By this device the waters of the lake may be raised or lowered when reports from the Alhajuela fluvigraph station warn of floods, or when the approaching dry season renders advisable a greater storage supply. The maximum overflow at the spillway may thus always be kept within safe limits, while storage for the dry season may likewise be provided.

Remember, while we walk the next mile, that we are still walking on the dam. An artificial mountain, indeed! Ribboned everywhere with railroad tracks, over which scores of trains run daily, carrying their mites to contribute to the ever growing dam. We again pass around the north side of the hydraulic fill, and approach the factories where the composition that is to go into the locks and into the dam is made.

A most interesting feature is the making, handling and placing of the concrete. The machines with the funnel-shaped nozzles are the concrete mixers. (See second cut, page 49.) The cars standing at the side are run by the third-rail system, so have a care. One of the mixers is now tilted and is filling the bucket with concrete. In a very few minutes all the buckets will be filled, and the little cars will go spinning down the track with their loads of sand, water, stone and cement. We shall see later how this material is deposited in the huge molds in which the locks are being cast. There are four of the big mixers on each side of the shed. We will now walk over to the
great concrete locks, where we can see one of them in process of construction. Note the middle wall rising to a height of ninety feet, between the east and west chambers of the locks. (See page 63.) The great cylinder at the base of this wall is one of the three delivery and drainage culverts. This, as you will note, is duplicated in size by culverts in the side walls. The three culverts are eighteen feet minimum diameter and extend the entire length of the walls, or more than three thousand feet.

Above the side walls to the right are the buckets which come from the concrete mixers we visited. These buckets, with their tons of concrete, are hoisted to wire cables attached to steel derricks on either side of the works, and run out on pulleys to the point where the concrete is to be used. They are then lowered, their contents is dumped, and spread by hand. The whole process of delivery involves the labor of a very few men. A daily average of more than twenty-four hundred cubic yards of concrete is thus laid.

A glance at the railroad tracks, regular width, running up into the chambers on either side of the middle wall, will indicate to some extent the proportions of the structure.

The view of the monolith on page 59 shows the culvert with a projecting steel tube. This tube is removed and replaced for another length when the
concrete about it becomes set. The steel framework against the left side of the middle wall is supporting a part of the mold into which the concrete form has been cast.

Looking from the east wall one gets a good view of the upper locks, the concrete gate sills, and in the distance the waters of the Chagres backed up by the elevation of the spillway. The lake will rise almost to the elevation of the wall when the dam is completed.

Again, one gets a fair conception of the proportions of this work by a glance at the opening through the gate sills. Through this opening a railway locomotive may pass. Over these gate sills will swing the heavy steel gates. Had you visited the place in March, 1910, you would have seen the foundation work of this mountain of concrete as reproduced on page 63.

The general plan of the locks and their operation is shown in the cross section diagram, page 58. The inside surfaces of the side walls are perpendicular, while the outside surface rises by steps. At the base these walls are fifty feet thick; at the top, eight feet thick. The middle wall is slightly more than sixty feet thick. As already indicated, the openings at the base of the walls are for delivery and drainage. The culverts are eighteen feet in diameter, and connect by lateral culverts with openings in the floor,
The second chamber in the middle wall, marked \( C \) in the cut, is the drainage gallery; the third, \( B \), will be used for the electrical connections, while the upper chamber, \( A \), will furnish working space for the operators of the machinery used in manipulating the gates and the valves and in propelling boats through the locks.

A ship passing south will enter the first lock at sea level; the gate behind it will then be closed and the first lock filled with water. This will raise the boat to a water level with the second lock, and so on. In passing north through the left series the order is reversed.

The danger of a boat's ramming the gates either by forward or by backward motion is guarded against in several ways. First, the boat will be drawn through the locks by electric locomotives running on the side walls. The stern of the boat will be controlled by two cables with power attachments, so
I. MONOLITHS IN MIDDLE WALL, UPPER GATUN, JULY, 1910
II. GATUN UPPER LOCKS, SHOWING GATE SILLS
that at any point the boat may be brought to a stand. This system of four cables likewise guards against any possibility of the lateral motion of the boat against the side and the middle walls. Second, the gates and the valves are operated by electric power and are as thoroughly under control as is the movement of the boat itself. Third, the higher level is separated from the level next below by two sets of gates. At each flight two barriers are thus provided. Fourth, above the upper gates are two movable dams or drawbridges which can be so manipulated as completely to cut off the water of the lake from the water of the locks.

