LOCK AND LAKE SAFEGUARDS.

Accident on Manchester Canal.—The Manchester Guardian of June 22, 1906, has the following:

"Shortly after 8 o'clock last evening a serious accident occurred at the Irlam locks of the Manchester ship canal—the most serious that has occurred since the canal was opened. The steamer Cassia, a vessel of about 700 tons, bound for Manchester with a cargo of sulphur ore, reached Irlam locks in charge of a ship canal pilot, and for some reason that has not yet been given made for the large lock that was being filled for a steamer outward bound, instead of the smaller lock, which was in readiness to receive her. The vessel collided with the lock wall, although she had very little way on her with the impact carried away one of the gates. This set free the water in the locks, and the weight of the water above the other gates caused them to give way. The result was that the water in the higher reach of the canal poured through the lock.

The Cassia had a narrow escape. There were eight or nine feet of water in the lock. It struck the vessel like a waterfall, and it was only by the prompt action of Captain Olgan that she was saved. In an interview last night, the captain said that this was the first time that he had been up the ship canal, and he had left the entire control of the vessel to the pilot. He thought it was almost miraculous that the boat was saved. "We were practically stopped," he added, "when the boat struck the gate, but the gate was carried away and the vessel, meeting the full force of water coming out of the lock, was tossed like a cork. Fortunately I was able to keep her bow on. Had she been struck broadside on, she would have been wrecked. A large vessel was coming from Manchester to enter the same lock, but luckily she was some distance off. The rush of water was felt for a considerable distance, and at the coal tips a quarter of a mile away a ship was torn from her moorings."

What Lock Wreck Means.—In this connection a representative of the Manchester Guardian wrote:

"A visit to the lock early this morning establishes the fact that for a week at least all traffic on the canal must be at a standstill. In the Irlam lock the water is 16 ft. below the normal level; the muddy bottom is in many places exposed, and an abominable stench fills the air; gangs of men are busy preparing for the work of repair, and up till a late hour Mr. J. K. Bythell and other officials of the Ship Canal Company were directing affairs. Everybody able to give information was pledged to secrecy, but certain facts were obtainable. When the Cassia entered the lock, Manchester-bound, she was traveling at normal speed for such a waterway, but from some unexplained cause maintained her headway, and ere the gates behind her could be closed she had crashed into the gates in front. "The force of the impact," said one who was near, "caused a terrific noise, and this din
was repeated shortly after, for the officials on the spot, seeing what had happened, hastened the closing of the hind gates to prevent the inevitable onrush of water. Quickly as the machinery worked, it failed to achieve the purpose desired. The water in the lock, finding an open course to Liverpool the moment the collision occurred, rushed onward in a seething current, and the volume of water on the Manchester side of the lock forced its way through the hinder gates, defying machinery and every restraint.

"The Cassia cleared the gates she had destroyed, but landed on the lock sill, and close by she now remains. The damage to her bow is slight. Coming from Manchester was another steamer, and soon its plight was perilous. The water in the lock is at ordinary times 16 ft. above the level of the water on the Liverpool side of the damaged gates. Very soon the 16 ft. were reduced to a dozen, and then the muddy bottom of the canal became visible, and the steamer was high and dry. For a time the captain expected his vessel to turn turtle, and he was powerless to do anything. Fortunately she swung across the canal, and as the lock emptied the vessel was propped up to prevent her taking too great a list. For some days she must remain for all practical purposes a steamship on dry land, shored up to keep her on even keel."

The stretch of canal affected by the disaster is from two to three miles long. Fortunately, the tremendous onrush of water from the higher to the lower level caused no further calamity.

The Ship Canal Company propose issuing to-day an official statement as to the causes of the disaster. Meanwhile gangs of men, with every possible appliance for quick repair, are being organized for the rectification of the damage. It is intended to work night and day, and it is hoped that in about a week the canal will be again open for traffic.

This was the fourth accident upon the Manchester canal in ten years. Each of the other three also resulted from dangerous collisions with the gates. Yet locks here are separate.

In twelve years on the Cornwall Canal in Canada the gates have been carried away three times.

The Peril at Gatun.—With such a showing and behavior as are recorded in these two accidents just a month apart on the Welland and Manchester, it is in order to examine what occurrences similar to either one would entail at Panama with locks not single and isolated as were the latter, but in flight.

What of the lock ladders at Gatun and Sosa when the inexorable mathematics of mishap bring a steamer crashing through the gates? The conclusion is beyond challenge.
At Manchester in the last accident it was a small vessel with but 1,500 tons of cargo that wrecked the two gates. At Ogdenburg it was a small steamer of but 700 tons that crashed through five gates. The former vessel landed on the sill and the short level was quickly emptied. What will be the commensurate consequences of a vessel with 40,000 or 50,000 tons going through an upper gate of the Gatun flight from the great lake? There is no room, as was seen, for a safe safety dam.

