THE PANAMA CANAL

By COL. GEORGE W. GOETHALS, Chief Engineer of the Canal.

In the Youth's Companion.

At its narrowest part, the Isthmus of Panama is only forty miles wide as the crow flies. It runs east and west, and the canal crosses it diagonally from Colon on the north to Panama on the south, in a general direction from northwest to southeast. The Pacific terminus of the canal is twenty-two miles east of the northern entrance. In length it is fifty miles from deep water in the Caribbean to deep water in the Pacific.

The distinctive geographic feature of the portion of the isthmus traversed by the canal is the Chagres River, with a drainage basin of about 1300 square miles. It rises in the San Blas country and flows parallel to the coast lines for the greater part of its length, until the Obispo river joins it. Then it turns almost at right angles to the westward, pursues this general course for nine miles, and then follows a tortuous route in a general direction to the Caribbean, which it enters about seven miles west of the canal entrance. It has twenty-six tributaries betwen the mouth of the Obispo and the Caribbean. Of these, the Gatun and Trinidad rivers, which enter from the east and west respectively in the vicinity of Gatun, are the most important.

The country is low and flat for a mile and a quarter from Limon Bay to the Mindi hills, which rise to an elevation of from 50 to 60 feet above sea level. The valley of the Chagres lies on the south side of these hills. Except where the Quebrancha range encroaches on it at Gatun, it is low and broad, extending for miles up the Gatun and Trinidad rivers. Toward Bohio, about eight miles above Gatun, the hills converge, but at this point the river is still virtually at sea level. Above Bohio the ascent is rapid, the valley contracts and the adjacent hills are steep. At Gamboa, about 31 miles from Colon, the Obispo River, which rises in the continental divide, joins the Chagres from the south.

Route Across the Isthmus.

The line of the canal, after crossing the Mindi hills, follows the valleys of the Chagres and Obispo rivers, and after crossing the continental divide, passes through the valley of the Rio Grande to the Pacific ocean. That valley broadens out as it approaches the Pacific; the banks are low and flat.

The rainfall on the isthmus averages about 120 inches during the nine months of the year that constitute the rainy season. This, together with the extensive drainage area and the precipitous character of the hills, makes the Chagres river and its tributaries torrential streams. How to control them was the chief problem that had to be solved.

Various methods had been proposed. The French company, which contemplated the construction of the sea-level canal, considered the method of diverting the river entirely away from the canal line, and also the method of constructing a dam sufficiently high to keep in check all the flood waters, which might then be gradually discharged through the completed canal by means of sluice gates at the bottom of the dam. While these projects were being considered and discussed, the company excavated a section of the canal, and in order to protect it from the flood waters of the streams, built additional channels on either side of the canal to care for the flood waters. When, owing to lack of funds, this type of construction was changed, it was proposed to build a dam across the valley of the river at Bohio, and thus create a lake that would give control, to a limited extent; the surplus flood waters were to be carried through a diversion channel specially constructed for the purpose.

The new Panama canal company adopted the lock type of canal, with a dam at Bohio. This meant a solution similar to that adopted by the first company. By adopting this construction the new company was able to utilize to the best advantage all the excavation that had already been done. Acting under authority of law, the President of the United States secured from the republic of Panama, the necessary concession for the work and for jurisdiction over a strip of land for the construction of the canal; he also acquired the rights and properties of the New Panama Canal Company. The transfer took place on May 4, 1904. By the same act Congress adopted the recommendation submitted by a board of engineers in its report of 1901. The plan, in this instance, provided for a dam at Bohio—the solution for the control of the Chagres and its tributaries that had been outlined by the French company.

De Lepinay's Plan.

Shortly after the United States took over the work, the question of the type of canal was again agitated and because of the importance of the question the president convened an international board of engineers to consider the subject. He accepted and recommended the adoption of the plan proposed by the minority of the board, and as a result, the type of canal now building was authorized by Congress in June, 1906. The developments during construction leave no doubt as to the wisdom of the choice.

The plan adopted differed from the one proposed by the board in its report of 1901, by placing the dam across the Chagres valley at Gatun, instead of at Bohio. In other words, it conforms to the plan submitted to the international congress of 1879 in Paris by Godin de Lepinay, who asserted that it would cost less, require shorter time for construction, call for less sacrifice of life because it would concentrate the work at three different points, instead of spreading it over virtually the entire isthmus. As the result of the Spanish War, and the investigations made relative to the transmission of yellow fever, the health conditions in 1906 were of less importance than they had been in 1879, but the considerations advanced by de Lepinay found favor with the minority of the board, who advocated the lock type of canal. Moreover, this type of canal meant straighter courses, and therefore greater ease and safety in navigation.

The plan contemplates a sea-level channel 500 feet wide at the bottom, and forty-one feet deep at mean tide, from deep water in the Caribbean to Gatun, a distance of eight miles. By the construction of a dam across the valley of the Chagres at this point, the great flow of the river is checked and the water rises, flooding the surrounding country. In this way is created an artificial lake through which will pass the canal channel. This lake is to be maintained at a normal elevation of 85 feet above sea level, and will have a total area of 164 square miles.

The difference in level from the sea to the lake is to be overcome by three locks in one flight. The water will be back through the channel cut in the continental divide to Pedro Miguel, about 32 miles from Gatun. There another dam with locks will confine the waters on the south side. Then a descent will be made by means of one lift from the 85 foot level to the 55 foot level, and a lake will be maintained by two dams at Miraflores, one and a quarter miles south of Pedro Miguel. From this point to sea-level in the Pacific the descent will be made by two locks in a flight at Miraflores.

