Both men told him frankly that Gorgas was the best person for the job. Lambert explained to the president that the whole canal project rested on his decision: "If you fall back upon the old methods of sanitation, you will fail, just as the French failed. If you back up Gorgas and let him pursue his campaign against the mosquitoes, you will get your canal." Roosevelt took the advice and admonished Shonts to give Gorgas the political support and resources he needed. Shonts complied, making public health an independent bureau with Gorgas reporting directly to him. Mosquito eradication could now begin in earnest.

It had not been an easy thing for Gorgas to endure powerful and ill-informed opposition. Neither arrogant nor combative, he had relied, in part, on a strong support system, including his close-knit family. He also had the backing of the Army Medical Department, from Surgeon General O'Reilly down to talented, loyal assistants such as Carter and Le Prince. The American Medical Association strongly defended him, as well, waging an editorial campaign in its journal on behalf of his program.

Equally important, Gorgas had confidence in his science. In later years he mused: "It seems singular that, after the demonstration at Havana, there should have been any doubt in the mind of anyone with regard to the mosquito transmission of yellow fever." If he had not embraced the facts, he realized, "the reputation of Dr. Carter, Dr. Ross, Mr. Le Prince, and myself as sanitary officials would have been irretrievably ruined." Gorgas described his political strategy to a friend and fellow medical

officer: "I either had to acquiesce to the sanitary ideas of Gen. Davis and Mr. Grunsky, or be constantly advising pretty strong in the directions they did not like." He chose to stick to what he knew to be right, because "I could see, from the Cuban experience, that in following the tack they were [,] we would be exposed to a great [deal] of criticism, and that to save myself I must get on record as advising differently." Science would bear him out. Moreover, he vowed: "I know that yellow fever and Gorgas cannot exist at the same place."

William and Marie Gorgas

A Partnership Against Yellow Fever

Maj. Gen. William C. Gorgas at work as the Surgeon General of the Army during World War I. Without Gorgas' confidence in his science and his determination to implement a thorough program of preventive medicine, disease and death would have imperiled the project in Panama.

Yellow fever played a key role throughout William Gorgas' life, beginning with the introduction of his parents. His mother, Amelia

Gayle, the daughter of a former Alabama governor, and his father, Josiah Gorgas, a West Point graduate, met when his mother fled to an Army arsenal during a yellow fever epidemic in Mobile. Their son, William, was born there in 1854. Josiah went on to serve as a general in the Confederate Army during the Civil War.

As a young man, William Gorgas wanted to pursue a military career, as well. He was so determined that when West Point rejected him, he decided he would become a physician so he could be a soldier. He enrolled in Bellevue Hospital Medical College in New York City, graduating in 1879. He joined the Army Medical Department the next year.

He met his wife, Marie Cook Doughty, in a fashion similar to his parents' introduction, during a yellow fever epidemic at Fort Brown on the Texas-Mexican border in 1882. She became so ill with the disease that her family began to make funeral preparations. William, called to treat her, soon got yellow fever himself. The two ended up convalescing together and acquired permanent immunity to the virus. Married in September 1885, they began a partnership in the fight against yellow fever. For the next several years, they lived in a number of posts where Gorgas pursued the study of the disease. To yellow fever, one of his colleagues would later observe, "he owed wife, opportunity, fame and great place, and the personal immunity which enabled him to walk without fear in the shadow of death."

When William was assigned to Havana, Marie and their daughter Aileen joined him there. He would confess to a colleague that he "got weak in the knees and was afraid to keep our small girl down here, even though we had no infected mosquitoes." The family also went with him to Panama, despite its reputation for unhealthful conditions. During the dark days of early 1905, when William was enduring a firestorm of criticism in Panama, Marie returned to the United States to undergo radical surgery and X-ray treatment for cancer. William wanted to resign his post in Panama to be with her, but she encouraged him to stay in the fight and she rejoined him after her own medical battle.

During their nine years in Panama, Marie served as hostess to the scores of visitors who came through the zone during construction. Aileen would marry one of her father's assistants, W. D. Wrightson. Marie's nephew, Theodore C. Lyster (whose life William had saved from yellow fever) came to Panama as an Army medical officer and would go on to become the founder of the U.S. Army's aviation medicine program during World War I.

Despite his rise to power and fame, Gorgas preferred the field to the office and the fight against yellow fever to the struggles with bureaucracy. He traveled to Ecuador, known as the pest hole of the Pacific, to advise on prevention of yellow fever and plague; worked with the British government in South Africa on the control of pneumonia; and served on the Rockefeller Foundation's International Health Board, traveling with members of his Panama team to Central and South America to educate others on the prevention of yellow fever. Marie usually accompanied William and, according to a friend and colleague, "intelligently helped him in his work."

Upon retirement from the Army in 1918, the couple continued their effort. When he and Marie were passing through London on their way to Africa to investigate yellow fever there, he suffered a stroke in May and died on 4 July 1920. The King of England knighted Gorgas before he passed away. His body came home to a hero's welcome, lying in state in Washington, D.C., before being buried in Arlington Cemetery. Honorary pallbearers included the secretary of war; members of Congress; and official representatives from Peru, Ecuador, and, of course, Panama. Honors continued in 1921 when Panamanian and American medical officials established the Gorgas Memorial Institute for Tropical and Preventive Medicine in Panama, and in 1928 when Congress renamed Ancon Hospital the Gorgas Hospital.

After William's death, Marie sought to guard his legacy against critics by writing his biography. Her book also provided "some of the earliest first impressions of Panama as recorded by one of the American canal force." Having survived yellow fever and cancer, Marie died suddenly in 1929 and joined William in Arlington Cemetery.

With commission support and resources, the public health department attacked the problem of yellow fever in Panama as if at war. They fought simultaneously on several fronts—identifying all victims of yellow fever and screening them off from mosquitoes to prevent the spread of the disease, killing as many *Aedes aegypti* mosquitoes as possible, destroying their larvae and breeding areas, and inspecting the work continually to ensure effectiveness.

The weapons included city ordinances outlawing the harboring of mosquitoes, hundreds of tons of insecticides, miles of lumber and copper screening, and several thousand workers. In this round, Gorgas spent $90,000 on screening alone, compared to his original total budget of $50,000.

In order to identify all cases of yellow fever, the health department offered a $50 reward (a sizeable sum at the time) to the first person reporting an individual with the disease. They then brought the patient to a hospital where he or she remained in a screened enclosure that was guarded around the clock. If patients insisted on staying at home, regulations required that they, too, be screened in and watched by public health officials until they were no longer contagious. When the case ended in death or recovery, workers fumigated the room or house to kill any remaining mosquitoes.

Health department researchers, headed by Le Prince, sought to learn as much as they could about the enemy. They investigated the reproductive processes, feeding habits, and flight range of the female *Aedes aegypti* mosquitoes, so they could better destroy them. They soon discovered that whereas *Aedes aegypti* constituted only about 5 percent of the mosquitoes in Havana, they composed the vast majority—90 percent—in Panama. The public health department ended up fumigating the houses in Panama City three times to get rid of the mosquitoes, using 120 tons of pyrethrum and 300 tons of sulfur. The department also developed a variety of traps and employed mosquito catchers who tracked down and caught individual insects with test tubes and killed them with chloroform. True mosquito hunting!

Next, the public health teams searched for and destroyed places where mosquitoes propagated. The *Aedes aegypti* was quite domesticated, living in inhabited houses, not straying far from home, and preferring to lay eggs in clean, still water. Panamanians depended on rain for their water supply and stored it in cisterns and barrels in their homes, providing ideal breeding areas for these insects. Gorgas issued a decree to change old habits: "Breeding of mosquito larvae (wigglers) is prohibited within the limits of the city of Panama and the occupants of premises will be held accountable for violation of this regulation." Offenders could be fined five dollars in gold. With this authority, public health inspectors set about mosquito-proofing water containers throughout the zone, covering barrels with wire gauze and replacing water scoops

with spigots. They also cleaned up gutters and oiled pools of water where mosquitoes might lay their eggs. Sometimes the violations were surprisingly close to home. In the hospitals, inspectors found that nurses set bed legs in tins of water to prevent ants from climbing up and annoying the patients. The cans, of course, were swimming with mosquito larvae and had to be banned. The department followed up all mitigation measures with weekly inspections to ensure that the mosquito population remained in check.

The Panama Canal Treaty obligated the United States to install sewage and water systems in the zone. When the commission completed these projects, first in Panama City and Colon, and then in smaller communities, many of the mosquito-breeding places disappeared. As 1905 progressed, Gorgas and his team could watch the number of cases of yellow fever decrease steadily from a high of 62 in June, to 42 in July, 27 in August, 7 in September, and 3 in October. When Secretary Taft visited Panama in November, he declared the "sanitary conditions excellent." The last case of yellow fever in the Canal Zone occurred in Colon in May 1906.

Panamanian support for the anti-mosquito program was not automatic, for three reasons. First, to a large degree the public health department's program was not intended to help Panamanians as much as to protect the newcomers—the Americans and their canal project. Theodore Roosevelt was unabashed about the importance of the waterway to U.S. dominance in the region, and Gorgas put it in stark racial terms at times. In a 1909 speech to the American Medical Association, entitled "The Conquest of the Tropics for the White Race," he suggested that "advances in tropical sanitation in the last fifteen years have shown that the white man can live in the tropics and enjoy as good health as he would have if living in the temperate zone." Within a few centuries, he predicted, "localities in the tropics will be the centers of as powerful and as cultured a white civilization as any that will then exist in the temperate zones." Second, the methods for fighting yellow fever were quite invasive. Public health personnel entered Panamanian homes, took their sick to the hospital, drew samples of people's blood to test for infection, changed their water supply systems, and modified cooking and washing practices. And third, since many Panamanians had no fear of yellow fever because they acquired immunity as children, they had little sense of urgency in the matter and were often reluctant to change their practices. Gorgas therefore had to employ not

only incentives and penalties in his program, but also diplomacy (or, as one visitor put it, "tactful policy") in enforcing public health regulations.

Part of this tact was Gorgas' gentle and reassuring manner. He also made a good impression because his name was Spanish, he spoke the language to a limited degree, and he soon became friends with Panamanian physician Manuel Amador, the first elected president of the country. Gorgas also was a student of intelligent public health practice. For example, in Cuba, when he became convinced that clothing and bedding did not transmit the disease, he stopped the disruptive practice of disinfecting homes of the sick because it often damaged property and discouraged reporting of infectious disease. He instead employed the less-invasive approach of fumigating homes against mosquitoes. As he wrote Walter Reed: "From my experience here in municipal sanitation, I think this is of the greatest importance, viz: To put people to as little inconvenience and loss as possible by methods of disinfection." He explained that "the destruction of mosquitoes in a building can be accomplished with very little annoyance to the inmates but the thorough destruction of fomites [material objects thought to be contaminated with germs] causes a great deal of inconvenience and some loss." Similarly, when his researchers confirmed that yellow fever victims were not infectious after three days, Gorgas stopped quarantining patients on the fifth day of their illness. He also required his staff to be considerate. When the Office of the Surgeon General told him he needed stronger assistants in Panama, he replied with some emotion, "I do not want any man who will *make* anybody clean up his back yard; I want him to *persuade* him to clean up his backyard; that is the key to my business."

Battling Malaria and Other Threats

Once he got yellow fever under control, Gorgas turned to what he considered an even greater menace to the construction project—malaria. Although it did not have as high a mortality rate as yellow fever, Gorgas told a medical conference in 1906 that "malaria in the tropics is by far the most important disease to which tropical populations are subject," because "the amount of incapacity caused by malaria is very much greater than that due to all other diseases combined." He could speak firsthand to its ravages, having

suffered through both diseases: "The mental depression caused by this general sickness can hardly be appreciated by any one who did not see it."

Although yellow fever and malaria were both transmitted by mosquitoes, they were quite different. Yellow fever was an acute, short-term disease caused by a virus. It struck in epidemic episodes and was often fatal. Malaria, on the other hand, was a chronic, long-term illness caused by parasites called plasmodia that took up residence in the bloodstream. While malaria could at times be deadly, it more commonly generated high hospitalization rates. Yellow fever patients were contagious for only the first three days of the illness and survivors acquired lifetime immunity, whereas malaria victims could recover but continue to harbor plasmodia in their blood, resulting in subsequent episodes of illness and providing a reservoir of pathogens for mosquitoes to transmit to other people. Even the mosquitoes that carried them were different. *Aedes aegypti* were urban and domestic, confining themselves to inhabited areas, whereas malarial *Anopheles* were country cousins preferring swamps and forests, which made them much more difficult to find and destroy. Marie Gorgas aptly characterized the difference: "Making war on the yellow-fever insect is like making war on the family cat, while a campaign directed against the malarial parasite is like fighting all the beasts of the jungle."

The malaria campaign in Panama had two approaches, to destroy the parasites in the victim's body, as well as the adult mosquitoes and their larvae. By 1904, medical scientists had identified four different parasites or plasmodia that caused the disease. All varieties fed upon and destroyed red blood cells, causing a cycle of fevers and chills every two days, clogging arteries in the brain and kidneys, and often enlarging the spleen. The most common and malignant parasite was the *Plasmodium falciparum*. Although relatively helpless against a case of yellow fever, physicians did have medicine to treat malaria. Quinine, made from bark of the chincona tree, could reduce the plasmodia in the blood, thereby serving as both a therapeutic remedy and a preventive drug.

When people suffering from malaria first arrived at the hospital in Ancon or Colon, medical personnel examined their blood to identify the parasite and screened them in to prevent mosquitoes from spreading the infection. They then injected the patient with large doses of quinine, switching to an oral version as the patient recovered. While the drug rarely cured malaria, it did

help people regain enough strength so they could return to work. Researchers also found that three grains of quinine could suppress plasmodia levels in the blood enough to keep a person relatively well and reduce the chance of transmission to the noninfected. As a result, the health department began dispensing quinine to Canal Zone employees. Its use was controversial, though, and not always popular. In addition to its bitter taste, it could cause side effects. Gorgas later asserted: "No attempt was ever made to force anyone to take this prophylactic quinine, but explanation and persuasion were used to their fullest extent." But here diplomacy may not have been that effective. In 1906, Gorgas reported 40,000 doses of quinine were consumed daily by 40,000 workers, but by 1909 the department was distributing only 20,000 doses daily to 45,000 employees.