A SWEEP OF DISASTER.

Should the lower gate, say, of the upper lock at Gatun be overrun before the upper gate is closed, it would release a head of water of 28 1-3 ft. into the middle lock. Allow, for example, that the safety dam for the summit level could be set in five minutes. The theoretical velocity of water with a head of 28 1-3 ft. is 43 ft. per second, equal to a rate of 30 miles per hour. In the five minutes, or 300 seconds, needed to get the safety dam set, a weight of over 500,000 tons, including the ship, will be precipitated upon the middle lock. If ships are following close after one another it is possible that there may be a difference of 56 2-3 ft. in the levels of the upper and middle lock, and consequently the velocity, momentum and weight of the torrent will be more than doubled. The ship will become a swift, gigantic catapult in the grasp of water. Reversed engines could avail nothing against this avalanche. In a few seconds the ship would strike the third set of gates, release another 85,000 or 100,000 tons, get an accelerated speed, overwhelm the last set, and dive in a maelstrom of hundreds of thousands of tons, rushing in great waves down the 85-ft. stepped slope.

Without a safe safety dam nothing else can happen either here or at Lake Sosa than that the ship will be seized by the flood, millions of pounds of steel gates and millions of tons of water will hurdle down through the lower gates, tear everything to pieces, bury the flight-wreckage in a fathomless gorge in the marshes, and sweep its devastating way to the sea.

The deep concrete-founded locks must inevitably be eroded by the torrent flowing through and then around. The huge Gatun dam itself would be in almost inescapable peril, because the locks are an integral part of it. Every vessel in the waiting basin and every building and structure between Gatun and the sea in its path would be swept to utter annihilation.
The damage to the canal and locks could not be repaired for years. To refill the Gatun lake would consume nearly a year of itself. The adoption of the lock flight arrangement, which puts so fearful a premium upon an accident, cannot be characterized as other than a most colossal and disastrous mistake. No money should be voted for construction except as the canal is safeguarded by the exact proviso, "Locks in flight are prohibited at Panama."

With the passing of the lock flights will pass also the monster dams.

What can be done to remedy the situation? The analysis of all safety measures brings one back to the living fact—the lock flight cannot be safeguarded, its perils are inevitable. It must go; in that direction alone lies safety. With one separate single Gatun lock of but 29 ft. lift the efficiency of the safety gate system can be much more than doubled by inserting an intermediate gate midway down the lock. To any vessel less than 600 ft. long there would be on entering the far greater safety of having not merely 80 or 100 but at least 400 ft. of water to overrun after breaking through the doubled gates before reaching the extra gate on the same level. Besides, there is ample room for a safe safety-summit dam and well-founded approach piers.

In the case of a vessel larger than 600 ft. there is still far greater leeway allowed by the single full separate lock proposed, than under the Minority's system.

Considering the event of a ship's crashing through all gates, though it is far less likely under the separate single-lock disposition, still it is possible. But the damage would be confined there largely to the lock gates themselves, because there is the further surety of controlling by the right safety dam system.

But even with the low head, though an accident is far less likely, the eventuality must nevertheless be faced of a gate's being knocked out sometime. It is in the absence of serious consequences therefrom, in addition to the smaller likelihood of the event, that the final superiority of the isolated lock type rests.

A Torrent of Death.—Under the experts' design a torrent would tear down into the canal itself, and the ship's waiting basin, while the water escaping in this separated four-lock canal would be caught, and its shock dissipated and absorbed
not in the channel but in the broad lake below. The low slopes on its borders would permit an immense volume of water to be added without a great rise of level. In addition to this lake absorbing and neutralizing the shock, the row of ample sluices especially designed in the barrage to discharge any excess flood, would further prevent undue rise. The consequences from a breaking loose of the upper level, thus guarded against, would be confined almost entirely to the damaged gate and things afloat.

The Three Lake Project made on this principle of isolated locks and low summit level incorporates not six locks, but four locks. The danger here again is therefore, from this elimination of two locks, reduced one-third. The only efficient solution giving a safe plan for the canal is this low head and isolated lock system.

In November, 1907, another complication is bruited—two kinds of gates!

"The gates are to be in duplicate and of the miter type and the rolling gate similar to that now in use on the Ohio River will be substituted for the duplicate set at the lower end of each summit level lock. In addition, there will be provided an auxiliary pair of gates at the lower east end of each flight for use as coffer dams in case it may be necessary to pump out the locks."