Commenting on these various provisions against accidents, Commissioner Rousseau said in an address at Denver: "These devices have all been successfully tried, separately, on different locks in this country and abroad, but in no case has it ever been deemed necessary to install all of them in the same work." Referring to the first named safeguard, Mr. Rousseau continues: "Practically all recorded accidents to locks in recent years have occurred through some mistaking of signals between the pilot house and the engine-room while the vessel has been passing through locks under its own steam. To obviate this source of danger, it is proposed to provide on the walls of the locks electric locomotives, which under proper control will tow vessels through the locks,
there being one locomotive on each side of the lock forward and astern, or four in all, vessels not being allowed to move their propellers meanwhile."

The gates are hollow steel structures seven feet thick and sixty-five feet long, and they vary in height and weight from forty-five to eighty-two feet and from three hundred to six hundred tons, respectively. Intermediate gates cut the locks into chambers four hundred and six hundred feet long. As over 90 per cent of the merchant ships of the world are under six hundred feet in length, this arrangement makes possible a great saving of water.

Adequate water supply is a subject of great importance and interest. The November visitor to the Zone who has seen the floods of the Chagres carrying before them trees, houses and bridges, submerging steam shovels, destroying miles of railroad, will never question the adequacy of the water supply. Somebody has said that in the Canal Zone there are two seasons of the year, the rainy and the wet. Still, it rains only occasionally during the months of January, February and March, and during the dry season of 1911–1912 there was very little rain from December first to May first. Decidedly there is a dry season here, and during this period of three months or more the average flow of the Chagres for the past twenty years has been something like six hundred cubic feet per second; while at one time
during that period it reached the very low figure of three hundred feet per second.

Besides the use of water for electrical power, the water supply will be drawn on in three ways — leakage, lockage and evaporation. It is estimated that the loss in these ways will be about three thousand feet per second. When the Chagres flow is at its minimum of three hundred feet per second there is a disparity between loss and supply of 2700 feet per second. The possible net loss in one day would be over 130,000,000 cubic feet, and in one month about 4,000,000,000 cubic feet. It must be remembered, however, in this connection that three hundred feet is the minimum flow of the river itself, and that these figures have not taken into account the discharge of its tributaries below Bohio. The slope of the land on the Isthmus is very sharp, and as a result the minimum flow is reached early in the dry season, and as that season lasts at times for over three months, it is obvious that in an enterprise of such magnitude as the Panama Canal, involving so large a part of the world's commerce, provision must be made against the possibility of any interruption from a shortage of water supply. This contingency is met by the large area, 164 square miles, of Gatun Lake. It provides ample storage capacity — losses from all sources are not likely to lower the lake more than three feet — while the canal will be usable after the lake has been
lowered by five feet. In the very improbable event that future commerce should make demands on the lake beyond its estimated capacity, a dam which might be constructed at Alhajuela would furnish additional storage to be drawn upon in time of need.

On our way to lunch we shall pass the Administration Building of the Atlantic Division, the Commissary and Panama Railroad Depot, and the Y. M. C. A. Clubhouse. We will visit the Isthmian Canal Commission hotel for luncheon. The Jamaican waiter first serves us with soup of a choice variety, then with an A 1 steak, baked beans, mashed potatoes, salad, good bread, genuine butter, apple pie, of the variety mother makes, coffee and ice cream. You may top off the meal with a Gatun cocktail from that amber bottle if you like. Bitter? Well, yes, but you didn’t give us time to explain. The cocktail is a solution of liquid quinine! You will find such a cocktail as this at every I. C. C. hotel.

After lunch let us take a special train across the line of the canal. From Gatun the old line, which long ago was taken up but on which we are to take our imaginary trip, winds its snaky way out through the jungles of the great Black Swamp. To right and left the impounded waters of the Chagres already spread out before us for miles. The cleared passage in the jungles to the right is the line of the canal. Little excavation is necessary here, for the
land to Bohio is practically all below the grade line of the canal.