Getting rid of the mosquitoes was an even bigger challenge. The fumigation, screening, and draining of water sources employed against yellow fever's *Aedes aegypti* also helped reduce malaria mosquitoes, but *Anopheles* needed additional measures. For this, research teams set out to learn more about the enemy. In one of the first experiments, men laid on cots in a ward in the Ancon hospital with pill boxes and a clock. "Each time a mosquito bit them, or tried to, it was captured and placed in a pill-box and the date and hour written on the box," explained Le Prince. The researchers found that the *Anopheles* attacked men at rest all hours of the day and "at night they became too numerous to make the work pleasant." The *Anopheles*, they also saw, "absolutely refused to follow a man out into the bright rays of the sun."

Another research group surveyed the Panamanian population to assess the extent of malaria infection. In 1906, they collected blood samples from the residents of the towns of Bohio and Gatun and found that more than 60 percent harbored the plasmodia parasites. Since the infected individuals were functioning well, however, researchers figured that they apparently had acquired enough immunity to survive and continue working. In an ingenious study, Le Prince and his crew dyed mosquitoes blue and released them into the environs. They then set traps throughout the vicinity to see how far the mosquitoes migrated and where they fed and bred. Confirming that *Anopheles* disliked bright light and finding that it typically did not fly more than 200 yards, workers needed only to cut grass and drain standing water for that distance around inhabited areas in order to effectively reduce malaria. Researchers

also identified mosquito-eating creatures such as lizards and bats, and bred mosquito-eating spiders and ants, to increase predation. Public health workers even cleared weeds from ponds so that fish could better see the larvae to eat. Finally, in a rather clever ploy, workers set out basins of fresh water—luring mosquitoes to lay their eggs in these attractive locations—then emptied the containers periodically to destroy the larvae.

Such familiarity with the *Anopheles* caused Gorgas and his colleagues at times to speak almost affectionately of them. Gorgas remarked that the mosquito's long hind legs "give her when at rest the appearance of standing on her head." Commenting on his adversary's abilities, he noted, "the *Anopheles* larva is most noticeable from its superior intelligence. It will dive and seek shelter in the grass at any sound or shadow thrown upon the water." Another kind of mosquito larva, the *Culex*, however, "is sluggish and pays little attention to such things."

To organize the anti-malaria campaign, Gorgas divided the Canal Zone into twenty-five districts, the whole overseen by a chief inspector, a mosquito expert, and an engineer. Each district, in turn, had its own inspector, who supervised twenty to thirty men cutting brush and keeping drainage ditches clear, a number of carpenters for screen maintenance, and one or two quinine dispensers. The mosquito work was prodigious. In 1908, for example, the "*Anopheles* brigade" for Panama City cut 2.5 million square feet of weeds and grass, oiled 5,182 pools, and fumigated more than 5 million cubic feet of homes and buildings. Gorgas ultimately calculated that his team constructed 6 million feet of open ditches, one and a half million feet of concrete-lined ditches, and one million feet of subsoil-tiled ditches, all to carry away standing water.

None of these measures would be effective, however, if public health workers let down their guard, so Gorgas put in place a rigorous inspection process to monitor the progress of their work. District medical officers reported the number and location of employees with malaria each week and "the work of the district inspector is judged by this report." If malaria cases increased, the inspectors had to find the cause, i.e., the mosquitoes, and correct it. The work paid off. In three years, malaria rates fell from more than 50 percent of employees to 28 percent, and hospitalization rates for malaria plummeted from a high of 821 per 1,000 in 1906 to just 76 in 1913.

The Canal Zone became so safe that Roosevelt traveled to Panama in November 1906 and returned home with high praise for Gorgas and other officials. In a special address to Congress, Roosevelt equated them with military heroes, "entitled to the same credit that we would give to the picked men of a victorious army." The triumph over yellow fever, he said, would "stand as among the very greatest conquests, whether of peace or of war, which have ever been won by any of the peoples of mankind." The speech thrilled Gorgas: "I do not think that an army medical officer ever had such recognition in a Presidential message. It probably marks the acme of my career. I have had greater recognition and success than I ever expected."

Yellow fever and malaria were not the only maladies that killed workers or kept them away from their jobs. Between 1 May and 31 August 1905, for example, yellow fever took 47 lives and malaria nearly 90, but another 49 people died of pneumonia, 57 of chronic diarrhea, and 46 of dysentery. Hospitalizations were also a problem, not only causing lost work time but consuming medical resources, as well. Gorgas therefore labored to reduce the sickness or "non-effective" rate, because: "The best measure of the health of a body of men is the average number of daily sick."

The department's methods included surveillance and recording of disease incidence, investigating the causes of outbreaks, enforcing sanitation and preventive measures, researching new ways to treat and control illnesses, and, of course, caring for the sick and injured. Quarantine—keeping sick people out of the country—was the first line of defense. Henry Carter managed that system at Panama's ports, directing the fumigation of ships and requiring isolation in quarantine for all passengers who had not been exposed to yellow fever and any passengers suspected of harboring an infectious illness. Medical staff also vaccinated all new canal employees against smallpox in order to prevent an outbreak such as the one in August 1906 during which thirty-three people contracted the disease and one died. In 1908 alone, public health teams trapped and poisoned some 11,000 rats to control plague and destroyed 973 dogs with strychnine to control rabies. Screening mess tents and making latrines fly proof helped prevent typhoid, while new water and sewer systems removed many other sources of disease. These programs were effective and Gorgas soon grew accustomed to stating in his monthly reports: "There were no reported cases of yellow fever, plague, smallpox, or typhoid."

Other hazards remained, chief among them pneumonia. It was especially prevalent among the West Indian laborers. By April 1906, Gorgas would report that "pneumonia is by far the heaviest cause of death among the employees, 32 having died from this disease." The workers' poor standard of living, he believed, was to blame: "They seldom have more clothing than they have on their backs. . . . When they come home in the evening their clothing is soaked. They go to bed at night, sleep soundly and as the air gets chilly the men get thoroughly chilled." This, along with poor nutrition, was "amply sufficient" to cause pneumonia.

Gorgas would speak on this subject for the rest of his career. In 1914 he explained to a business club in Cincinnati: "That poverty was the greatest single cause of bad sanitary conditions was very early impressed upon me." If he would again encounter a situation such as in Cuba or Panama, and was "allowed to select only one sanitary measure," he told them, "I would select that of doubling wages." Taxing these wages, however, would put workers back where they began, so Gorgas supported a special levy on land that would "increase wages without increasing the burden on labor. Thus, it will lower death rates and increase health and efficiency rates." Although he could not implement those ideas in Panama, Gorgas introduced places for workers to dry out their clothes before going home, and sought to reduce crowded housing by moving laborers out of barracks into shacks scattered throughout the zone. These changes seemed to produce results, and reported deaths from pneumonia fell from 416 in 1906 to 47 in 1913.

Another significant cause of death in Panama was workplace mishaps. In 1908, for example, 46 employees drowned, 23 died in dynamite explosions, and 181 succumbed to "accidental traumatisms." Thus, as the public health department got infectious diseases under control, accidents became more important as a percentage of mortality. Department figures showed that in January 1906, disease accounted for 95 percent of all fatalities, but in January 1912, only 60 percent. When the overall death rate increased from 10.64 per 1,000 employees in 1909 to 10.98 in 1910, Gorgas pointed out that the rise "is due to the increased number of deaths from external violence, the death rate from disease being less than that of 1909." That year there were 3,950 hospitalizations for "external violence," about 10 percent of the canal employees at the time. According to another estimate, on average ten workers were killed each month during the construction period; and deaths by

drowning, suicide, explosions, railroad mishaps, homicide, and accidents of various kinds accounted for one-fifth of the roughly 5,600 fatalities during canal construction.

Workers operate tripod drills in the foreground. Other crews filled the holes with dynamite. The resulting explosions loosened the earth for the steam shovels, visible at work in the background.

The official weekly newspaper, the *Canal Record*, reported many of these incidents. A story in September 1908 told about four men—Rejelio Castillo, Juan Sanchez, Coementi Gonzales, and Rivio Arios—who were killed when two engines fell off a trestle crossing a river. The next month, two explosions made the news in one week—one when a steam shovel struck the cap of an unexploded charge buried in the ground and the other when lightning detonated a cache of dynamite. The blasts killed twelve men—ten black laborers and two white engineers—and injured eighteen. In another accident in late 1909, a steam shovel struck a "soft place in the track bed" and turned over. The paper reported in a matter-of-fact tone: "In falling, the shovel caught David Thomas, a Barbadian, killing him almost instantly." Completion of construction ended the dangers of explosions, but in 1915, the Panama Canal authority was still struggling to reduce railroad accidents—costly

in dollars and time, as well as lives. "By increasing the thoroughness of investigation and of discipline in cases of operating accidents on the Panama Railroad," the *Canal Record* explained, "the transportation department has been able to reduce considerably the number of accidents." Although train mishaps fell from 57 in December 1914 to 17 in March 1915, the Canal Zone would remain a hazardous place to work.

As early as October 1906, when yellow fever seemed to be under control, Gorgas wrote, "I do not argue that in the Rio Grande reservoir we have found Ponce de Leon's spring of perpetual life, but merely that Panama is not so bad a place, from the health point of view, as is generally believed." By 1911, the *Journal of the American Medical Association* suggested that Panama was an "ideal health resort" because its death rate of 12.48 per 1,000 compared favorably to the U.S. figure of 16.10. The *New York Times* made a comparable analogy. Measures worked out by Army public health officers in Panama paid dividends elsewhere. Public health officials were able to contain yellow fever in New Orleans in 1905, and make it the last such outbreak in the United States.

Despite all this success, in some ways the years 1907–1914 were troubling ones for William Gorgas. In February 1907, after Roosevelt visited the Canal Zone and praised Gorgas' work, the president appointed a new commission composed almost entirely of Army officers, including Gorgas. But he gave the primary authority to Goethals and thereby set the stage for discord between the two colonels that was "intense almost from the outset." The reasons for this hostility are not completely clear, but Marie Gorgas believed, with some justification, that Goethals jealously sought and guarded his power and resented the independence of the health department. Gorgas, however, wanted an entirely free hand to implement sanitary policy as he saw fit. The secretary of the canal commission would observe at the time that, among its members, there was an "acute sensitiveness as to the preservation of prerogatives."

A primary source of dispute was Goethals' objection to the price tag of public health projects. Gorgas countered by emphasizing how his organization saved both lives and money. In 1910, he conducted a survey of hospital expenses in major U.S. cities and found that the cost per patient per day of running his medical facilities in Panama compared favorably with Stateside counterparts,

and in some cases was significantly less. Gorgas also liked to point out that his operations actually raised revenue for the canal commission, in the form of fees charged to nonworkers. As the Ancon and Colon hospitals developed good reputations for medical care, private patients began to use them instead of going to the United States or Europe. Eventually that income rose to an estimated $20,000 annually. And, Gorgas pointed out ruefully, the money went into the general fund, not into his organization's coffers.

Goethals sought to reduce the public health department's staff and authority in various ways. Gorgas issued detailed monthly medical reports, but at one point the chief engineer cancelled them, even though they invariably generated glowing press accounts. The secretary of war, however, restored the requirement. Gorgas' organization did decrease in size as it completed sewer and water systems and the need for garbage collection abated. Goethals further cut the department by transferring mosquito mitigation measures, such as grass cutting and ditch digging, to the quartermaster department, which accomplished the work at lower cost.

In a rare show of public criticism, in 1915 Gorgas suggested in a speech that the shift of work to the quartermasters was responsible for the persistence of malaria in Panama: "I was much disappointed that we did not get rid of malaria on the Isthmus of Panama as we did at Havana." He noted that in the first four years in Panama, his methods had reduced the malaria rate from 821 per 1,000 to 282, and then recounted how in 1908 the new commission chairman (Goethals) "took execution of the anti-malarial work out of the hands of the sanitary authorities and placed it in the hands of men who had no special knowledge of anti-malarial work." He claimed that if Goethals had been in charge from the start "we could not have accomplished the sanitary success at Panama which we had accomplished prior to the year 1908." This speech set off a letters-to-the-editor duel in the *New York Times* between supporters of the officers arguing who was most responsible for the construction of the canal. Goethals, for his part, claimed that Secretary Taft had personally directed the transfer of work and that the malaria rate had continued to decline despite the change.

The dispute festered long after, featuring competing accounts by biographers sympathetic to each man. Marie Gorgas described an exchange between the two colonels closing out one

of their arguments over sanitation policy. Goethals supposedly told his subordinate: "Do you know, Gorgas, that every mosquito you kill costs the United States Government ten dollars?" The doctor replied with barbed humor: "But just think, one of those ten-dollar mosquitoes might bite you, and what a loss that would be to the country." Goethals denied such a conversation ever occurred.

When William Gorgas left the Canal Zone in 1913, the death rate among canal employees was less than half that of the general population in the United States, having fallen from a high of 41 per 1,000 in 1906 to 8 in 1913. Such a comparison was not entirely valid given the differing makeup of the two groups—there were no old and infirm people working on the project, and some of those who took ill in Panama may have gone back to their home countries to die. Nevertheless, the record had improved dramatically over the course of construction and was remarkable compared to the French average of 240 deaths per 1,000 in the 1880s. Measuring his effort against de Lesseps' experience, Gorgas estimated that he had prevented the loss of 70,000 lives, preserved the health of three times as many people, and had saved $80 million, half of it in hospital costs. The medical infrastructure was much improved, too. In 1913, the Ancon Hospital boasted such an excellent reputation that Congress appropriated funds for a new facility. Completed in 1919, it became the largest hospital in the western hemisphere south of the U.S. border.

Tributes for Gorgas' medical work on the canal project came from near and far. President Wilson named him Army surgeon general in 1914, and Congress followed with the unprecedented step of promoting him to major general in March 1915. In 1916, the Association of Military Surgeons established the Gorgas Medal to recognize outstanding work in preventive medicine. Army medicine basked in the glory, with one officer remarking: "The sanitation of the Canal Zone, which made [construction of the canal] possible, is an imperishable tribute to the Medical Corps of our Army." Even Gorgas himself succumbed at times to hyperbole, concluding in his book, *Sanitation in Panama*: "The discovery of the Americas was a great epoch in the history of the white man. . . . The demonstration made at Panama that he can live a healthy life in the tropics will be an equally important milestone in the history of the race."