The rolling gates increase the hazards but they take up less room than the mitering type and thus help fit the locks to the abbreviated sites. Incidentally they increase the cost several millions.

In the light of these most conspicuous facts it becomes apparent therefore in review that there are five vital technical objections to the Government's lock flight here:

1.—The tier arrangement is the most hazardous possible.

2.—The rocky ridge of Gatun is too narrow for three locks to be themselves properly bedded on solid strata, with their approaches and the safety dam.

3.—The 1,000-ft. locks in flight cannot be lengthened.

4.—The divided lock system is eliminated, with its inherent advantages of water economy, speed in locking smaller vessels and the availability of an intermediate safety gate at sufficient distance that the momentum of a vessel breaking through an intervening gate would be least likely to carry to it.
5.—The locks shown on the drawings sent to the Senate Committee and announced by the Secretary of War in a magazine contribution as 100 ft. wide set an unwise limit to the width, tonnage and fighting power of our battleships, some day to be sorely needed one side or the other of this Isthmus. The locks ought to be 115 ft. wide.

These are plain and unanswerable arraignments.

The existence of an adequate solution is the warrant of criticism. Let but one lock be put at Gatun; make the lift not from ocean level, but from a 33.5-ft. lake impounded exactly as is Lake Panama, which the Minority itself has adopted for the other end, but of double its height. Set the upper Lake Gatun at the 62.5-ft. level, instead of at 85 ft. With only one lock on this Gatun site, the technical objections which hold against the three-lock flight are resolved. One Gatun lock lifting between the levels can be located in Gatun hill, so that the lock proper, the safety devices and both upper and lower approaches will be directly in or on the solid rock. No great back fill of concrete will be needed to buttress the walls, no upbuilding of masonry at lavish expense to secure a solid platform. At once the whole foundation question is settled by nature herself in the then sufficient dimensions of Gatun hill.
CHAPTER XIX.

Chagres Control.

The gigantic dam and the staircase of locks, too big for its site, together make a high navigable lake. But the water is admitted and the lake created only when the dam is practically completed. The lake is so high that it makes a continuous Isthmian railway all but impracticable. This feature will be considered separately. Through the lake there is a channel of "45 ft. minimum depth." But the ruling depth over lock sills is 40 ft., and in the Panama approach there was provided a depth of but 36 or 37 ft. at low tide. Besides these limitations the Sosa Locks have a lift of but "27½ feet each" or 55 feet for the two in flight, while Lake "Sosa" is 65 feet above low tide.

A large ship is thus hampered, having to await a three hour rise of tide. Delays are momentous emergencies.

The 40 ft. on the lock sill in fresh water is the canal's fixed measure of effective available depth. No ships of deeper draft than the lock sill will pass can negotiate the canal. Owing to the difference in density between fresh and salt water a vessel drawing 38 ft. at sea may draw about 39 ft. 4 ins. in the lake, varying with her block coefficient. Hence, the proposed locks will pass a vessel whose load line limit is 38 ft. at sea with but 9-in. margin. This fact ought also to be reflected in the lock experts' design, but the blue print sent to the Senate Committee indicates that nothing is recognized in this direction.

The flow line of the summit lake is 85 ft. above sea level. It would run far up the tributary valleys of the Gatuncillo and Trinidad. On the latter stream surveys have been extended 60 miles by its tortuous course, perhaps 30-odd miles in a straight line, and in three places the rim of the low range between the Trinidad valley and the slope facing the Atlantic is so low that special measures are compulsory to supplement the Gatun dam. In one saddle the natural height is but 86 ft., one foot above the 85-ft. lake level and this is many miles west of Gatun. The lake would extend up the main Chagres river past Gamboa and the mouths of the Palenque and Rio Chilibre beyond. Here it is to be recorded and observed that the hills of the Isthmus are characteristically steep and the valley bottoms flat and swampy. It follows, therefore, that the flow line of a lake at 85 ft. is, in a
horizontal plane on the average only a little distance beyond or outside of the flow line of a lake at 62.5 ft. A lake at 62.5 reaches beyond and covers as does the lake at 85 the mouths of the Palenque and Chilibre beyond Gamboa. Its flow line does not menace any part of the low Trinidad range. Hence, as a receptacle and regulator of floods the lake at 85 performs no office and has no function which the 62.5 lake does not equally perform. It is no better for canal navigation either. Some stress has been laid on the following table of channel widths:

<table>
<thead>
<tr>
<th>Bottom Width</th>
<th>Length</th>
<th>Per Cent of Route.</th>
</tr>
</thead>
<tbody>
<tr>
<td>of Channel.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1,000 feet</td>
<td>19.08</td>
<td>38.4</td>
</tr>
<tr>
<td>800 feet</td>
<td>3.86</td>
<td>7.8</td>
</tr>
<tr>
<td>600 feet</td>
<td>12.29</td>
<td>24.7</td>
</tr>
<tr>
<td>450 feet</td>
<td>0.00</td>
<td>0.0</td>
</tr>
<tr>
<td>300 feet</td>
<td>7.21</td>
<td>14.5</td>
</tr>
<tr>
<td>200 feet</td>
<td>4.70</td>
<td>9.4</td>
</tr>
<tr>
<td>150 feet</td>
<td>0.60</td>
<td>0.0</td>
</tr>
<tr>
<td>Locks and approaches</td>
<td>2.58</td>
<td>5.2</td>
</tr>
<tr>
<td>Total</td>
<td>49.72</td>
<td>100.0</td>
</tr>
</tbody>
</table>

But this is distinctly misleading in its practical application because the proper speed in such a lake area should not be over 9.5 or 10 miles per hour for the best steering control in vessels closely following or passing each other. Such a speed requires surface width more than bottom width for the displacement of the water moved in the ship's path. Owing to the flatness of the Chagres-swamp-valley from Mindi to Bas Obispo, in the lakes there is ample width for a ship's bow wave to get away, and for the water to close readily in at the stern and for vessels to pass at the regulated speed. The question is really one of comparative lengths of lake navigation, as the Culebra section is the same for the 85-ft. level as for a summit plane of 62.5.

In this comparison the lake navigation afforded by a 4-lock canal is longer than in the 85-ft. canal by the distance between the Mindi lock and the Gatun lock, something over two miles. Further there are two less locks. This means much to conditions of navigation.

A lake created by a dam at Gatun at whatever level has several functions—
1.—To sanitize the swamp areas.
2.—To assist in regulating the Chagres.
3.—To reduce the excavation between Gatun and Pedro Miguel.
4.—To create lake navigation for the service of vessels.
5.—To enable floating plant to be employed on excavation and thus minimize unskilled labor.

If the lake be allowed to collect only at the completion of the construction period, it, of course, can perform no sanitizing office during the many years in which the vast labor forces are at work and when sanitation is most demanded. The 85-ft. lake being dependent upon a dam and summit level design, which must indubitably postpone its creation until the great dam is done—ten years hence at least—has absolutely no sanitary value during the construction era.

The regulation of the Chagres by a navigated lake is a desirable and vital function. It resolves best and completely the problem of preventing the silting up of the navigable courses, because the debris of the hills will be deposited far from the navigated tracks at the upper ends of the various valleys and ravines. The lake does more, it acts as a safety reservoir, minimizing currents and absorbing the down-rushing torrents characteristic of the Isthmus.

In connection with this discussion is published a graphic résumé of the hydrology of the Isthmus. The circular diagram shows the record of a decade of wet and dry seasons, as compiled from French observations of rainfall and runoff. It reveals the sequences and suddenness of floods and their short duration. It discloses also their relation to the ordinary regime and to the seasons of drought. It has been demonstrated conclusively that owing to a divergence in results between the American and French observers, who employed different gauging methods, a factor of safety for contingencies should be added to the French totals and averages. The American method gives a smaller flow in the dry season and a larger flow in the wet period, as shown by the following table and by the graphic diagram No. 2.

BOHIO.
Monthly Range, 1900-1901.

| Month   | Company | U.S. | Differ. | Per C’t U.S.
|---------|---------|------|---------|--------------
| January | 2,120   | 2,203| 83      | 3.9          |
| February| 1,080   | 1,062| 9       | -0.7         |
| March   | 749     | 681  | 58      | -7.9         |
| April   | 708     | 652  | 54      | -7.6         |
| May     | 1,620   | 1,670| 50      | -3.1         |
| June    | 2,860   | 3,185| 225     | 11.3         |
| July    | 5,610   | 5,960| 350     | 6.2          |
| August  | 5,260   | 5,880| 620     | 11.7         |
| September | 4,770 | 5,190| 420     | 8.9          |
| October | 7,000   | 8,220| 1,220   | 17.4         |
RETRIEVAL AT PANAMA.