The depths of the channel between Gatun and Miraflores is to be 45 feet, and below Miraflores in the sea level section of the Pacific, 45 feet at mean tide. The variation in the tides on the Atlantic side averages two feet; on the Pacific side between 20 and 22 feet. The mean tides of the two oceans must be on the same level and as the datum plane (that is the plane from which all differences of level are figured) is mean tide it follows that on the Atlantic side there is a maximum lift between the sea and the lake of 86 feet, when the lake is at its normal stage, and that on the Pacific side there is a maximum difference in level of 96 feet to be overcome between sea level and the summit. The plan provides a channel in the lake that has a minimum of 300 feet bottom width through the Culebra cut, a distance of nine miles and widens toward Gatun to 500 feet for a distance of three miles 800 feet for a distance of four miles and 1000 feet for a distance of 16 miles. Between Pedro Miguel and Miraflores the channel has a bottom width of 500 feet, and this width obtains through the sea level section from Miraflores to deep water in the Pacific.

Limon Bay opens on the sea in such a direction as to be exposed to the violent storms that at times prevail on this coast, and are known as northerns. To protect the channel, as well as to obtain a shelter under which vessels may securely lie during such storms breakwaters are proposed virtually enclosing the bay. The general direction of the northers is west of north, and the breakwater from the shore on the west side of the bay, or Toro Point, is at right angles to this direction. During the dry season, the prevailing winds are from the northeast.

Against Wind and Sea.

Although these winds create a sea, the waves are not dangerous; the east breakwater is proposed to protect the channel against any silting that these seas may create. The west breakwater is to be 11,000 feet long, its top will be ten feet above mean tide, and will have a thickness of fifteen feet.

On the Pacific side there are no storms that necessitate artificial protection for the entrance. But the littoral drift—from east to west—caused such deposits of sediment in the French channel as to cause the constant use of dredges in order that shipping might reach the wharves constructed at that end for the railroad. To prevent this silting, a breakwater is constructed at right angles to the direction of the littoral drift, and extending from the mainland to the islands in the Pacific, about four miles off the coast. This breakwater is being constructed from spoil taken from the Culebra cut.

In order to hold its concession the new Panama canal company continued the work of excavating in Culebra cut until the transfer of property was effected. The United States, upon taking possession, continued this work of excavation, made use of the appliances that had been received from the French and at the same time undertook such preliminary arrangements as seemed necessary for the vigorous prosecution of the work. These preliminary arrangements consisted of sanitary work; draining or oiling pools, cutting grass and brush to prevent mosquitoes from breeding; municipal improvements in the cities of Colon and Panama, as well as within the Canal Zone; providing suitable quarters for employes; enlarging the commissary department of the Panama Railroad, in order to supply the necessaries and comforts of life to those engaged on the work; purchasing the heavy equipment needed for the advantageous and economical prosecution of the work; establishing machine shops for the erection, maintenance and repair of various kinds of machinery; establishing a civil government, with courts, police, fire department, schools and postoffices; double tracking the Panama railroad, thus giving increased facilities for handling spoil; and organizing a purchasing department in the United States. To the care, foresight and thoroughness with which this preliminary work was carried out is due the success that has attended the project.

The work of construction naturally divides itself into four parts, the excavation of the central portion through the summit level; the construction of the locks and dams at either side, the excavation of the channels below the locks to deep water in the ocean; and the reconstruction of the Panama railroad, so far as it is made necessary by the creation of the lake, which obliterates virtually the entire length of the old line.

The excavation of the central portion, mainly a transportation problem, is divided into two parts; the lake section, extending from Gatun to the Chagres river, and the Culebra Cut section, commonly called "the Cut," extending from the Chagres river to the Pedro Miguel locks. Because of the lake, the amount of material that had to be removed in the former section was relatively small, and the excavation there is virtually completed; the total amount removed aggregated 12,384,655 cubic yards. There remain about 150,000 cubic yards of gravel and silt brought down by the Chagres river during its flood stages, to be removed by the dredges.

The difficulties encountered in the excavation through the continental divide are due to the heavy rainfall and the consequently varying geological formation. Provision had to be made to keep the water of the adjacent country from entering the excavated area and for the rapid and thorough drainage of the water due to rains and seepage that collects within the limits of the Cut. Following, as the canal does, the valley of the Obispo river, which has two tributaries entering from each side, it had to be provided with two diversion channels, one on either side, to take care of the waters that would otherwise have flooded the excavation. By these the streams are carried outside of the Cut and flow into the Chagres far enough below the canal to cause no trouble. On the south side of the divide, a dam built by the French across the Rio Grande, created a reservoir for supplying water to the adjacent towns and Panama, and thus, in a measure, the control of these waters was secured, the surplus is carried off by a diversion channel also constructed by the French.

The rains that fall within the excavated area or that seep into it, are cared for by the drainage ditches made during the progress of the work. So far as the excavation is concerned, although the present machinery is more powerful and of greater capacity than that of the French, the methods adopted by the French for doing the work have been used by the Americans. They consist of cuttings in the direction of the length of the Cut, up grade from either end, and sufficiently steep to provide for the proper drainage. As the cuttings are in benches, the greatest amount of material can be removed with the least changing of the plant. There results then a summit within the Cut from which the water flows in either direction. As the bed of the canal is below the water surface of the Chagres, a dike has been left as a barrier at the north end of the Cut to keep this stream out.

All the water that drains north from the summit is carried by gravity to a sump near this dike, and the accumulation is pumped into the Chagres. The water collected to the south of the summit is drained by gravity to the old bed of the Rio Grande, at present through the central culvert of the Pedro Miguel locks.