Digging Down

As the work expanded under Goethals, he oversaw a number of significant changes in the plan. The width of the bottom of the channel through Culebra Cut increased from 200 to 300 feet to ease the flow of two-way traffic through this chokepoint. The size of the lock chambers also grew to 110 feet by 1,000 feet, to accommodate the largest U.S. Navy vessels—the *Pennsylvania*-class battleships—and soon-to-be-completed commercial ships such as the *Titanic*. On the Pacific terminus, planners added a seawall across the mudflats to Naos Island (a distance of three miles) to block silt-laden currents that otherwise would choke the mouth of the canal. A similar new barrier on the Atlantic side would protect Limon Bay and Colon Harbor from stormy water. Finally, the site of the two-step locks and man-made lake on the southern end shifted from La Boca to Miraflores, a move necessitated by unstable ground at the initial location. This last modification also was desirable from a military standpoint, since relocating the locks further inland made them less vulnerable to naval bombardment.

The most challenging and disheartening construction task was digging the Culebra Cut, where the first American steam shovel had begun operating on 11 November 1904. This aspect of the project also received most of the public's attention. The area of work extended for nearly nine miles, crossing the Continental Divide at its lowest point of 333 feet above sea level in a saddle between Gold Hill on the east (540 feet high) and Contractor's Hill in the west (410 feet tall). Workers would have to dig out a substantial portion of both peaks as they went down. This would be the narrowest segment of the canal (other than the locks) and form the southern arm of Gatun Lake.

Years of toil and heartache passed before the cut reached completion. The French had made some headway in the excavation of the massive trench, as had the Americans under Wallace and Stevens. Yet what they had done was trifling compared to what Gaillard and his Central Division workers eventually achieved. Merely preventing the waters of the Chagres River from entering the cut during excavation required a temporary barrier, known as the Gamboa Dike, which was a large construction project in its own right.

Each day some six thousand men labored on the great man-made canyon. Officially, they worked every day but Sunday; in actuality, on the cut as elsewhere on the canal, there was usually something that needed to be done on Sundays, as well. Most employees were on the job from seven in the morning until five in the evening, but there was round-the-clock activity. Dynamite crews performed their task during the midday break (from 11 a.m. to 1 p.m.) and after five in the evening. Repair crews worked at night, tending to the steam shovels and other pieces of equipment, while others brought in coal by rail to replenish fuel for the gigantic machines. At the Central Division office in the town of Empire, managers carefully coordinated all phases of the work to prevent the various activities from getting in the way of each other.

The chief means for attacking the daunting task were dynamite, steam shovels, dirt trains, dredges, and pneumatic rock drills. Air to power the latter came through miles of pipes from large compressors at Rio Grande, Empire, and Las Cascadas. Three hundred of the drills, all noisy, were in operation on a typical day. They created the holes—in an average month, 345,223 feet or 65 miles worth—for dynamite charges that loosened the rock and soil for excavation.

These explosions routinely punctuated the continuous cacophony of machines, providing onlookers (including sightseers from throughout the world) with dramatic evidence of progress on the cut. Most of the 61 million pounds of dynamite used on the canal were employed at Culebra. About half of the workforce there was involved in the blasting effort in one form or another—drilling the holes, hauling the explosives, and placing the charges. The dynamite arrived by ship from the United States, with some of the vessels carrying as much as a million pounds of the dangerous cargo. Laborers transferred it by hand to rail cars, which transported it to concrete magazines where it was stored until needed. Workers placed dynamite sticks by hand into the drill holes and gingerly laid the fuses to simultaneously set off entire fields of buried charges.

Premature blasts accounted for numerous deaths and injuries. The worst of these disasters came on 12 December 1908, at Bas Obispo, where 23 men were killed and 40 injured when an undetermined cause detonated a series of charges without warning. The project used so much dynamite on

a daily basis that the engineers could observe, experiment, and develop new methods as they went along. As the work progressed, these improvements in handling the dangerous material reduced the number of accidents.

Steam Shovels

A steam shovel digs out the latest slide at Cucaracha and piles dirt on flatcars with one open side. The efficient system of moving spoil and the eagerness of crews to compete against each other made it possible to move a mountain at Culebra in less time than planned.

The workhorse and conspicuous symbol of the canal project was the steam shovel. More specifically, it was the 95-ton behemoth manufactured by the Bucyrus Company. Widely published photographs of President Roosevelt seated at the controls of one during his inspection tour of the Canal Zone in 1906 made a lasting impression on the American public. And the big machines lived up to their gargantuan reputation.

The firm, founded in 1880 in the Ohio town of the same name, moved to South Milwaukee in 1893. In 1889 it had announced: "We have by far the largest and best equipped shops in the country for the manufacture of steam shovels and dredges." They backed up their boast, winning the lion's share of contracts to produce earth-moving machines for the biggest dig in history. The corporation ultimately supplied 77 of the 101 steam shovels (including some smaller 45- and 70-ton models) employed in the building of the canal, as well as two 15-yard dipper dredges, a railroad pile driver, and a 100-ton wrecking machine. Their primary competitor was the Marion (Ohio) Steam Shovel Company, which provided most of the remaining shovels.

The largest machines could, in one bite, take out five cubic yards of dirt and rock (about eight tons of so-called spoil). That was four times the quantity that a French machine had been able to scoop two decades earlier. The system of continuous dirt removal put in place by Stevens, which allowed the steam shovels to work at maximum capacity, also vastly increased the efficiency of the process. It took a crew of ten to keep the Bucyrus moving at top speed. An engineer (among the highest paid employees in the project) operated the main controls. A craneman handled the dumping of spoil into the rail cars. Two more men kept the boiler fed with coal. And six readied the new sections of track on which the Bucyrus advanced into the mound of rock and dirt it was tackling.

Well-designed and solidly constructed, the steam shovels held up remarkably well under heavy use.

The interface of men, machines, and process was a model of the industrial efficiency of the age. Once the dynamite had done its work, the steam shovels, each on its own rail spur, moved in to dig out the loosened spoil and load it onto wooden flatcars made by the Lidgerwood Manufacturing Company of New York City. These uncomplicated but highly effective cars were open at both ends and had only one side. To remove the spoil from the cars, workers placed a three-ton plow, also manufactured by Lidgerwood, on the end of the last car. The locomotive provided power to a winch that pulled the plow the length of the train, with steel aprons bridging the space between the cars. It took but ten minutes for the operation to unload a twenty-car train.

One hundred sixty trains per day, consisting of a locomotive and up to twenty flatcars, ran to and from the cut. In a further boost to efficiency, the empty dirt trains went in going uphill and rolled out full going downhill. Every few minutes one departed from the cut heading to any one of over sixty dumping grounds or to the sites employing the material in construction. Spoil went into the dams, embankments for the new line of the Panama Railroad, the dike at Gamboa, and the breakwater extending out to Naos Island. The largest disposal areas were those at La Boca (Balboa), Tabernilla, and Miraflores.

The dumps, located up to twenty-three miles from the cut, were more complex than the name implies. Yardmasters at each recorded arrivals and departures of the trains, directed their movement on the tracks running along the terraces of the dump, and indicated where to place the spoil. Spreaders, railcars equipped with steel blades operated by compressed air and pushed by locomotives, distributed the dumped dirt. Track shifters, devised by William G. Bierd (former head of the Panama Railroad), were capable of lifting a complete section of rails and ties and swinging it up to nine feet in either direction. Both machines did the work of many men and in much less time, keeping the entire dumping process moving fast enough to handle the seemingly endless chain of incoming trains burdened with spoil. Not counting the Panama Railroad, there were 209 miles of construction track in the Central Division. As excavation and dumping changed the landscape, workers had to continually move track for shovels and dirt trains, a task that continued around the clock.

At the peak of the excavation effort in March 1909, sixty-eight shovels removed 4,062,632 cubic yards of earth and rock, setting the record for a single month. The biggest year was 1908, when they dug out 37 million cubic yards. Shovel number 123 set the record in March 1910 for a single machine in a month, excavating 70,000 cubic yards. The total amount of spoil taken from the canal was 200 million cubic yards, of which 96 million came from the Culebra Cut.

As if the job of excavation was not enough of a challenge, much of the work had to be repeated numerous times because of slides—massive amounts of soil and rock that tumbled or, more often, simply shifted slowly from the slopes of the cut into the excavated areas. These frequent disasters, which had plagued the

French attempt to carve out a route through the Continental Divide, made life a living hell for Colonel Gaillard and all those toiling on the cut. The slides buried equipment, rails, and structures, and wiped out thousands upon thousands of man-hours of hard work.

A particularly bad slide occurred during the French period at Cucaracha, on the east bank of the cut and south of Gold Hill. It happened there again early in the American period, on 4 October 1907. Heavy rains sent mud and rocks plummeting into the excavation, destroying two steam shovels and burying railroad tracks. Slippage continued at the rate of ten to fifteen feet a day. At the end of ten days, half a million cubic yards lay at the bottom of the dig. Recalling the ice floes he had observed in Alaska, Gaillard called the slides "tropical glaciers." On 22 October 1910, a slide at the same place buried sixteen flatcars, two locomotives, and two steam shovels. Slides hit Cucaracha twice more in 1910, after which Gaillard announced his belief that the problem was largely a thing of the past. More and worse, however, was to come. From 1911 until the completion of the canal, increasingly severe slides occurred—twenty-two all told. The most damaging struck at La Cascadas, Empire, Lirio, and East Culebra. Slides eventually accounted for more than one-fourth of the total material excavated at the cut. And the problem never completely disappeared. Fresh slides occurred for years after the canal was in operation.

To carry off some of the water that contributed to the problem, Goethals directed the Central Division to dig diversion channels parallel to the cut, a remedy also attempted by the French. One of the large ditches extended for five and one-half miles; another required the excavation of one million cubic yards. Unfortunately, the planners put them too close to the cut; water seeping from the trenches into the shoulders of the main excavation quite likely caused even more slides.

At first, the slides came, not unexpectedly, after heavy rains, and were termed gravity slides. Later types, called structural breaks and deformation slides, came during the dry season. They were caused by unstable rock formations, the steepness of the slopes, and the incessant blasting. They lasted anywhere from an hour to several days. Sometimes water came boiling out of the fissures in the exposed rock surface, causing panicky workers to believe that they were uncovering a volcano.

Desperate for a solution to the problem, the engineers explored many possibilities, several suggested by outside experts. Nothing worked, including plastering the slopes with concrete. All that could be done was to continue cutting back the sides until the excavation reached an angle of repose—"the angle of maximum slope at which a heap of any loose solid material (as earth) will stand without sliding." Until reaching that point, all Gaillard could do was to comply with Goethals' directive following a massive slide on 19 January 1912: "Hell, dig it out again."

Gaillard never saw the completion of the Culebra Cut. In the summer of 1913, major slides seemed to have unhinged him. He began talking incoherently and suffering from memory loss. Goethals and others assumed that a nervous breakdown was the cause. He sought treatment in Baltimore, where an examination revealed that he had a brain tumor. After unsuccessful surgery, he died on 5 December 1913. His widow attributed the death to overwork and blamed Goethals for the loss of her husband, even though the tumor had nothing to do with the strain of the project. Nevertheless, members of the Gaillard family continued to shun Goethals and his family. In recognition of what the much-admired Army engineer had achieved, President Wilson ordered in 1915 that the channel through the mountains henceforth be known as the Gaillard Cut.

Dredging was less dramatic than the blasting and digging, but no less essential. Wherever there was a body of water and appropriate geology, dredging provided an added element of efficiency, since there was no need to constantly shift and rebuild track for steam shovels and dirt trains. In all three geographical divisions, a variety of specialized vessels scooped up and removed mud, silt, sand, and loose or soft rock. At first, the Americans used Belgian- and British-built dredges originally employed by the French (in many cases raising and restoring vessels that had sunk after years of neglect). Later, they ordered new and more powerful American-built types like those the Corps of Engineers had been using in its river and harbor work in the United States.

Depending on the kind of material being removed and where the spoil would be deposited, the canal builders employed ladder, pipeline suction, five-yard dipper, clam shell, seagoing suction, and hopper dredges. Suction dredges, for example, handled soft material such as silt and sand; ladder and dipper types dealt with harder strata, such as coral rock and argillaceous (clay-like) sandstone. The French had often aptly named their ladder-type

machines after burrowing animals, such as Badger, Mole, Gopher, and Marmot. Other types drew monikers from Panama geography; Chagres, Mindi, and Gamboa were a few examples. Some had only numerical designations, such as "French Ladder Dredge No. 6" and "Pipeline Suction Dredge No. 83."

Dredging operations were significant on the old French channel on the Atlantic side; the sites for the Gatun, Miraflores, and Pedro Miguel Dams; the harbors at Cristobal and Balboa; gravel bars on the Chagres; and the site for the Colon seawall. Probably the biggest task of this type was the removal of 39,962,470 cubic yards of material to create the eight-mile sea-level channel from the Pacific to Miraflores. Relatively little dredging took place in the Central Division, where steam shovels did all of the excavating until water filled the cut, at which time dredges took over the task of handling the ongoing slides. At the large Cucaracha slide, dipper and suction dredges worked around the clock for months in order to clear the channel.

Dredges work at the Cucaracha slide in December 1913 after the flooding of Culebra Cut three months earlier. Though less glamorous than the steam shovels, these waterborne machines made their own large contribution to moving dirt for the canal.

Dredged material for which there was no use ended up in the sea or on a dump site on land. Much of the spoil, however, was of value in canal construction. Gravel went to the concrete mixing plants. Rock, sand, and dirt served as fill at the dam sites. Generally steam launches towed barges filled with dredged material to the sites where it was to be deposited, but there also were some self-propelled mud scows.

Building Up

Colonel Hodges, Goethal's primary assistant from 1907 onward, also had responsibility for designing the locks, dams, spillways, and regulating works. To guide him, he had an abundance of precedents and models in America and abroad, as well as considerable personal experience. But no engineer, military or civilian, American or foreign, had ever confronted such an enormous and complex undertaking.

Hodges set about the task assisted by two remarkably talented civilians, Edward Schildhauer, a mechanical and electrical engineer, and Henry Goldmark, a civil engineer and recognized expert in steel bridges and lock gates for canals. Together they drew up plans for the structure of the locks and the system of culverts, tunnels, wellholes, and valves for filling and draining the huge chambers. Goldmark designed the immense steel gates through which ships would enter or leave the locks. Schildhauer came up with the system that would open and close these doors weighing hundreds of tons each.