<table>
<thead>
<tr>
<th></th>
<th>Company</th>
<th>U.S. Comm.</th>
<th>Difference</th>
<th>Per C't U.S. Greater</th>
</tr>
</thead>
<tbody>
<tr>
<td>November</td>
<td>6,600</td>
<td>7,540</td>
<td>940</td>
<td>14.2</td>
</tr>
<tr>
<td>December</td>
<td>3,740</td>
<td>4,100</td>
<td>360</td>
<td>9.3</td>
</tr>
</tbody>
</table>

1901:

<p>| | | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>January</td>
<td>1,482</td>
<td>1,508</td>
<td>25</td>
<td>1.6</td>
</tr>
<tr>
<td>February</td>
<td>989</td>
<td>927</td>
<td>62</td>
<td>-5.2</td>
</tr>
<tr>
<td>March</td>
<td>706</td>
<td>624</td>
<td>82</td>
<td>-7.8</td>
</tr>
<tr>
<td>April</td>
<td>588</td>
<td>521</td>
<td>67</td>
<td>-7.8</td>
</tr>
<tr>
<td>May</td>
<td>2,296</td>
<td>2,400</td>
<td>104</td>
<td>4.5</td>
</tr>
<tr>
<td>June</td>
<td>2,790</td>
<td>2,890</td>
<td>100</td>
<td>3.5</td>
</tr>
</tbody>
</table>

Average total 1900 and 1901: 2,828, 3,069, 241, 3.3
Average 9 wet months: 1900 only 4,398, 4,883, 485, 11.
Average 3 dry months: 1900 only 835, 795, 40, 4.7

From this comparison one deduction of special value can be made. This is that there must be allowed in all calculations a margin of safety which for conservative practice must be figured in the least favorable aspect. The French observations were taken over a long period of time. It is wiser to build upon the extended average so obtained and to employ a factor of safety than to count upon a shorter average from the United States Government records.

The Minority submitted an important technical feature at the Gatun lake spillway without providing all that a necessary caution here would demand. This is the second excess which they neglected in their spillway provision.

Diagram No. 3 pictorially presents the facts as to the flow of the Chagres at the main observation stations. It particularly emphasizes the value of the watersheds of the Lower Chagres, of the Gatuncillo and Trinidad and Mindi to the problem of all sufficient lockage water for the future demands of commerce.

An elaborate study of the hydrology of the Isthmus was incorporated into the volume, "Panama Canal Systems and Projects," by the writer and published in September, 1905, and the following conclusions were adduced:

1.—The average yearly wet-and-dry-season flow to be figured on past the ruling points named is:

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Alhajuela</td>
<td>2,484</td>
<td>2,919</td>
<td>966</td>
</tr>
<tr>
<td>Gamboa</td>
<td>3,184</td>
<td>3,837</td>
<td>1,176</td>
</tr>
<tr>
<td>Bohio</td>
<td>4,798</td>
<td>5,340</td>
<td>1,371</td>
</tr>
<tr>
<td>Mindi-Chagres</td>
<td>8,469</td>
<td>10,510</td>
<td>2,020</td>
</tr>
</tbody>
</table>

The above table is from French sources and records, and, as shown, must be used with a factor of safety due to the differences in gauging methods.
MEAN MONTHLY, YEARLY AND SEASONAL DISCHARGE OF CHAGRES RIVER. DIAGRAM NO. 3.
BY LINDON W. BATES.
2.—The flood volumes to be allowed for past critical points are:

<table>
<thead>
<tr>
<th>Location</th>
<th>Maximum cu. ft. sec.</th>
<th>Average cu. ft. sec.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gamboa</td>
<td>99,600</td>
<td>83,000</td>
</tr>
<tr>
<td>Bohlo</td>
<td>140,000</td>
<td>102,140</td>
</tr>
<tr>
<td>Gatun (Bohlo + 75%)</td>
<td>247,800</td>
<td></td>
</tr>
</tbody>
</table>

3.—Floods of over 44,000 cu. ft. per second occur about every 10 years, and last but 48 hours.

4.—Fresheats over 10,000 cu. ft. per second occur 5 times a year on the average, and last 20 hours.

5. The minimum amount of run-off of the whole Isthmus is, for purposes of calculation, 6,000 cu. ft. per second, which, as was seen, is fairly taken as the lowest likely limit of river flow. This volume will practically all pass Gatun.

6.—As to run-off the Chagres valley is normal, and does not differ essentially from another in per cent of run-off to rainfall. Percolation is normal, nor is there any formation which makes the comparative percentage of either surface or underground water at all abnormal.

The 85-ft. project provides for the regulation of this turbulent torrential stream lake regulation only, and precisely such regulation also is afforded by a lake at 62.5—since the flow line of one is so very closely that of the other.

The Lake canal design in addition to its lake provided against Chagres floods at Gamboa, Alhajuela and on the Cano undersluice regulating works like those at Assuan, controlling the vast volume of the Nile. These afforded additional insurance against flood or drought.

Thus the Chagres regulation measures are based upon navigable lake regulation and also what may be termed empty basin control by means of undersluice dams.