Take a look at nature now, while we are out of sight of the canal. Over there is a twenty-foot alligator, basking his huge bulk in the sun. Just beyond him are forty or fifty white cranes; wheeling above the water, now high, now low, are many varieties of sea birds, for we can still scent the salt sea. The train dashes into the jungles and we see "fronded palms," ferns, canebrakes, bamboo, wild bananas, lignum-vitæ with its gaudy dress, and myriads of botanical species garbed in purple, pink, red, white and gold. You may not see them, but these jungles teem with snakes, lizards, deer, jaguars, monkeys, wildcats, armadillos, tapirs, wild hogs, sloths and countless varieties of plant and animal life. Here and there a stream penetrated the otherwise impenetrable network of vegetable life to break the monotony of the fast moving panorama. Only at such intervals does one get an adequate notion of the grace and beauty of the tropics of Panama.

Bohio is called, and as our train slows down, the voice of the ever-present vender of bananas is heard, luring the hungry passenger to invest. Just as we pull out from the station, on the right side of the track, there is a funny little structure with a cylindrical brick foundation supporting a miniature house, reached by a long flight of stairs. This is
the Bohio fluviograph station, and the river is the far famed Chagres. This is one of several stations along the river where records are made of the volume of water discharged by it. This one was installed by the French in 1890, and has been in use for more than twenty years. The fluviograph work comes under the Division of River Hydraulics, Meteorology and Surveys. The other three stations along the Chagres are at Gatun, Gamboa and Alhajuela. The importance of measuring the river's discharge has already been indicated. The other work of this division, as its name indicates, is the determination of the amount of rainfall and evaporation, and observations of seismological disturbances.

The table on page 71 summarizes the results of the observations of the Subdivision of Meteorology on the distribution of rainfall on the Canal Zone, showing hourly periods of maximum and minimum rainfall during an average year.

This table will help one to appreciate one of the greatest difficulties with which the Commission has had to contend, as well as the mathematical precision and the scientific method brought to bear on this great engineering proposition.

The station just called is Tabernilla. To the left is the Tabernilla dump. Here millions of cubic yards of dirt from Culebra Cut have been piled up. Had we passed this point in 1910 we should have
## DISTRIBUTION OF RAINFALL

<table>
<thead>
<tr>
<th>Station</th>
<th>Average Total Rainfall in Inches</th>
<th>Total Rainfall from 7 A.M. to 5 P.M.</th>
<th>Maximum Rainfall</th>
<th>Minimum Rainfall</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Amount in Inches</td>
<td>Per Cent of Total</td>
<td>Hour of Maximum</td>
</tr>
<tr>
<td>Cristobal</td>
<td>137.71</td>
<td>67.32</td>
<td>49</td>
<td>1 to 2 P.M.</td>
</tr>
<tr>
<td>Bohio</td>
<td>118.98</td>
<td>83.82</td>
<td>70</td>
<td>2 to 3 P.M.</td>
</tr>
<tr>
<td>Culebra</td>
<td>77.45</td>
<td>64.83</td>
<td>84</td>
<td>2 to 3 P.M.</td>
</tr>
<tr>
<td>Pedro Miguel</td>
<td>77.45</td>
<td>65.22</td>
<td>84</td>
<td>1 to 2 P.M.</td>
</tr>
<tr>
<td>La Boca</td>
<td>56.71</td>
<td>39.67</td>
<td>70</td>
<td>1 to 2 P.M.</td>
</tr>
</tbody>
</table>

(71)
seen dirt train after dirt train going out on this dump with its cargo from the Cut, unloading with its great plow. This plow will unload a dirt train of twenty-one cars, carrying more than six hundred tons of material, in less than fifteen minutes. The train just pulling out from the siding there is a typical labor train, which will carry out on the works some six hundred of the thirty-five thousand employees of the Commission.