Now it was up to two other engineers, one military and one civilian, to build what Hodges and his team had planned. As head of the Atlantic Division, Lt. Col. William Sibert was responsible for the construction of the locks and dam at Gatun. Sydney Williamson's Pacific Division would construct locks and dams at Pedro Miguel and Miraflores. As Goethals had anticipated and desired, a rivalry between the two divisions developed, "each striving," wrote Williamson, "to beat the record of placing concrete in the locks of the other."

From his arrival in Cristobal, Williamson found it to be "the most interesting and absorbing piece of engineering I have ever been connected with." According to Goethals' son: "Without question the record of the Pacific Division . . . was the great achievement of [Williamson's] whole professional career, as it combined

all the elements of engineering, construction, and administration over a period of four and a half years, and brought to a peak those qualities which made him a leader in each."

Operations in the Atlantic Division caught more of the attention of the press and public. The construction of the enormous dam at Gatun and the creation of Gatun Lake seemed more dramatic than did the equally important projects of Williamson's outfit. Preliminary work on the Gatun Dam site had begun under Stevens in 1906. By June 1907, laborers had cleared 500 acres of jungle. Before commencing serious construction, Sibert built two experimental dams, each of them one-twelfth the size of the Gatun project. After these tests demonstrated that the actual dam would be practicable, the effort began in earnest.

Workers first erected two parallel wooden railroad trestles across the valley, with more than a thousand feet between them. They then dumped rock spoil from Culebra Cut off these elevated tracks to create two ridges, known as toes. Next, using a process known as hydraulic filling, they pumped dredged mud into the trough between. The water leached out through the rock or drain pipes, leaving a packed core of sand and clay buttressed by the toes. Dry fill raised the structure to its full crest above the toes. Ultimately the dam required 23 million cubic yards of rock and dirt.

On 21 November 1908, when construction on the dam was still in its early stages, a long section of one of the toes sank twenty feet. Enemies of the Panama location, joined by proponents of a sea-level canal, circulated sensational accounts of the incident that played on American memories of the catastrophic Johnstown (Pennsylvania) flood of 1889, caused by the collapse of the largest earthen dam in the United States. Some of the public began to question the feasibility of the entire project. The episode, however, did nothing to discourage those directing the work on the canal. They soon repaired the damage, slightly modified the design of the dam to further spread the load over the soft underlying ground, and continued apace. Rumors and irresponsible news stories to the contrary, no other significant incidents, except for occasional slides, delayed the work for long. Sibert's division put the final touches on the massive structure on 12 December 1912.

The completed dam measured a mile and a half across, spanning the valley of the Chagres River and closing off two other

streams—a portion of the old French canal and its West Diversion channel. The largest earthen dam in the world, it rose to a height of 105 feet above sea level or 20 feet higher than the 85-foot level of the lake. At its base, it measured almost half a mile thick. At the top, it tapered to 100 feet. Near the center, in the form of a 740-foot-long arc, was a spillway that released excess water from frequent heavy rains into the remaining stretch of the Chagres. The spillway's fourteen openings allowed a discharge of 140,000 cubic feet per second. This part of the dam had called for 225,000 cubic yards of concrete.

The enormous lake that the dam brought into existence submerged 164 square miles of jungle, many miles of the old Panama Railroad line, part of the French canal, much of the Chagres River, and numerous villages and farms. (The inhabitants were compensated for their loss, but after the failure of the French, many refused to actually move until the rising waters lapped at their doors.) The lake extended for thirty-two miles from Gatun Dam through the Culebra Cut to the dam at Pedro Miguel. At that time the largest man-made body of water on earth, it also went far beyond the borders of the Canal Zone, covering significant areas in the remainder of Panama.

An important component of the dam and lake was the hydroelectric plant erected at the spillway. Water from the lake, falling about seventy-five feet, would generate all the power needed to open and close the locks, light the system, operate the Panama Railroad, and run many other activities vital to the success of the canal. It would replace oil-fueled steam turbine plants at Gatun and Miraflores that had provided electricity during the construction phase (although the latter would remain in place as a backup). The heavy reliance on electricity was itself a pioneering effort, since the primary motive force for industry at that time was still steam.

The wisdom and sheer elegance of the decision to dam the Chagres River were now on full display. Instead of being an impediment, as the French had viewed it, the Americans had found a way to make the river serve as the vital cog in the canal. The lake created by the river's basin was the longest and most easily navigated portion of the route, stored the water to fill the locks by the simple force of gravity, and generated the electricity to power nearly all aspects of the canal.

The Pacific Division erected four dams in all, one on either side of its two sets of locks. At Pedro Miguel, the dams

contained the waters of Gatun Lake at the south end of Culebra Cut and, in Sibert's words, "simply connect the locks with the sides of the cut." The west dam was an earthen structure that measured about 1,400 feet long and 50 feet wide at the top. The east dam had a concrete core wall. At Miraflores, the west dam contained 1,758,423 cubic yards of hydraulic fill, while the east dam was a concrete structure approximately 500 feet long. The area between these dams would become Miraflores Lake. Minuscule in comparison with its cousin at Gatun, it covered only 1.6 square miles. It would play a similar role, however, both forming a navigable part of the canal route and providing water to fill the Miraflores Locks.

Work on the equally immense task of building the locks went on simultaneously with the construction of the dams. That effort started on the three locks at Gatun on 24 August 1909, on the single lock at Pedro Miguel one week later, and on the two at Miraflores on 30 May 1910. Each lock consisted of a pair of parallel chambers to allow two-way passage for vessels going through the canal. The inside of each chamber measured 1,000 feet long by 110 feet wide and 81 feet high. At its base, each exterior side wall was from 45 to 50 feet wide; at the top, only 8 feet. A wall 60 feet wide separated each of the side-by-side chambers. The thickness of the floors varied from 13 to 20 feet.

The lock walls were reinforced concrete, a relatively new building material at the time. Workers first constructed a form, out of wood or metal sheets, corresponding to the ultimate shape desired for a 36-foot section of the lock. Inside the form, they erected a skeleton of steel bars and then poured the wet concrete around them. After the mixture hardened, they stripped away the forms and began the process anew for the next section. No other reinforced-concrete structure in the world then in existence approached even a fraction of the size of the Panama Canal locks. The Gatun trio would consume 2 million cubic yards of concrete, those at Pedro Miguel and Miraflores required 2.4 million.

The concrete itself was a mixture of water, sand, gravel, and portland cement. The canal commission ultimately purchased 5 million bags and barrels of the latter component from the Atlas Portland Cement Company, all shipped from Jersey City. An order by Goethals for workers to shake every

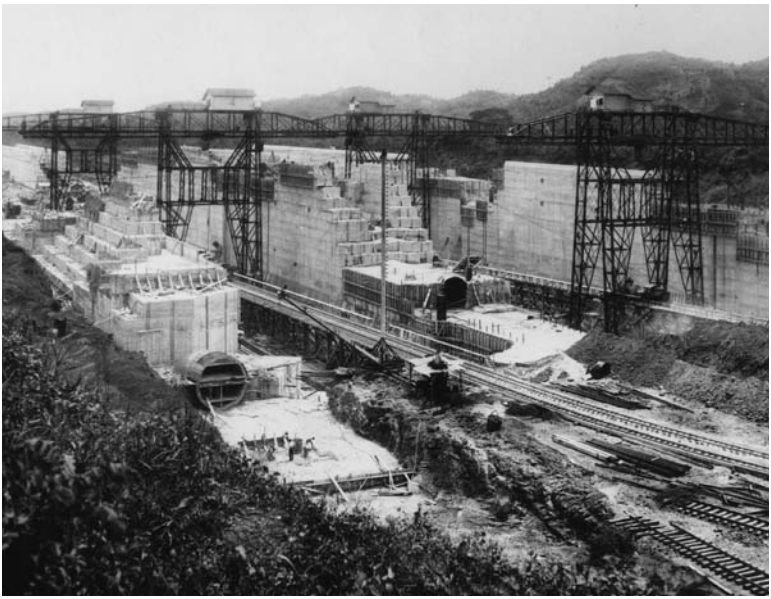
cement bag after it was emptied saved an estimated $50,000. Each coastal division had a plant dedicated solely to crushing rock. On the Atlantic side, it was at Porto Bello, twenty miles up the coast from Colon. On the Pacific, they quarried stone and made it into gravel at Ancon Hill. The sand, which had to be of a particular quality, came from farther away on both coasts. Barges brought the gravel and sand via the French channel (and later the American-built waterway) to Gatun, while the Panama Railroad provided the means of transport in the Pacific Division to get the material to Pedro Miguel and Miraflores.

Each division came up with its own system of handling the concrete. Major Jervey directed the work on the Gatun Locks. He had a dedicated plant that mixed concrete and deposited it into large buckets, each capable of holding six tons. A small train of flatcars, each loaded with two buckets, transported the wet concrete to the lock construction site. There eight movable towers (four on each side of the locks) supported a system of overhead cables. The cableway (another Lidgerwood product) picked up the buckets and brought them over the forms, then dumped the mixture inside, where laborers ensured that it filled every nook and cranny.

The sites at Pedro Miguel and Miraflores were not conducive to a cableway system. Instead, Williamson employed eight huge cantilever cranes that were visible for miles. Four were known as berm cranes. These self-propelled giants moved on tracks laid along the sides of the lock excavations. A long arm picked up sand, gravel, and cement and deposited them into mixers at the base of the crane. Another arm transferred buckets of concrete to the chamber cranes, so-called because they operated, also on rails, within the locks. They, in turn, dumped the concrete into the forms.

Once the concrete shell was finished, crews had to install the large steel gates devised by Henry Goldmark. On 12 May 1911, the McClintic-Marshall Construction Company of Pittsburgh, a bridge-building firm, started fashioning the gates onsite out of parts manufactured in the United States. Each gate consisted of two leaves that swung on hinges like double doors; when closed they formed a flattened V shape. Each leaf weighed from 300 to 745 tons, stood up to 82 feet high, and was 65 feet wide and 7 feet thick. They consisted of a watertight metal skin on a girder frame, which meant that they floated when submerged

in water. Coupled with Schildhauer's unique system of electric motors, gears, and wheels, the process of manipulating the heavy gates seemed almost effortless. The forty-six gates in the system required a total of 58,000 tons of steel and cost $5,374,474.82. This was the only element of the canal project (other than the provision of materials and equipment) that the government contracted out to a private firm.



Work proceeds on the Pedro Miguel Locks. The four chamber cranes visible here moved large buckets of concrete and poured the mixture into the forms.

There was a double set of gates at each end of a lock, as well as another set in the middle. The latter feature was a measure to save water and time, since the vast majority of ships of that period could fit inside half of one of the immense locks. (The transit of a large ship through all six locks required 52 million gallons of water; a small ship needed only half that amount.) The twin sets of end gates served as a safety factor—if the first set for some reason should fail or be damaged by a ship, the

second set would prevent a mass of water gushing into the next lower level of the canal. The locks also contained a large iron chain and an emergency steel dam to provide additional safeguards against the possibility of a ship breaching the gates and leading to a catastrophic flood from Gatun Lake. The chain would act to slow a runaway ship, while the dam would fall into place across the lock opening if all other measures failed.

Williamson and Sibert, the men who built the critical locks and dams, both continued distinguished careers after the canal project. In December 1912, when the Pacific Division had almost completed its work, Williamson resigned to become chief of construction in a London firm. During World War I, he again put on the uniform he had last worn in the Spanish-American War, this time commanding the 55th Engineer Regiment in France. He attained the rank of colonel and received the Distinguished Service Medal. Much later, President Herbert C. Hoover appointed Williamson to the Interoceanic Canal Board, a body investigating the cost and feasibility of building a canal in Nicaragua and constructing additional locks for the waterway in Panama.

Sibert served in Panama until the completion of the Atlantic Division's work in 1914. In recognition of his effort, he received a promotion to brigadier general and, along with the other members of the canal commission, the formal gratitude of Congress. The following year, he and John Stevens coauthored a book, *The Construction of the Panama Canal*. He went on to command the storied 1st Division in France during World War I and then established the Chemical Warfare Service. In 1928, President Calvin Coolidge appointed him chairman of the Boulder Dam Commission, a body that studied the viability and economic impact of what would become Hoover Dam (the first project since the Panama Canal locks to rival them in the amount of concrete poured).

Looking back on the canal project, Sibert could have been speaking of Williamson's accomplishments as well as his own when he wrote: "The engineering problems involved in the construction of the Gatun locks . . . were not more difficult than many engineering problems in other places; the marked difference was the required speed of work in order to complete the task in the specified time." He might well have added that the sheer size and technical sophistication of the structures he and Williamson erected were without precedent.

Working on the Railroad

The first modern method of transit across the Isthmus of Panama had been the forty-eight miles of railroad built by American investors between 1849 and 1855. De Lesseps' company acquired it in 1881, though Americans continued to operate it. The U.S. government took possession of it as part of the French assets purchased in 1904, along with the associated steamship line, which sailed between New York and Colon.

Although the canal was supposed to largely replace the railroad, Stevens' background had allowed him to see what de Lesseps had overlooked—that the line could play an integral role in constructing the waterway. But it had to be bigger and better to do so. In the half century of the Panama line's existence, railroading in the United States had leapt forward in capability while the isthmian company had stagnated. Stevens immediately began replacing old equipment, ties, and rails with newer, heavier American versions. Although much of the work would be done under Goethals, Stevens initiated projects that double-tracked the existing line for thirty-seven miles and added more than eighty miles of sidings and spurs to facilitate spoil removal and the movement of men, equipment, and supplies. His plans also included rebuilding bridges; installing new signal, telegraph, and telephone systems; erecting warehouses, repair shops, and locomotive sheds; and procuring thousands of larger cars and 150 more-powerful engines. To operate the rejuvenated system, he recruited a completely new group of personnel—everyone from superintendents to switchmen—all experienced in running the type of large, efficient rail lines that crisscrossed the United States.