The Assuan Dam.—The gifted designer of the Assuan dam, Sir William Wilcocks, C. M. G. and M. I. C. E., thus described his monumental contribution to science:

The Assuan dam is a work of a type which is new in the world. If successful, it will mark an epoch in dam building. There must be sites on the torrential rivers of the arid and semi-arid regions of South Africa, Australia and North America where dams of the type of the one at Assuan will supply a want which has long been recognized. A reservoir dam which will allow the early floods laden with deposits a free and unimpeded passage, and which will afterward capture the comparatively clear waters of the terminal inundations and early percolations, and store them for subsequent use, ought to put new life into many abandoned projects for perennial irrigation. But the provision of perennial
irrigation is not the only object for which this type of dam
may be employed. Provided with its numerous flood open-
ings, it may be looked upon as a weir capable of controlling
the mightiest rivers in flood, just as ordinary weirs control
them in times of low supply; it may be thus utilized for the
regulation of the flood supplies of rivers.

In projecting dams of this type at Cano, Alhajuela and
Gamboa, as well as at Mindi and Sosa Barrages, cognizance
is taken of this inspiring mile-and-a-quarter-wide demonstra-
tion that a continental river may be valved as a waterpipe,
and may as perfectly form its allotted task. The Assuan
dam, however, had as its function to impound a large volume
of clear Nile water, and to let it out gradually during the irri-
gation season, after allowing the early silt-bearing floods
to pass.

Two Methods Compared.—The reversal of this duty was
proposed for the three-lake canal in its Panama sluice dams.
What is here required is to catch and hold the high floods
and by maneuvering the sluices let them run off gradually
and harmlessly.

The 85-ft. project is chained to one mode of Chagres con-
trol. The new proposal has a primary advantage from hav-
ing realized the application of the second fundamental
method in addition. Its superiority lies in applying both
lake regulation and the empty-basin and divided-channel system
in combination.

The fundamental method of equalizing the current in a
flowing stream has been carefully studied abroad, and, to
a lesser extent, in this country. But in general the science
depends on the expanding of cross-sections in the right ratio
to normalize the currents induced by an increase in volume
from affluents.

From Bas Obispo to Pedro Miguel the section of the
canal should show a slight expansion with a view to taking
scientific care of the watershed of the summit section. An
increase of 3% in a standard section at Obispo of 8,000 sq. ft.
will rightly accomplish this desired result of having currents
normal and regular.

Canvass and scrutinize the records of drought and storms
reflected in the tables, the graphic registry of the data gained
by a generation of study, the differences between gauging
methods; take the lowest minima and the highest maxima
and it is not possible to find an hydrologic condition which
this, the combined method of control, does not surmount
with abundant and satisfactory ease. It is not possible to find a day, an hour, a moment, when the currents need be undue or when the lockage supply need be inadequate to pass all the tonnage of all the deepwater canals in the whole world.

Silt Problem Met in 62.5-Ft. Lake.—The silt problem, as it occurs in the Upper Chagres, is met through standard and approved means, by incorporating perfect silt traps, whence the deposit is to be removed by independent and self-loading, self-propelling and self-discharging hopper dredges, such as

are now being used in raising the grade of Galveston, Texas.

It is recognized that a large economy might be effected by leaving out the Alhajuela and Cano dams, and that their sluice gates might not be required for service in a decade or perhaps two. It may even be held that a single large dam at Gamboa of the insubmergible under-sluice type will answer all the flood conditions for their practical regulation and canal navigation, under the severest tests of such deluges as those of 1879 and November, 1906. But the United States should set itself to a perfect work, and to one with every reasonable factor of safety. With the three dams and the 62.5 lake, the nation possesses the instruments by which the
river can be adequately and at all times controlled. It can be governed by any two of them or by the Alhajuela or Gamboa separately without the possibility of harm to the canal or delay to transit. In the contingency of damage from earthquake, from a canal slip or a flood exceeding that of 1879, by possessing these three dams, the control of the Chagres is rendered as certain and precise as human provision can make it. There is in providing three dams no excess of precaution. The goal of solutions and mechanisms should be ideal and the margin of surety should be so great and clear as to lift them high above all intelligent criticism. The combination puts the standard of safety in regulation where no other project can at all rise to it.

In the Nile valley, 500 miles above Cairo, where the rugged hills have closed in to bar the desert, such a dam has been built. Below it stretches to the far sea the Old World granary, the land whose soil has been a treasury. Under this structure holding back its 36,000,000,000 cu. ft. of river, the Nile people are safe and untroubled. Through its gates come measured and controlled the fertilizing waters, and nine millions of Egyptians live under the warrant of the Assuan dam. In the experience of its success no further word is needed in defense of the safety of a project incorporating its construction as an additional feature of flood control, and even this, not with full, but with a normally empty basin above it.