Another very interesting piece of work which you could have seen here a little while ago is that of track shifting. Special machinery for this purpose has been put into service. As the track quickly gets out of reach of the edge of the dump, it becomes necessary to shift it. This is not done by taking it to pieces, for not a spike is lifted, not a bolt removed. The machine by which the process is performed is a track shifter. It lays hold of a section of track, picks it up bodily, and puts it in position again with very little ceremony. One of these machines is said to be capable of moving from one to two miles of track a day. It is manipulated by nine men and will do the work of six hundred laborers. There are ten of these big machines in the service of the Commission.

The man you see there with the queer little machine strapped on his back, and the two others just beyond him, are members of the small army whose
business it is to guard the large army of canal diggers against a flank attack of the enemy most dreaded in Panama—the mosquito. One man is spraying the sides of the ditch with larvacide; the other two are burning the grass along an open ditch to prevent the hatching of eggs deposited in these moist places by mosquitoes.

*Mosquitoes*

Figures a and b show the larvae in water. At c is shown the position assumed by the harmless type (Culex) upon alighting, and at d the position of the dangerous one. At e is shown the Anopheles with spotted wings and two hair-like feelers in front; at f the Culex with plain wings and three feelers.
You will note by this time that we are following the valley of the Chagres. The conductor calls San Pablo just as we cross the bridge over this river. To the right there are signs of excavation. We are fast approaching the continental divide, and the shallow excavation observed is really the beginning of the great Cut. Just below San Pablo the railroad crosses the line of the canal and follows that line almost to the Pacific. If you will watch closely, you will see some old French dredges, long ago sunk to the bottom of the channel — silent reminders of the French failure. Such part of the old French machinery as is no longer of use to the Commission is sold to the highest bidder, as so much junk.

But remember that this first part of our trip is an imaginary one. For the route we have covered since leaving Gatun has been submerged for some time, and the people of the little towns we have passed fled long ago to the hills bordering the man-made Gatun Lake. Had we traversed the relocated line from Gatun to Gorgona, we should have seen many of them in their new homes. When warned of the rising floods, one old lady who had lived at Bohio for a half century, so the story goes, expressed, with a religious fervor to be envied by more enlightened Christians, her faith in the promise, "And the waters shall no more become a flood." She was, however, doomed to disappointment, for her
little homestead, like thousands of others in the lake district, is now fathoms under water. The government has reimbursed her for the losses she sustained.

As we pass Gorgona, Matachin, Bas Obispo and Las Cascadas, we are rapidly coming to the crest of the continental divide. At Matachin the Chagres breaks off to the east, and we now leave its valley. In some remote geological age this river found its way through the divide somewhere near Culebra and poured its floods into the Pacific. The final upheaval which gave the Isthmus its present contour diverted the course of the Chagres to the north. Were it not to minimize the work of man, we might compare the present artificial diversion of this river with nature's diversion on the divide.
CHAPTER V

THE BIG CUT

It has already been said that the construction of the canal involved at once the greatest piece of constructive work and the greatest piece of destructive work ever undertaken by man. We have seen something of the constructive work, and we will now descend into Culebra Cut to see the other phase of this great work. We enter the Cut just below Matachin.

Note the solid stone walls on either side. Through this flint-like rock the workers have cut a channel three hundred feet wide at the bottom, and at places nearly two hundred feet deep. The depth of the Cut at various points is indicated in the diagram. In the Cut millions of pounds of the dynamite we saw unloading at Cristobal have been discharged. As we go up the Cut you may witness a blast of several tons which will displace thousands of yards of the granite-like mass, on which the steam shovels are set to work. You will notice at the top of the bank of rock and to the right several queer-looking machines. These are the compressed air drills manipulated by West Indians, and used in drill-
THE PAY CAR AT CULEBRA, JANUARY, 1908
CULEBRA SLIDE, WEST BANK LOOKING SOUTH, NOVEMBER, 1909
ing holes for the dynamite charges. The charges are detonated by means of electric connections, and it is done with such skill and care that accidents in the way of premature discharges, so common in the handling of explosives elsewhere, are now entirely relegated to the past.

As we pass up the Cut to the next point of attraction we may make some observations of interest.