The mid-1906 decision to construct a lock canal added a new facet to the railroad rebuilding effort. The existing line had followed the lowest suitable terrain across the isthmus—areas that in most places would be inundated by Gatun and Miraflores Lakes. The final plan thus required the relocation of almost all of the track bed. Keeping the line in operation to support the construction of the canal added complexity and challenge to the task. In 1904, the railroad handled 17 million ton miles of freight. By 1910, the movement of supplies and spoil had increased the total to 300 million ton miles.

In July 1906, two parties working from each end of the Canal Zone began surveying a new right-of-way for the rail line. They

completed the work in March 1907. Construction began soon after but there was relatively little early progress because of a lack of funds and the need to create an organization to carry out the project. Ralph Budd, chief engineer of the Panama Railroad, took on the job of supervising the initial work. In 1909, Lieutenant Mears replaced him and completed the mission. Ultimately the railroad company employed much the same sort of manpower model as the overall canal project. In addition to its regular employees, it contracted with a few skilled workers and hired large numbers of West Indian laborers, many of them doing excavation. Mears observed that they "cooperate, some doing digging and loading and some dumping and spreading. They work hard and steadily until their 'task' is done."

Frederick Mears—Soldier and Builder

Frederick Mears' background was not altogether different from that of the West Point–trained Army engineer elite. The son of a career Army officer, he was born in Nebraska on 25 May 1878, and went on to graduate in 1897 from the Shattuck Military School of Faribault, Minnesota. It was the same institution his father had attended and it modeled its program after that of the U.S. Military Academy (with somewhat similar technical classes, although Shattuck was at the high school level). A fellow student and best friend was the son of John Stevens, and Mears grew enamored with engineering and railroading during frequent visits to the Stevens home. At age 19, Mears went to work for the senior Stevens on the Great Northern Railroad as a laborer on a survey party. As he proved his capability, he quickly advanced, becoming a resident engineer for the company within two years despite his lack of substantial formal training in the field.

During the Spanish-American War, Mears wanted to pursue his other dream of being a soldier, but he felt compelled to finish a job he had started on a new railroad line in British Columbia. By the time he was done, so was the war, but a new conflict had broken out with insurgents in the Philippines. Mears enlisted in the Army in 1899 and joined Company K of the 3d Infantry, which promptly sailed to join the campaign against the Filipino rebels. He made the same meteoric rise that he had in railroading,

quickly climbing to sergeant, then earning a commission as a second lieutenant in 1901. He returned to the States in 1903, was a distinguished graduate of the Army's Infantry and Cavalry School in 1904, and immediately went on to complete the Staff College.

Mears was serving in a cavalry regiment in 1906 when John Stevens requested that the 28-year-old lieutenant be detailed to Panama to serve as track foreman at the Culebra Cut. He shifted to the railroad relocation project later that year as Budd's primary assistant and in 1909 succeeded him as chief engineer of the Panama Railroad, serving in that capacity until 1914. During his final two years on the project, he also became general superintendent of the railroad and its steamship line.

Col. Frederick Mears in 1918. He began his military career as a private in the cavalry and fought in the Philippine Insurrection before gaining his commission and spearheading the rebuilding of the Panama Railroad.

Following the success of the canal project, the government was planning to build a railroad in Alaska. President Woodrow Wilson deemed the venture the "key to unlocking" the territory's resources. Initially he hoped Goethals would take on the task, but

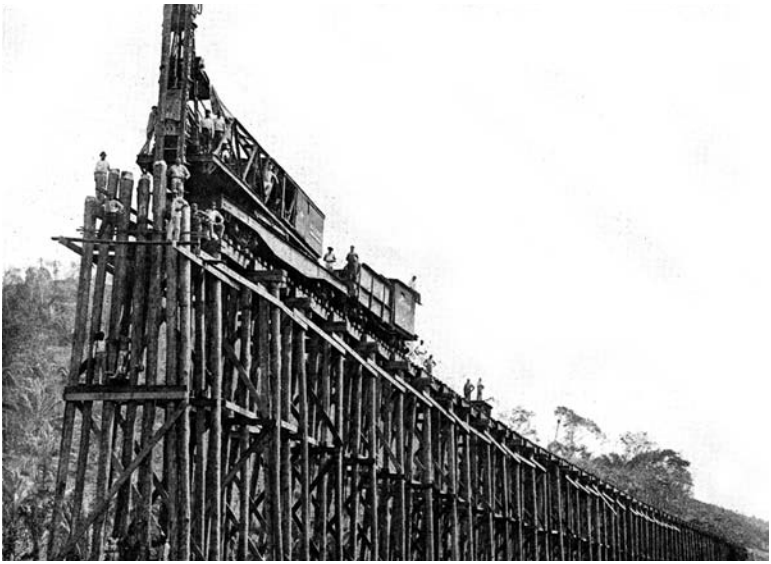
when the general declined because of his pending retirement, the president asked for a recommendation. Goethals replied: "Get Mears!" The Army was reluctant to assign a junior cavalry officer to the project, but a special act of Congress authorized Mears to fill the post that had been set aside for the Corps of Engineers. Now a captain, Mears completed the 500-mile line from the coast into the interior by 1923. It included construction of what remains today the second-longest single-span railroad bridge in the nation—a structure eventually named for him. Along the way, he also founded the city of Anchorage and designed and built the port there.

During World War I, Mears took a detour from the Alaska project, accepting a commission in the Corps of Engineers with the temporary rank of colonel. He formed and commanded the 31st Engineer Regiment (a railway unit of the American Expeditionary Forces in France), earning the Distinguished Service Medal and inclusion in France's Legion of Honor. After the war, he remained with the corps as a lieutenant colonel in the Regular Army—a rare career change for an officer who was not a West Point graduate—and resumed work on the Alaska project. He retired with the rank of colonel in 1923 and became chief engineer of the Great Northern Railroad in 1925, remaining there until his death in 1939.

The same sort of slides that had bedeviled workers at Culebra Cut proved to be an equal hindrance to progress along the route of the railroad as it snaked its way through the hilly terrain. The excavation and timbering of the critical Miraflores Tunnel was virtually complete by June 1908. Although most of Miraflores Ridge consisted of soil, it had been necessary to bore through 400 feet of solid rock at the northern end of the passageway. In July and August, tropical rains sent a hill sliding along the axis of the tunnel, destroying the earth section. The rock segment was not affected and workers lined it with concrete that fall. But rebuilding the rest of the tunnel had to wait until the coming of the dry season at the beginning of 1909.

The project hit another snag when soil along the path originally projected across the valley of the Gatun River proved to be too soft. A survey in 1908 laid out a new route, but the entire section crossing what would become Gatun Lake remained a major

challenge. First, the track had to be above the projected water level of 85 feet. To achieve this, the engineers built wooden trestles at the desired height, then used them as a platform to dump spoil trains from Culebra Cut. The eventual result was an embankment underneath the track. Second, even the new route rested on ground consisting largely of soft clay and decomposed vegetation to a depth of over one hundred feet. As the weight of the massive dirt mounds built up under the trestles, they caused the unstable soil to compress and sink (in some cases up to sixty feet), requiring yet more fill to keep the top at the required elevation. Ultimately the engineers had to double the width of the bottom of the embankments to help spread the load and minimize the sinking. Before they were done, the total fill needed along the line was more than 18 million cubic yards.



A Bucyrus pile driver and crew build a railroad trestle across a valley. Trains then dumped spoil from the excavations to build embankments that served as the permanent roadbed across what would become Gatun Lake.

When the engineers were not spanning valleys, they were digging cuts or boring through hills to minimize the grades that trains would have to negotiate. Each cut (164 in all) was a miniature ver-

sion of the work at Culebra, with steam shovels, dynamite, and spoil trains contributing to the effort. The largest one had a maximum depth of 95 feet. (The Culebra Cut, by contrast, had dug down about 300 feet.)

The last major segment of the rebuilt railroad system was the Gold Hill Line. Plans originally called for laying track along the east berm of the Culebra Cut, ten feet above the projected water level. But repeated slides within the cut made that proposition dubious and Goethals appointed a board of engineers to study the question. The panel's report recommended that it be built outside of the footprint of the cut altogether. Goethals agreed. The final choice was to begin at a point near the Gamboa Bridge over the Chagres River and from there climb to the Continental Divide, crossing it at an elevation about 240 feet above sea level on the east side of Gold Hill. This area would be the steepest grade on the new line. Tunneling through rock and dealing with slides made this section as difficult as any. Nevertheless, workers completed the 9¼-mile segment in May 1912 and turned it over to the railroad company that month.

The relocated right-of-way became the logical route for a high-tension power line, especially since planners believed that eventually the hydroelectric plant at Gatun would supply electricity to operate the trains. Steel transmission towers rose alongside the tracks at 300-foot intervals (250 feet on the curves). Also running along the route, in underground concrete ducts to prevent disturbance from the power lines, were cables for the telephone, telegraph, and the automatic signal systems. As construction moved forward on the track, other workers were building new facilities, such as passenger stations at Colon and Panama City and freight yards at Cristobal and Balboa. Even with restoration of normal operations in 1913, other work remained to be done, including construction of a railroad trestle to Naos Island, completed in November of that year.

Despite the disruption from construction, throughout the project trains had maintained a hectic pace in support of the canal effort and also continued to serve their original purpose as a means of interoceanic transportation. In 1910, for example, the railroad carried over 2 million passengers (primarily canal workers), hauled more than a million tons of commercial freight, and moved almost 40 million tons of spoil.

The 1906 report calling for a lock canal had estimated the cost of the railroad relocation at $3.7 million. The total reported by Mears at the completion of the effort came to $8,786,566.58. By far the most

costly item was the work of cutting and filling, which accounted for $6,431,484.39. Responding to concerns over the unexpected tab, the Army lieutenant cited the expense entailed in putting the line above the water levels of the new lakes and routing it outside Culebra Cut. Even so, the amount was not that much higher than the $7 million cost in the 1850s for the original, less-capable line.

According to Mears, the rebuilding of the Panama Railroad had been "a necessary part of the plan, not only to furnish a system of transportation during the period of canal construction, but to provide a suitable means of crossing the isthmus at all times, linking the important points along the canal one with the other." He further underscored the vital role of the railroad—and the significance of his work—by noting that throughout the entire canal project there was "no other highway across the Isthmus of Panama—no road or trail which could be used by man or beast to pass between the oceans."

Completing the Mission

Army engineers had long believed that a lock canal would be safer, straighter, and cheaper than a sea-level canal, plus it could be completed sooner. Even before the final decision in 1906 on the type of canal, everyone was determined to finish the job as quickly as possible. Stevens had announced during his tenure that the waterway could be operational on 1 January 1915. When Goethals took over, he publicly adhered to that date. Privately, however, he believed that the goal could be achieved even earlier and he set a pace calculated to do so. His subordinates came to share their chief's optimism as the work progressed rapidly.

As the end of the project was coming into sight, several events seemed to threaten the objective. In August 1912, while the Gatun Dam was still under construction, an 800-foot section of it settled 20 feet (reminiscent of a similar occurrence with one of its toes in November 1908). On 20 January 1913, three days after the disastrous Cucaracha slide, a 300-foot bluff south of Gold Hill fell, taking a half million cubic yards of rock into the canal. During the first two weeks of October that year, an earthquake and forty aftershocks rattled the zone. Another earthquake in May 1914 damaged buildings in Panama City and Balboa. Fortunately, the tremors did not affect any canal structures. In fact, none of

these incidents seriously slowed the progress toward finishing the project before January 1915.

Meanwhile, several preliminary actions remained before the waterway became fully operational. These consisted mostly of eliminating the dikes, dams, and diversion channels that had been preventing water from entering various segments of the canal while they were under construction. The removal of each major obstacle occasioned cheering and celebrating by workers and onlookers. The most thrilling came in early September 1913, when workers departed the Culebra Cut in preparation for flooding it. The first water into the excavation came from Gatun Lake through drain pipes in the earth dike at Gamboa. To complete the task, on 10 October President Wilson, in Washington, touched a button that sent an electrical signal to eight tons of dynamite at the dike. The explosion opened a hole greater than one hundred feet wide, sending a torrent of water rushing into the cut. Dredges removed the remainder of the broken dike. That did not immediately allow vessels to traverse the canal, since the slide at Cucaracha still blocked the cut, but dredges finally completed the task.

Well before the first official transit of the canal, vessels were plying parts of the route. On 26 September 1913, *Gatun*, a seagoing tug, made the initial trip through the locks of the same name. The pioneer passage on the Pacific side took place on 14 October when the tug *Miraflores* rose through the twin locks into Miraflores Lake. The first passage of a vessel through the canal from ocean to ocean was singularly lacking in drama. A crane boat, *Alexandre La Valley*, had come up through the Atlantic locks to Gatun Lake to perform a task. Much later, on 7 January 1914, it went down through the Pedro Miguel and Miraflores Locks to take on a fresh assignment. There was still a month to go before Gatun Lake rose to its projected 85 feet.

The unofficial opening of the canal came with the 3 August 1914 test voyage of *Cristobal*. She had spent recent years at the lowly task of carrying cement for the project from New York to Colon, but she was also the first ocean-going ship to make the passage in a single voyage. The grand opening of the canal came on 15 August 1914, when *Ancon*, an equally humble sister ship of *Cristobal*, made the passage. Aboard were the president of Panama, other Panamanian dignitaries, and personnel of the diplomatic corps. American passengers included canal officials, as well as officers of the infantry and coast artillery units in the zone. Notably absent were the U.S. president, secretary of war, and members of Congress.

On the same day as C*ristobal*'s transit, Germany declared war on France. The global conflict that quickly ensued not only overshadowed events at Panama, but also had an impact on initial usage of the long-awaited waterway, since there were many fewer commercial ships on the high seas due to blockades, submarine attacks, and commerce raiding. Daily transits usually could be counted on the fingers of one hand until the conflict ended late in 1918. (A severe slide in mid-September 1915 also closed the canal for seven months, further depressing traffic.)

The onset of war cancelled the celebratory inauguration of the canal planned for 1915, when an international fleet was to have sailed from Norfolk to San Francisco via the waterway. That year did see two other events that appropriately commemorated the great achievement. They took place neither in Panama nor Washington. The Panama-Pacific International Exposition in San Francisco and the Panama-California Exposition in San Diego both attracted visitors from around the world. Among their many exhibits were ones devoted to the wonders of the Panama Canal.

In what must rank as one of the most anticlimactic events in history, President Wilson publicly proclaimed the opening of the canal on 12 July 1920. This action was in belated compliance with an obscure and hitherto neglected clause of the Panama Canal Act of 1912 that required the president, following the completion of the project, to "cause the same to be officially and formally opened for use and operation."