The Gatun Cut-Off.—When a 62.5-ft. lake is made by a low dam of a 29-ft. net head at Gatun it becomes practicable to shorten the canal alignment by a mile and 2,000 ft. (a mile and two-fifths) and to reduce the curvature between Gatun and Bohio. The comparative courses are shown on the drawing herewith. This means an actual shortening of the transit time by an important saving—a time item is worth counting. The three-lake canal incorporated this passage, the sea level and the 85-ft. schemes do not. The profile discloses that this saving of distance, curvature and time may be secured at the price of but a little dredging. What a ship needs especially for lake speed is top width to the navigated section. Then the vessel-made wave has ample room to run away. All the channels across Lakes Timsah and the Great and Little Bitter lakes on the Suez canal, are submerged channels cut through the lake bottoms.
In Lake Timsah there was just such a condition as the Gatun-Bohio section affords. The first navigated course was a roundabout one following the deepest depression of the lake. The Government route in the 85-ft. lake is likewise circuitous. Later a cut-off was made in Lake Timsah and every ship passing directly through, takes it. The very few vessels that stop at Ismailia have naturally to reach it by the old lake channel which opens thither. From a navigation standpoint no navigator would think of taking the long course in this section of the Panama canal, either in the 85 or the 62.5-ft. lake, if the cut-off was opened and buoyed. The failure of experts and Commission to recognize the ship's point of view, in this case also, is in line with all the other defective developments of their project-making at the Isthmus. The Lake Timsah case in the Suez affords a complete parallel, but its cut-off was one comparatively much shorter and hence less advantageous, as well as a very much more expensive matter. Yet its shortening was held of sufficient importance to be incorporated despite the cost.

Another Characteristic Slip.—On page 426 of the Board Report occurs the following:

"Earth Excavation (dredging)—12,960,000 yds. at 35 cts., $3,240,000." This is above the plane of 40 ft.

Now self-evidently this cannot be dredged unless there is water in the lake, 50 ft. of it, or enough to float a dredge over the 40-ft. plane. Hence it follows that this work cannot be begun until the Gatun dam is finished and the 50 ft. of water has accumulated against it. This 12,960,000 cu. yds., which will take a large plant of special dredges two years or more to excavate, must be dug in the "dry," or very seriously delay the completion of the canal. It is another
Gatun, to construction levels, which will not interfere with the railway, provided a small amount of grade raising near the ends is first accomplished, it becomes possible to obviate all dry excavation and employ floating excavators, except at the locks and in the central section between Obispo and Pedro Miguel. The great moment of this provision to minimize unskilled labor has already been strongly impressed.
CHAPTER XX.

THE CULEBRA DIVISION.

The Chagres, running westward, parallel to the backbone of the Isthmus, on its Atlantic side, turns abruptly at Bas Obispo to the north. Here the navigated route meets the Cordillera. Between Bas Obispo and the basin made by setting a lock and dam at Pedro Miguel is the pass of the continental divide, whose lowest point was west of Contractor's Hill. In order to secure a better alignment the French elected to locate their canal bed between Culebra or Gold Hill and Contractor's Hill. The Cerro Culebra is a conspicuous sugar-loaf eminence; being at the place of the deepest cut, its name is broadly attached to the whole central section. At Bas Obispo the height of the river surface above the sea is about 45 ft. at low water. The flow line of an 85-ft. Gatun lake and that of the 62.5-ft. lake are within a short distance of each other, because of the steepness of the Chagres hills.

On the accompanying map the flow line of the 62.5-ft. lake and that of the 85-ft. lake—the 26-meter contour—are both clearly indicated, as well as the profile of the Gamboa gap, dam and the pool for accumulating the silt which may travel down with the river freshets. This would be here provided in both projects.

Can Eliminate Dry Methods.—The spoil dumps left by the French from their sea-level effort are shown in shaded areas; their relation to the channel to be navigated is clear. It is very apparent that when the 62.5-ft. lake is filled to 50-ft. dredges and floating rock-breaking plants have free, safe water access to the north end of the central mass and can attack the whole of the excavations between Bohio and Obispo in dozens of places. They can thus completely there eliminate the dry method, the vast labor forces incident to this, and the severe and crippling handicaps of the nine months' rainy season. They can in addition attack the northern end of the central section, where the rains so adversely affect the steam shovel system to which the government has been exclusively committed in dealing with the central excavation.