Culebra Cut begins at Bas Obispo and the excavation gradually increases in depth for a distance of about five miles to Gold Hill, where it reaches the maximum elevation of 534 feet on the east bank, 312 feet on the center line, and 410 feet on the west bank. (See diagram above.) At Gold Hill, Culebra, the Pacific slope begins, and the Cut continues down the southern incline to Pedro Miguel, a distance of three miles. While the Cut proper, as the engineers define it, is said to be nine
miles in length, the excavation is continuous from San Pablo to Pedro Miguel, a distance of sixteen miles. The amount of excavation throughout this distance in the Cut is estimated at something near 100,000,000 cubic yards, equivalent to a mound of earth three hundred feet high, three hundred yards wide, and two miles long. The total excavation for the canal is estimated at nearly 200,000,000 cubic yards. You may now extend our little mound two miles farther. To make these figures more concrete, imagine a team of horses and the ordinary one-yard gravel wagon at work moving this dirt an average distance of twenty miles, and you have the size of the job.

You will notice that the banks of the canal on either side are rising higher above us. We are approaching Culebra. The suspension bridge over the canal at Empire hangs high above our track, and still the side walls of the canal are rising. The hills rising beyond Culebra are the famous Gold Hill and Contractor’s Hill. Through these the steam shovels are gradually but surely cutting their way. Many obstacles present themselves, but all are insignificant in comparison to the one in evidence yonder — the famous Culebra slide, which, like the mighty American glaciers of days gone by, is working its way, inch by inch, toward the prism of the canal. It is now estimated that this and other slides involve the removal of an extra seventeen million cubic yards
I. BOTTOM OF CANAL RAISED EIGHTEEN FEET THROUGH PRESSURE OF THE BROKEN EAST BANK, JUNE, 1910

II. CULEBRA CUT FROM CONTRACTOR'S HILL, APRIL, 1910  (84)
of dirt. The bulk just in front of us is only one of many subsidiary slides—the mere breaking off from the main bulk of huge chunks which tumble into the Cut like avalanches, burying steam shovels, cars, locomotives, tracks, everything in their way. There are two kinds of slides; those which slowly and imperceptibly move toward the Cut, such as the largest Culebra slide, covering an area of nearly thirty acres, and the Cucaracha slide, covering an area of about fifty acres; and those that break off and topple over precipitately into the Cut. The latter are insignificant in point of size as compared with the former. The total area involved by the slides in Culebra Cut is one hundred and sixty acres, equal in area to a good-sized farm in the States. The Cucaracha slide began moving in 1884, or twenty-eight years ago.

The Culebra and Cucaracha slides are the most notable among the obstacles to the speedy completion of the work in the Central or Culebra Division. These caused Colonel Goethals to say in an interview in New York that the only significant elements in the uncertainty as to the date of the completion of the canal are the two big slides, and the obstacles growing out of them. The mound of earth there in the middle of the prism and to the left of our tracks is one of these obstacles. The mound is the result of the buckling of the bottom of the prism,
supposed to have been caused by the pressure of the broken east bank.

If you could brave the tropical sun and make the climb to the top of Gold Hill, you would get a splendid view of the Cut, and such an appreciation of the magnitude of the work as you could not otherwise get. Here the canal makers have had to cut through solid rock for a distance of nearly five hundred feet.

By climbing these steps we shall come up into the town of Culebra, and incidentally get, through the muscular sense, a concrete notion of the depth of the Cut. As we come out on level ground we may get a second concrete notion of the magnitude of the work, for it is near the middle of the month, and the pay car has arrived to present "the laborer with his hire." From one end of the Zone to the other this train goes on its errand each month, distributing the earnings of the makers of the canal.

Before we leave this spot, notice the big steam shovels at work below us. They seem almost human when at work. Under favorable conditions the big fellow there will load a Lidgerwood car in about two minutes, and a whole train of cars in less than fifty minutes. Watch him as he dips down for his mouthful of dirt, then watch him hoist the seven or eight tons of clay and rock, swing it over to the car, and deposit it again with less show of effort than would be displayed by a boy with his toy shovel.
A SEAGOING SUCTION DREDGE
I. PEDRO MIGUEL LOCKS LOOKING SOUTH, AUGUST, 1910
II. PEDRO MIGUEL LOCKS LOOKING NORTH, NOVEMBER, 1910

(88)