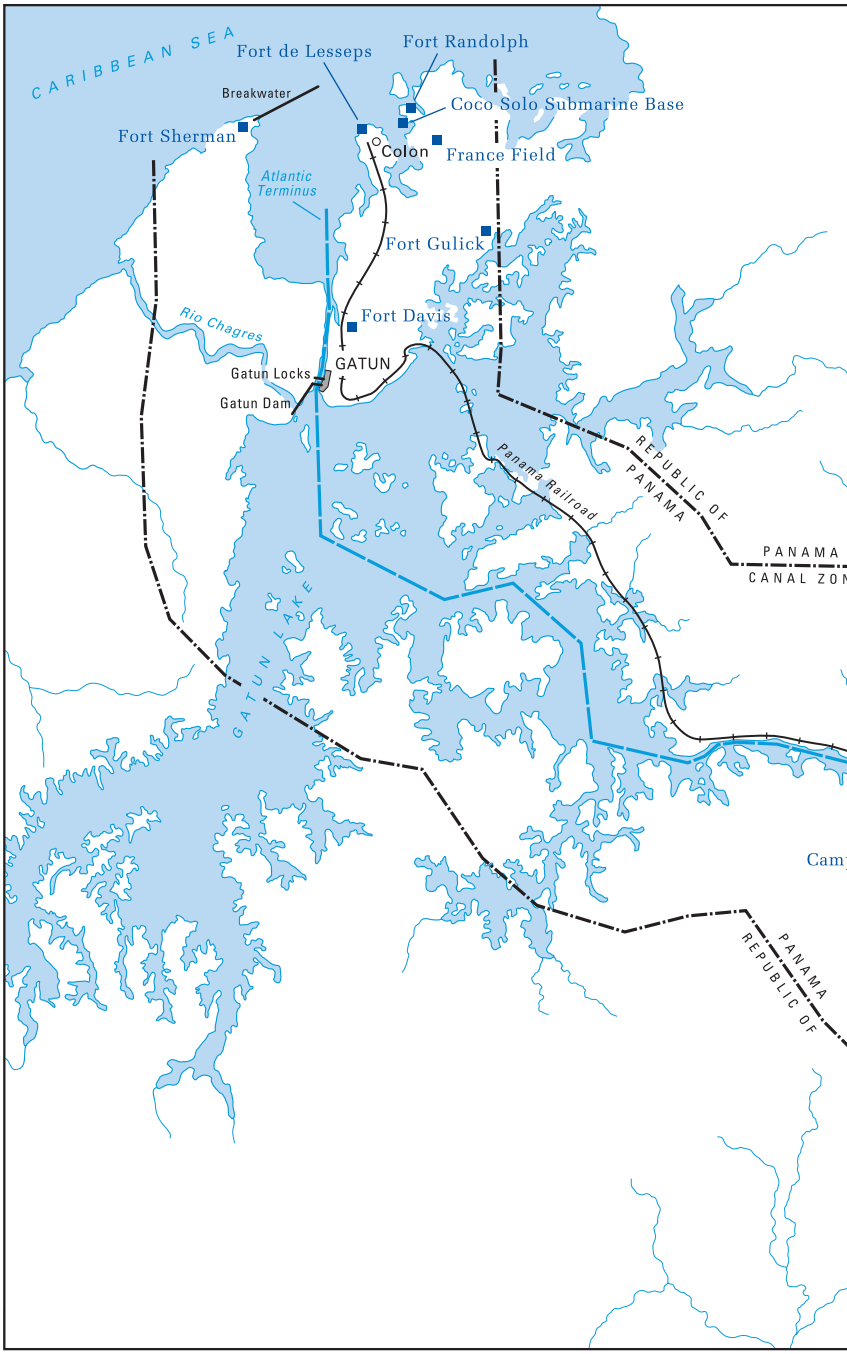
The final cost of the American effort, not including fortifications, was $340 million, $50 million of which had been the initial payments to the French company and Panama. At the time, the only national expenditure to exceed it had been the country's wars. The project rivaled combat in another way, since a little more than 5,600 workers gave their lives to make the canal a reality. While that total was high, it paled in comparison with the estimated 6,000 who died building the original Panama Railroad (a much smaller project in scope) and the 16,500 or more dead suffered in the French attempt. Although no reliable figures seem to exist for construction of the Suez Canal, more than 2,000 died in a single cholera epidemic during one summer of that decade-long effort. That the number of deaths was considered extremely low by the standards of the time was a testament to the public health expertise of Gorgas, the leadership of Goethals, and the dedication of their respective staffs.

The Panama Canal Act of 1912 gave authority to the president to maintain, operate, and protect the waterway. He, in turn, appointed the governor of the Canal Zone, subject to approval by the Senate. The governor oversaw both the daily business of the canal and civil government in the zone, and reported to the president via the War Department. In January 1914, President Wilson issued an executive order abolishing the Isthmian Canal Commission, establishing the post of Engineer of Maintenance, and requiring that a Corps of Engineers officer fill it. The new billet directly supervised the operation of the canal and was the second-ranking official in the zone. Wilson made Goethals the first postconstruction governor that same month. Goethals arranged for Colonel Harding to fill the maintenance job with the goal of eventually making him the next governor. Thereafter, it was standard practice for the occupant of the number two post to succeed to the governorship. Through 1939, every governor entered office as a colonel and, with one exception, earned promotion to brigadier general during his tenure. (Congress jumped Goethals direct from colonel to major general in March 1914.)

Defending the Canal

Out of all the work accomplished by Army personnel on the canal project, only one task was truly a primary mission for soldiers—protecting the strategic waterway from attack. *(Map 3)* Oddly enough, the initial assignment of this task went not to the Army, but to the Navy and Marine Corps. That simply may have been a consequence of the role of the latter services in securing the independence of Panama, as they were already committed on the scene at the start. Another factor may have been the Navy Department's traditional sway over the region, with Marine units having gone ashore in Panama to restore order and protect the railroad eight times between 1856 and 1902.

No matter the reason, Major Lejeune and his Marine battalion (which had first landed at Colon for a brief time in November 1903) returned to Panama to stay in December of that year. The outfit moved into Camp Elliott, a group of abandoned French buildings on a hill near the village of Emperador (later anglicized to Empire) overlooking the northwest end of Culebra Cut. Maj. William Black of the Corps of Engineers had selected the site. A month later, the force


CARIBBEAN SEA
Fort de Lesseps
Fort Randolph
Breakwater
Coco Solo Submarine Base
Fort Sherman
Colon
France Field
Atlantic Terminus
Fort Gulick
Fort Davis
Rio Chagres
GATUN
Gatun Locks
Gatun Dam
Panama Railroad
REPUBLIC OF PANAMA
PANAMA CANAL ZON
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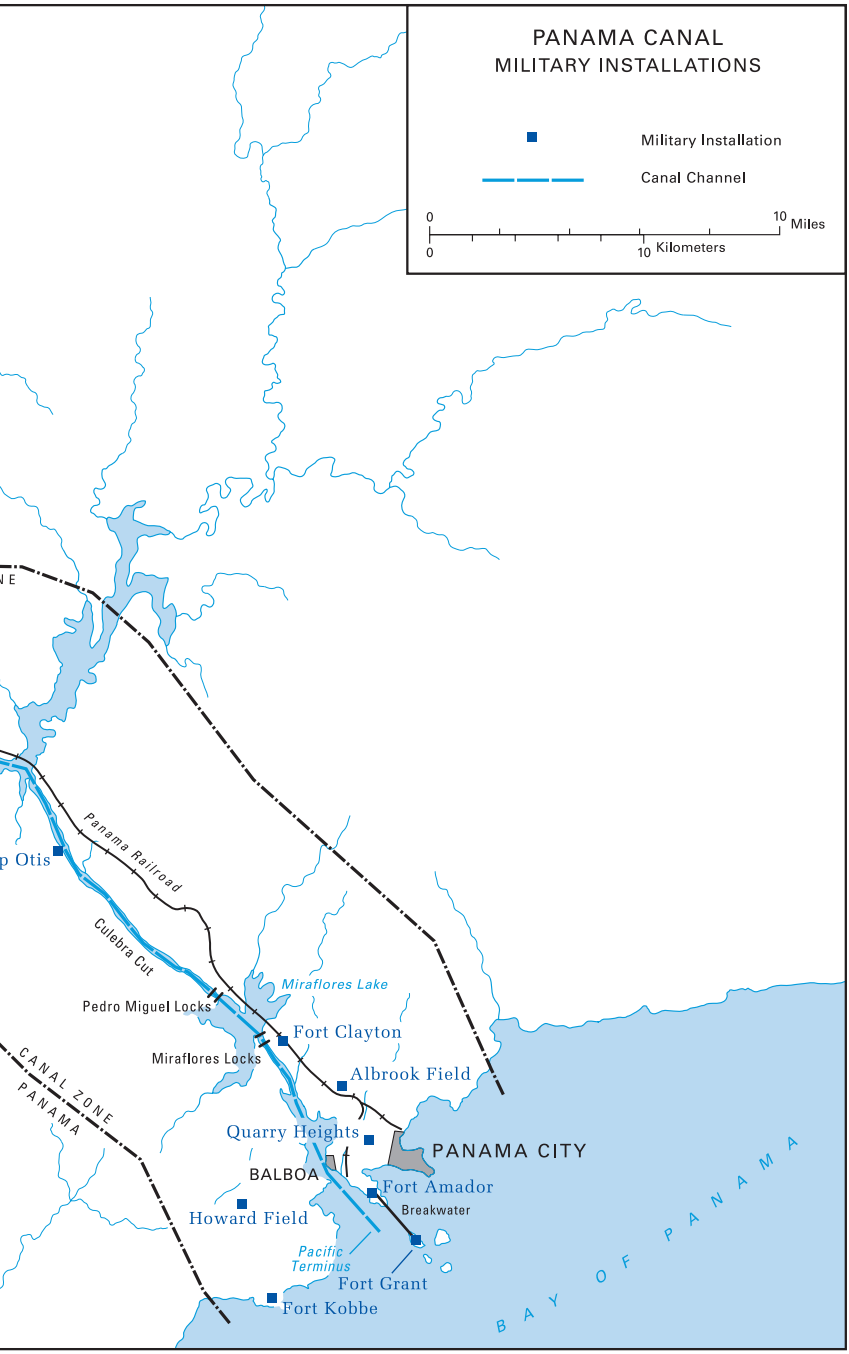
Map 3


PANAMA CANAL
MILITARY INSTALLATIONS
Military Installation
Canal Channel
0
10 Miles
0
10 Kilometers
Panama Railroad
Culebra Cut
Miraflores Lake
Pedro Miguel Locks
Miraflores Locks
Fort Clayton
Albrook Field
Quarry Heights
PANAMA CITY
BALBOA
Fort Amador
Breakwater
Howard Field
Pacific Terminus
Fort Grant
Fort Kobbe
CANAL ZONE
PANAMA
BAY OF PANAMA

grew to four battalions under the personal command of Brig. Gen. George F. Elliott, the commandant of the Marine Corps. Half of this force camped at Bas Obispo, near what would become the Gamboa Dike. After the initial threat of Columbian retaliation faded, Elliott and many of the troops went back to the States in February 1904.

The size of the force fluctuated thereafter, with elements departing to handle other regional emergencies and units coming in whenever the situation in Panama required it. The biggest crisis occurred in the fall of 1904, when the Panamanian Army (a battalion of former Columbian soldiers that had sided with the breakaway province in return for money) plotted to overthrow the government. The Americans backed the Panamanian president and saw to the disbandment of the force. During more peaceful times, there were fewer than 200 marines protecting the zone. Civil disturbances in May 1906 and elections in the summer of 1908 warranted temporary reinforcements.

When Secretary of War Henry L. Stimson submitted his annual report for 1911, he noted "continued satisfactory progress of the work on the Panama Canal." With the waterway nearly a reality, he believed: "The exits and locks of the Panama Canal must now be protected, and it has become necessary to send a mobile force of at least one brigade to the isthmus as well as coast artillerymen for this purpose." In turn, this Army commitment would set "the Navy free for its legitimate functions."

With the redeployment of six infantry regiments from the Philippines, the troops were available in the United States. Stimson ordered the 10th Infantry to the Canal Zone that year. The force, at a peacetime strength of fewer than a thousand men, arrived on 4 October 1911. While the War Department usually kept overseas units at full establishment, the lack of adequate quarters limited the number of personnel in Panama. Secretary Stimson observed: "In view of the time necessary for such construction, it is of the highest importance that such work should be begun at once." In the interim, the regiment went into temporary facilities made available by Goethals at Las Cascadas (near Camp Elliott). The soldiers named their home after Maj. Gen. Elwell S. Otis, who had commanded American forces in the Philippines during much of the insurrection there.

Although Goethals' gold roll workers had most of the comforts of home, military men in Panama initially had no such amenities. In addition to the threat of disease, one officer described what the ordinary soldier or marine could expect: "Drinking places, where vile liquor was dispensed, were everywhere; immoral women, many of

them diseased, were in evidence; gambling dens were plentiful, and added to it all were the heavy rainfall and its accompanying mud, the dense fogs which visited us nightly, the lack of wholesome diversion . . . and the thick tropical jungle which everywhere surrounded us." Alcohol was one of the few distractions, as one young soldier recalled: "The natives had stills in the jungle and plenty of sugar cane available. So a lot of us boys got off to a bad start. No ice, no mixing, just right out of a bottle, ninety proof!"

This squalid, dreary climate bred friction with both the Panamanians and the marines, in one instance erupting into a large brawl in Panama City following an interservice athletic competition in 1912. As things got out of hand, the local police opened fire, resulting in more than a dozen American casualties, including at least one death. The uneasy relationships ended two years later when the last Marine unit departed the zone, much to the chagrin of its commander, Maj. Smedley D. Butler. The depth of the interservice rivalry was evident in his comment: "To have the Marines, who took this place, withdrawn *entirely* before the ships go through is terribly hard." The Navy retained the job of protecting the sea approaches to Panama, while the Army assumed full responsibility in early 1914 for land-based defense. The United States also disarmed the Panamanian police, who had routinely used excessive force against American servicemen outside the Canal Zone. Henceforth, the U.S. Army had a monopoly on armed might throughout Panama. The Marine Corps returned to the zone in 1923, but only as a small barracks detachment at the Navy submarine base at Coco Solo.

In the view of the War Department, the "highway between the two oceans" enormously increased the effectiveness of the fleet and U.S. military power in general. Thus the "unquestioned security of the canal" was the nation's "most important military problem." The garrison had to be able to handle both a direct naval assault from the sea, as well as a force that might land beyond the range of the seacoast guns and penetrate the jungle to attack the locks and dams or the forts from the rear. The defenses therefore had to include a mobile unit that could quickly respond to any threat throughout the zone. Even in peacetime, the force had to be large enough to defeat naval raids at the beginning of a surprise war and secure the canal until reinforcements could arrive.

Given the importance of the waterway, the Army-Navy Joint Board formed the Panama Fortifications Board to determine what was needed for defense. The group made its initial recommendations

in April 1910. It proposed a total of forty-two large-caliber guns and mortars manned by twelve coast artillery companies. These batteries would take on any enemy warships that made it past the Navy. The largest weapons—16-inch rifles that could reach out more than twenty miles—out-gunned anything then afloat. After a trip to Panama later that year, the fortifications board increased the number of weapons and troops, upping the cost to nearly $20 million. They advocated the addition of four infantry regiments, a field artillery battalion, and a squadron of cavalry to back up the coast artillery. President Taft, concerned that Congress would find the price tag too steep, ordered cuts. The board found them mainly by sharpening its estimated costs, and Congress ultimately approved a request for $12 million in January 1911.

Crews man a pair of 12-inch mortars, probably at Fort Grant on Flamenco Island. There were 28 of these among the 51 coast defense weapons of 12 inches or greater at Panama.

The War Department plan was a significant engineering project in its own right. There were "strong fortifications at each terminus of the canal" to house the seacoast guns and mortars, as well as

an "adequate submarine mine defense." These were complemented by "a defensive line of field fortifications for the protection of the more vulnerable portions of the canal from injuries by raiding parties." The project also involved "filling, clearing, and drainage to secure healthful surroundings for the troops detailed for the defense of the canal." Construction was soon under way on the batteries, and the first guns and their carriages arrived in June 1913. Most of the installations were complete by 1915, at a cost of $15 million. At the time, they were "regarded as the most powerful and effective of any [seacoast armament] in the world."

The coast artillery sites on the Pacific side, built on landfill as part of the Naos Island breakwater, became Fort Grant, named for the U.S. general and president. Nearby installations on the mainland were dubbed Fort Amador, after the first president of an independent Panama. Batteries on the west bank entrance of the canal were known as Fort Kobbe, after William A. Kobbe, a private in the Civil War who eventually retired in 1904 as a major general. On the Atlantic end, heavy batteries on the northwest shoulder of Limon Bay became Fort Sherman, after the famous Civil War general. Fort de Lesseps was a tiny installation with a handful of coastal guns surrounded by Colon. The final defensive base on the Atlantic side was Fort Randolph, located on Margarita and Galeta Islands and named after Maj. Gen. Wallace F. Randolph.

In 1913, Army planners established the "minimum peace garrison" as three regiments of infantry, one battalion of field artillery, one squadron of cavalry, eighteen companies of coast artillery, and ancillary supporting units. As the fixed fortifications at either end of the canal neared completion, the 81st Coast Artillery Company landed on 22 December 1913. During 1914, four additional companies manned fixed fortifications, while the 5th Infantry joined the mobile forces and set itself up near Empire. The following year saw the arrival of three more coast artillery companies; the 29th Infantry; the 1st Squadron, 12th Cavalry; Company M, 3d Engineer Battalion; and a signal platoon. On 6 January 1915, the War Department established United States Troops, Panama Canal Zone, as part of the Army's Eastern Department, to provide command and control.

The forces in the zone conducted their first real alert for potential combat in April 1914 when the United States occupied Vera Cruz and conflict with Mexico seemed likely. The second

came soon after when war broke out in Europe in August. The American military presence further increased in 1916 with the arrival of the 2d Battalion, 4th Field Artillery, and another five coast artillery companies. Elements of the 5th and 10th Infantry regiments combined to form the 33d Infantry, which took station at Gatun.

By the time the United States entered World War I in April 1917, it was clear that there was no significant conventional military threat to the waterway, since Britain's Royal Navy had bottled up the German Imperial Fleet in its home ports. However, there remained the distinct possibility that a hostile nation might sabotage the canal by blowing up a ship laden with explosives in one of the locks. To prevent such an act, soldiers boarded every ship and accompanied it during the transit. Although the 7th Observation Squadron and two support battalions arrived, the requirement for forces in Europe prompted the redeployment of the 5th, 10th, and 29th Infantry regiments back to the United States for assignment to combat brigades. Other units less suited to the needs of the western front remained in the Canal Zone, and there were still some 5,000 soldiers there at the end of the war in November 1918.

The global conflict highlighted one area of concern in the canal defense structure—unity of command. As the United States edged closer to being drawn into the war in 1916, both Governor Goethals and Brig. Gen. Clarence R. Edwards (the commander of Army forces in the zone) sought clarification from the president on their responsibilities. They each anticipated that danger (particularly in the form of sabotage) might develop before a formal declaration of war, thus making it essential to establish a clear chain of command in peacetime. Goethals argued that his office was the logical one to take charge, as it was "clearly the duty of the Governor to determine and take the necessary precautions to prevent surreptitious damage to the canal and to resist any action that may be undertaken with hostile intent." Wilson responded with an executive order making the governor responsible for defense until such time as the president should appoint an Army officer to assume command of both military and government functions. (Although Goethals and his successors were Army officers, subsequent events demonstrated that the provision implied that a combat arms officer would replace an engineer.) The

directive explicitly required both Navy and Army commanders in the zone to place their forces at the disposal of the governor to maintain the security of the waterway.

On 9 April 1917, two days after the United States declared war on Germany, Wilson gave the Army commander in Panama complete military and civil authority over the zone. General Edwards argued that this was the only logical course not only in war, but also in peace, since there too often were differences of opinion between the governor and the military commander that impacted on defense. He cited as examples the determination of the location of field fortifications and bases for the mobile forces, as well as the use of canal assets to transport troops during exercises. The War Department made one additional change, creating a new territorial command by activating the Panama Canal Department, thus giving the military commander a direct line to Washington.

In January 1919, following the end of the global conflict, President Wilson returned civil authority to the Canal Zone governor, with military leaders reporting to that office. Despite the minimal threat to the waterway in World War I, cutbacks inherent in postwar demobilization, an isolationist public sentiment, and austere budgets that grew even leaner with the onset of the Great Depression in the 1930s, the Army continued to see the defense of the canal as a priority mission. To facilitate planning for the next conflict, in 1923 the Army and Navy created a Local Joint Planning Committee headed by the commanders of the Panama Canal Department and the 15th Naval District. At first the body did not include the governor, but he became a member in 1925.

The configuration of forces in Panama during the interwar years evolved with changes in possible threats and military technology. Coastal artillery remained the centerpiece, at first, but a mobile force of soldiers retained a major supporting role. In recognition of that defensive scheme, the treaty with Panama allowed U.S. forces to operate beyond the Canal Zone. Peacetime training in those areas enabled the troops to become experts in jungle warfare and thoroughly familiar with the terrain over which they were likely to fight. The task was never easy, as one soldier recorded: "Trail reconnaissances are experiences that try the souls of men, and incidentally, their vocabularies also. Who can forget the first one? . . . Success crowned this

hard trip through uninhabited and practically uncharted wilds." One of the largest exercises involved a Navy fleet and a Marine regiment simulating an amphibious assault in January 1924.

Soldiers and mules move a pack howitzer along a hilly jungle trail. The mission of the mobile force was to deal with an enemy making an overland attack on the canal.

While training could be tough, life improved significantly for the troops of the mobile force when the Army established Fort Clayton on a former dump site for spoil adjacent to the Miraflores Locks and Fort Davis near the Gatun Locks on the opposite end of the canal. The cost of building both bases totaled $4 million. The installations were named after colonels—Bertram T. Clayton and William D. Davis—who had served in the zone and died in combat in France. The 33d Infantry moved to Fort Clayton in 1920, while the 14th Infantry arrived that year and went to Fort Davis. The two regiments combined to form the 19th Infantry Brigade. With the advent of new facilities, quarters and recreational opportunities equaled or exceeded conditions at Stateside posts. Duty in Panama also gained a special appeal during Prohibition in the United States, as alcohol remained legally available outside the zone. The base structure grew further when the Panama Canal Department

headquarters set up at Quarry Heights on Ancon Hill. In 1923, there were a total of 8,350 Army personnel authorized for Panama, with 4,000 in the mobile force and 1,800 in the coast artillery.

As the capabilities of aircraft grew, so too did the attention paid to that aspect of defending the canal. The 7th Observation Squadron of World War I gave way to the larger 6th Composite Group (more than 600 officers and men) by 1925. While the former had operated initially from the Fort Sherman parade field, the latter flew out of France Field, a specially constructed air base on the Atlantic end near Manzanillo Bay. The mission of aviation was to gain and maintain air superiority against an enemy force, observe fire for the coast and field artillery, provide air support to the infantry, attack enemy land or naval forces, and cooperate with the Navy in its operations. By 1931, the aviators also were beginning to operate from a new base on the Pacific side, Albrook Field (named for 1st Lt. Frank P. Albrook, a former member of the 7th Observation Squadron who died in a flying accident in 1924). It was soon supplemented by Howard Field, named after Maj. Charles H. Howard, another veteran of the same unit killed in a crash.

The increasing range and payload of land-based aircraft and the advent of aircraft carriers steadily eroded the importance of coastal artillery. A 1935 study placed a new emphasis on protection against aerial attack and noted that there were as yet no antiaircraft guns in the zone. An update two years later characterized the coastal artillery as "wholly vulnerable to overhead attack." As antiaircraft weapons finally began to arrive, some coast artillery soldiers transitioned to man them. Air defense also raised a contentious issue with the Navy, since the Army Air Corps wanted the right to conduct searches over the sea approaches to the canal, the traditional geographic responsibility of the sea service. The small size of the Canal Zone equally prevented the Army from establishing adequate ground-based early-warning facilities.

Political changes also impacted defense planning during this period. President Franklin D. Roosevelt's Good Neighbor Policy, for example, emphasized cooperative relations with regional governments. One aspect of this initiative was a 1936 amendment to the original canal treaty that surrendered many American rights outside the zone. Henceforth, the U.S. Army would no longer intervene in Panamanian affairs, as it had

numerous times since 1912, to restore civil order or ensure fair elections. While the new agreement achieved the positive goal of reducing friction with Panama, it made it much more difficult to obtain use of sites outside the zone. In particular, the Army Air Corps wanted to develop a landing field at Rio Hato, some sixty miles from the canal.

Rising world tensions in the mid-1930s provided additional impetus to improve defenses. Authorized strength for Army forces in the zone increased to over 13,000 in 1936, and planners advocated new and improved roads to allow the mobile force to respond more rapidly to any threatened point, as well as more housing for additional troops. As part of the preparation for potential war in 1939, Congress appropriated $50 million for improvements, such as upgrading the main runway at Albrook Field to accommodate newer, heavier bombers, the first of which began deploying in June. The Army also stepped up its operational security measures, banning photography near key installations and again placing armed guards on ships transiting the canal.

The outbreak of war between the European powers at the beginning of September 1939 triggered more steps. President Roosevelt transferred full responsibility for military and civil matters from the zone's governor to the Army's Panama Canal Department. Authorized troop strength in Panama increased dramatically to 31,400 during the course of the year. Among the major units to arrive was the 18th Infantry Brigade with its component 5th and 13th Infantry regiments, plus additional antiaircraft units and fighter squadrons. The high expectation of an attack on the zone was evidenced by the evacuation of all military dependants during 1941.

The issue of joint command proved a vexing one, exacerbated by the growing role of aviation. The Army recognized the need to expand its defensive horizons outward, creating the Caribbean Defense Command in January 1941. The general heading the Panama Canal Department took on this new role as an additional duty and assumed control of Army forces throughout the region. Simultaneously the Army sought outlying bases to establish long-range air patrols and early-warning stations. Planners knew that they could not wait until enemy planes reached Panama to intercept and stop them. The Navy, on the other hand, was more concerned with antisubmarine

warfare and organized its forces in the region into two coastal sea frontiers, one centered on Panama and other covering the rest of the Caribbean. President Roosevelt sided with the Navy view in December 1941, dictating the creation of two joint commands. That gave the Army operational control over Navy forces in and near Panama, but put the Navy in charge of Army forces and territory elsewhere in the region needed to defend the canal in depth.

The Japanese attack on Pearl Harbor on 7 December 1941 precipitated the United States into World War II. In this global conflict, the canal was more critical than ever. Within days, the War Department ordered two infantry regiments, a field artillery battalion, two barrage balloon units, radar equipment, and 1,800 coast artillery replacements to Panama. By the end of the next month, more than 47,000 troops were in the country. Soldiers arrested and interned Japanese and German nationals in Panama, while the entire zone instituted nightly blackouts against possible air attacks. In addition, the defenders prepared chemical smoke pots to obstruct target acquisition by hostile aircraft, emplaced fields of antiship mines near both canal entrances, and installed antisubmarine and torpedo nets at the locks. A main fear was that bombs or torpedoes would breach the lock gates or the dams and cause Gatun Lake to drain away.

By the end of 1942, almost 67,000 Army personnel were in Panama. They manned nine airfields, ten major ground bases, and more than six hundred other sites for searchlights, antiaircraft guns, and miscellaneous uses. The early threat had motivated Panama to agree to lease a number of areas to the United States, among them land for the aviation base at Rio Hato. Allied success elsewhere that year, however, spelled the end of the canal's favored status. The Battle of Midway in June, the campaign in Guadalcanal starting in August, and the TORCH landings in North Africa in November put the Axis forces on the defensive and made it highly unlikely that any conventional attack would strike the canal. During 1943, the United States began to divert forces to the active fronts and by February 1944 troop strength in Panama was cut in half. Soon after, the coastal artillery batteries were no longer manned. As the zone became a backwater in the conflict, it began to serve primarily as a training area for jungle warfare. The only casualties in Panama during the war came as a result of malaria, which sickened more than

10 percent of the forces stationed there, primarily those in remote jungle posts.

One of two 14-inch railway guns defending the canal. A rarity in the American arsenal, they were well suited for Panama because they could shift from one coast to the other as needed and occupy prepared positions.

For a time during the war, defense requirements almost brought about a major new construction effort that would have cost as much as the original canal project. The existing locks were not big enough to accommodate a new class of battleships planned by the Navy, while the Army remained concerned that a ship transiting the canal could be blown up to destroy one or more locks. The solution both services supported was the building of a third set of larger locks at some distance from the existing pairs. They would be an alternate if the main ones were ruined by sabotage. Although preliminary work got under way in 1940, the Navy eventually cancelled the super battleships and the Army decided that the new locks would primarily be an additional point to be breached by an aerial attack designed to empty Gatun Lake. The

expensive project died as resources went to more important war needs. Army engineers did complete one other major undertaking, construction of the first transisthmian highway.

Throughout the war, the canal served its strategic role of speeding the movement of forces from one theater to another. Following the desperate naval battles of Coral Sea and Midway in May and June 1942, aircraft carrier *Wasp*, battleship *North Carolina*, two cruisers, and seven destroyers transited the waterway to reinforce the depleted Pacific Fleet. Likewise, the 1st Marine Division moved via Panama on its way to the 7 August 1942 assault on Guadalcanal. After the surrender of Germany in May of 1945, 125,000 troops and their equipment, bound for the planned invasion of Japan, redeployed through the canal in what became known as Operation Transit.

With the end of World War II, the Army forces of the Panama Canal Department dropped to a strength of 20,000 soldiers. In 1947, the new Department of Defense activated the U.S. Caribbean Command, a unified command comprised of all services in the region. The Army component, U.S. Army Caribbean, replaced the Panama Canal Department. Continued postwar demobilization and requirements for troops in Europe and elsewhere brought further cutbacks in Panama, which hosted barely 9,000 soldiers by 1949. The number declined even further to 6,600 in 1959, but the successful Communist revolution in Cuba that year reversed the trend. Manpower rose to about 10,000 in the 1970s and stayed around that figure for the next two decades.

Although defending the Panama Canal remained a priority for the Caribbean Command, the Cold War brought the new mission of providing military assistance to Latin American governments opposing the spread of Communism. The U.S. Army Caribbean School, established in 1949 and located at Fort Gulick near the Atlantic side of the zone, became the prime facility for educating Latin American military personnel. By 1956, they constituted the vast majority of students and all classes were henceforth conducted in Spanish. Eight years later, it became the United States Army School of the Americas. Also in the 1950s, the Army established a new Jungle Warfare Training Facility at Fort Sherman. Its importance grew during the Vietnam War.

In 1963, the secretary of defense redesignated the Caribbean Command as the United States Southern Command to reflect a new global command system. Correspondingly, the Army

component command was renamed United States Army South. A more significant change in the canal defenses came in 1960 with the arrival of HAWK batteries, the first missile-based antiaircraft system in the zone. Throughout much of this period, the primary Army unit in Panama was the 193d Infantry Brigade.

Transitioning to a Panamanian Canal

Although the United States had played the major role in assuring Panama's independence from Columbia in 1903, it had not taken long for the Panamanian people to feel resentment toward the colossus from the north. American sovereignty over the Canal Zone and the fact that few Panamanians benefited economically from the waterway bred understandable discontent. The 1936 treaty revisions had addressed some issues between the two nations, but they did little to resolve the major grievances. Since the agreement made Panama responsible for its own defense, it did spur the strengthening of the National Police. That body became an increasing force in the country's politics, beginning with a coup that overthrew the elected president in 1941. In 1953, the organization grew to 3,000 men and became the National Guard.

In 1955, the United States and Panama agreed to a new treaty further revising the 1903 pact. Provisions increased the annual payment to Panama to nearly $2 million, returned more land to local control, and opened up more jobs in the zone to Panamanians. The treaty theoretically abolished the separate wage scales embodied in the former gold and silver rolls, but in practice American workers continued to hold the highest paying jobs. It also allowed the United States to regain use of the airfield at Rio Hato, which had reverted to Panama after World War II. The apparent progress in relations evaporated the following year when Egypt nationalized the Suez Canal, thus emboldening Panamanians to seek even greater control over the waterway in their country.

The issue of sovereignty over the canal came to be symbolized by the U.S. flag displayed in the zone. Panamanians demanded that their own national colors at least fly alongside it. Riots over the dispute ensued in early 1964, resulting in exchanges of gunfire that killed four American soldiers and more than twenty Panamanians and wounded hundreds more on both sides. In response,

President Lyndon B. Johnson agreed to open negotiations over the status of the waterway. These talks dragged on for more than a decade, but finally resulted in the signing of two agreements in September 1977. The Panama Canal Treaty obligated the United States to turn the waterway over to Panama at the end of 1999 and to gradually increase Panamanian participation in running it before then. The Canal Zone government dissolved immediately and a joint Panamanian-American commission took its place. Additional executive agreements returned approximately two-thirds of the zone to Panama in 1979 and authorized U.S. troops to continue use of their bases until 2000.

The Panamanian National Guard had steadily increased its role in government throughout this period, essentially establishing a military dictatorship. In 1983, the organization's intelligence chief, Manuel Antonio Noriega, took command. That same year, he renamed it the Panamanian Defense Forces and steadily expanded its size and capability. His brutal rule was underpinned by active involvement in corruption, narcotics trafficking, and money laundering, while his troops routinely harassed American military personnel and civilians.

As the crisis between the two nations deepened, the United States deployed additional military units to its Panama bases, eventually reaching a total of 13,000 men and women in country, and began planning for a possible conflict. Panamanian acts of intimidation grew ever more common and, in some cases, violent. On 15 December 1989, Noriega publicly proclaimed that a state of war existed between the two countries, a demonstration of bravado that would come back to haunt him. The very next day, Panamanian soldiers shot and killed a U.S. Marine Corps lieutenant at a roadblock, then arrested and assaulted a Navy lieutenant and his wife who had witnessed the event. With those final provocations, on 17 December President George H. W. Bush ordered military action to depose Noriega and restore a democratic government to Panama.

Operation Just Cause began in the early hours of 20 December 1989. The Army's 82d Airborne Division, 7th Infantry Division, and various special operations elements joined with Marine and Navy elements and Army units already in the zone to launch an overwhelming attack that defeated the Panamanian Defense Forces and occupied most of the country in one day. Noriega eluded the initial onslaught and fled to the Vatican consulate in Panama

City. He finally surrendered on 3 January 1990. (Two years later, a U.S. court found him guilty of drug trafficking and sentenced him to forty years in prison.) At a cost of 23 killed and 322 wounded, American forces had ended a dictatorship and maintained the security of the Panama Canal. They also engendered goodwill from the Panamanian people, who were generally happy to see Noriega deposed.

With the restoration of democratic rule in Panama, the United States resumed progress on implementing the 1977 treaties. The 193d Infantry Brigade cased its colors in 1994, leaving just a single infantry battalion in the area. The 5th Battalion, 87th Infantry, departed Panama in 1996. The U.S. Army South headquarters relocated to Puerto Rico in August 1999. Fort Clayton was the last military installation handed over, on 30 November that year, essentially marking the end of the Army presence in Panama. By the time of the formal transfer of control of the canal at the end of 1999, Panamanians held more than 98 percent of canal jobs and the waterway continued to operate efficiently, with over 12,000 ships making the transit each year.

The Legacy

Although the world had taken little notice in 1914 of the first passages through the Panama Canal, those who had witnessed them were suitably impressed. The smoothness of the operation attested to the thought that went into the design, the skill that went into the construction, and the training that preceded the inauguration of service. As use of the waterway increased over the years, so too did recognition of just what a marvel of engineering it was. The builders of the canal did their jobs so well that few changes have been necessary over the course of a century. In 1935, the Canal Zone government built a concrete dam across the Chagres at Alhajuela, creating Madden Lake and a reserve of 22 million cubic feet of water. The year 1962 saw completion of the Bridge of the Americas, which spans the waterway near Panama City. Four years later came the installation of lighting to allow nighttime transits (and thus more traffic).

Use of the canal has steadily increased over the years as global trade has expanded, but the waterway has grown outdated in one respect. The U.S. Navy, now strong enough to maintain major

fleets in both oceans at the same time, built its post–World War II aircraft carriers too wide to fit through the locks. In the decades that followed, commercial vessels also vastly expanded in size, and modern supertankers and container ships are far too large for the canal. In October 2006, the Panamanian public voted overwhelmingly to authorize a program similar to the one initiated and then abandoned during World War II—a third set of locks capable of handling all ships. The project will ensure that the waterway remains a vital transportation link well into its second century.

Americans at the beginning of the twentieth century had great confidence in medicine, science, technology, and professional engineering and believed that advancement in these areas would help the nation achieve one of its most valued goals, an efficient society. Similarly, they were certain that their national government was capable of carrying out the momentous enterprise of building the canal, even though the challenges at Panama had defeated the best efforts of the French (then considered a more powerful nation than the United States). In the course of this project, their unquestioning trust in knowledge and national institutions proved well founded.

Although progress in technical capability made a major contribution to the successful outcome in Panama, the important role of the individuals who achieved this feat cannot be overestimated. Had Gorgas been less sure of his methods and less determined in fighting for them, disease inevitably would have defeated the Americans as it had the French. Had Goethals let the enormity of the challenge overwhelm him, as had happened to his predecessors, he would never have seen it through to completion. Equally important, his leadership was a key ingredient in motivating his workforce not only to remain on the job in the face of danger from illness and accident, but also to attack their daily tasks with vigor and enthusiasm. Even those senior subordinates who did not like him stayed with the project, their commitment to the goal more important than any personal disagreements. The integrity and efficiency of all those involved also remain astonishing, given the vast amounts of money expended and the wide-ranging variety of work accomplished, from digging and building to purchasing supplies and equipment to caring for the sick.

All these efforts stood in marked contrast to the nation's performance in the Spanish-American War just a few years before. Both civilian and military leaders had been equally well-intentioned

then, but they had bungled logistics, poorly implemented health programs, and oftentimes made inept decisions. Only the weakness of the opponent and the courage of those who fought had brought about success in the end. The completion of the canal, universally regarded as "one of the supreme human achievements of all time," marked a new level of accomplishment for the United States. Coupled with the role the nation played in garnering victory for the Allies in World War I, it propelled the United States to the status of a major global power and marked the beginning of what would become known as the American Century. One hundred years later, the triumph at Panama remains a shining standard of success for both the United States and its Army.

Suggestions for Further Reading

The public fascination with the Panama Canal project ensured that it became a subject of numerous books and articles even before it was finished. The main participants themselves contributed several publications. George W. Goethals served as the editor for a two-volume collection of twenty-five essays on every aspect of the construction program, each chapter written by someone who worked in that area. *The Panama Canal: An Engineering Treatise* (New York: McGraw-Hill, 1916) remains one of the most thorough technical descriptions of the project. William L. Sibert and John F. Stevens coauthored *The Construction of the Panama Canal* (New York: D. Appleton, 1915). It shows a definite bias in favor of Stevens' role but provides the viewpoint of two major leaders of the project. David D. Gaillard even contributed an article before his death, "Culebra Cut and the Problem of Slides," *Scientific American* 107 (9 November 1912): 388–90. William C. Gorgas captured the medical efforts in *Sanitation in Panama* (New York: Appleton, 1915). The battle against insect carriers of disease received its own volume—Joseph A. Le Prince, A. J. Orenstein, and L. O. Howard, *Mosquito Control in Panama: The Eradication of Malaria and Yellow Fever in Cuba and Panama* (New York: G. P. Putnam's Sons, 1916).

The best and most comprehensive modern history of the effort remains David G. McCullough's *The Path Between the Seas: The Creation of the Panama Canal, 1870–1914* (New York: Simon & Schuster, 1977). Comparing favorably with McCullough is the newer work by Matthew Parker, *Panama Fever: The Epic Story of One of the Greatest Human Achievements of All Time—The Building of the Panama Canal* (New York: Doubleday, 2008). A new book by Julie Greene, *The Canal Builders: Making America's Empire at the Panama Canal* (New York: Penguin Press, 2009), focuses mainly on the tens of thousands of laborers from around the world who worked on the canal. Four other works of note are John Major, *Prize Possession: The United States and the Panama Canal, 1903–1979* (New York: Cambridge University Press, 1993); W. Storrs Lee, *The Strength to Move a Mountain* (New York: G. P. Putnam's Sons, 1958); Walter LaFeber, *The Panama Canal: The Crisis in Historical Perspective* (New York: Oxford University Press, 1989); and Paul J. Scheips, ed., *The Panama*

Canal: Readings on Its History (Wilmington, Del.: Michael Glazier Inc., 1979). Michael L. Conniff's *Black Labor on a White Canal: Panama, 1904–1981* (Pittsburgh: University of Pittsburgh Press, 1985) looks at race and class issues. A brief account of the U.S. toppling of Manuel Antonio Noriega is R. Cody Phillips' *Operation Just Cause: The Incursion into Panama* (Washington, D.C.: U.S. Army Center of Military History, 2004). A more complete discussion of the evolving political and military crisis in Panama from 1987–1989 is Lawrence A. Yates, *The U.S. Military Intervention in Panama: Origins, Planning, and Crisis Management, June 1987—December 1989* (Washington, D.C.: U.S. Army Center of Military History, 2008).

A few biographies provide portraits of those who made the canal a reality. Soon after Gorgas' death, Marie C. Gorgas and Burton J. Hendrick brought out *William Crawford Gorgas, His Life and Work* (Garden City: Doubleday, Page, 1924). John M. Gibson's *Physician to the World: The Life of General William C. Gorgas* (Durham, N.C.: Duke University Press, 1950) is a more recent and perhaps more objective account. The only significant biography of Goethals was written by a man who served on his administrative staff in Panama. Joseph Bucklin Bishop's *Goethals: Genius of the Panama Canal* (New York: Harper & Brothers Publishers, 1930) is an intimate but not necessarily thorough look at the chief engineer. Katharine Carson Crittenden's *Get Mears! Frederick Mears, Builder of the Alaska Railroad* (Portland, Ore.: Binford & Mort Publishing, 2002) does not devote too much space to the canal period but does explain how Mears became a key member of the project despite his lack of formal training as an engineer.

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