It is not the purpose to enter into elaborate details regarding the 8-mile Culebra division. The alignment is
substantially that selected by the French. All American surveys have but demonstrated the soundness of their adoption through these hills, although the centre line of the cut has been shifted slightly to the west at Gold Hill for reasons which will be mentioned later. The whole 8 miles between the Chagres and Pedro Miguel were strewn with French plant of every description, dredges and cranes, excavators, cableways, cars, locomotives, tracks. Barracks are here also and towns like Matachin, Las Cascadas, Emperador (now called Empire and made the canal headquarters), Culebra and Cucaracha or Paraiso.

Here are the American equivalents, steam shovels, cars and locomotives, steam drills, machine and erection shops, repair works, and a most notable array of hotels and hospitals, quarters and buildings for every conceivable use.

_Equipment the French Assembled._—The steam shovels and the attendant cars are kept in such a vivid forefront of this Panama activity that one is apt to forget how much vaster an equipment the French assembled for the canal. Their Chronicle at a similar stage reads:

"We should note first the seven large American dredges which are to do the excavation at the base of the Chagres valley between Colon and Bohio. These are mechanisms altogether remarkable and of great power. Their monthly output each reaches easily 97,500 cu. yds. Then there are three fairly good dredges which work in Colon Port and two others in the Bay of Panama. They are excellent tools, but of a lesser power. Their monthly output can scarcely exceed 65,000 cu. yds."* The dredges of 180 HP., which are destined to do the digging in the valley of the Chagres and up to Bohio and those of the valley of the Rio Grande up to La Boca, are also equal to getting out without any difficulty 65,000 cu. yds. a month.

The number of dredges actually operating at the Isthmus is 99. This number will be brought to 40 when the orders now in course of execution have been filled.

In the list of water transpots, I must specify particularly 10 steam hoppers which take to a distance the spoil of the marine dredges.

Excavators of very different systems have been employed in the Isthmus. Certain contractors praise very much the Osgood steam shovel, which has an effective and great power, and which can dig with its cutters armed with strong teeth not alone stiff earths but rock more or less disintegrated. Unfortunately this apparatus, extremely ingenious as it is, demands very skilled direction, and sometimes repairs very difficult of compassing on the Isthmus, and they have been superseded.

*These very machines rehabilitated after two decades are credited in the official reports of September and October, 1907, with double this French rating! The high record is perhaps explained by the very soft material upon which they are for the time employed.
THE CULEBRA DIVISION.

The greater part of the excavators which have been employed are of the multiple bucket system of Couvreux and Erard.

The number of locomotives for regular service actually engaged at the Isthmus is 169; that of the large cars for earthwork are 4,700; those of the wagonettes De Cauville total the number of 7,000. The tracks for the heavy spoil reach a length of 314 kilometers. The De Cauville tracks are around 180 kilometers. There are a certain number of

OLD FRENCH CARS.

excavating transporteurs at Tavernilla. An important supply of locomotives and of pumps are provided in the stores of the company, to be employed when the depths of the cuttings demand them.

Among the apparatus for loading and unloading we should first mention the two floating cranes of 40 and of 25 tons each which are located, the first at Colon and second at La Boca, for discharging ships. There are 58 light steam cranes. These are entirely insufficient, because of the difficulty which was pointed out of loading the large cars by hand. The company is arranging to increase very materially this part of its equipment. The plant of the workshops per-
mit them to do all the erection and all the important repairs. The foundry below Matachin can handle pieces of a weight of 3,000 kilograms.

There are also in the divers stores of the company provisionings of all sorts, in coal, coke, materials of construction and in repair parts. All kinds of supplies are there, destined, for the most part, to the maintenance and repair of the plant. These supplies are in general judiciously selected. There is to be noted, however, in the stores at Colon a considerable quantity of lime and of cement; 2,200 tons of lime and 2,000 tons of cement, which are already of an ancient date and which do not appear en rapport with actual needs. These materials were provided in view of original works projected at the Colon port which have been abandoned since. The warehouses are well kept up and their suitability seems to be good."

From this recount of the plant, which was everywhere in operation, and the 1,350,000 cu. yds. a month of excavation which the French succeeded in getting out, one can picture the activity which once prevailed on this narrow land width of the Isthmus. The greatest concentration of effort was naturally in the Culebra section, because at that time a sea-level canal was proposed, but the programme of excavation was well carried out simultaneously all along the line. In the Culebra the Americans before 1907 massed almost their whole attack, and here their whole system and achievement may therefore be judged.

A skilled engineer and superintendent from a special mission at the Isthmus supplied the following observations:

"In the first week of February, 1907, there were 63 steam shovels on the Isthmus, weighing, some 45, some 70 and some 95 tons. An attempt to work only about 47 of the 63 shovels was being made. The others were in the yards at Empire or Culebra, or were in the shops being repaired. The distribution of these shovels was about as follows:

From Pedro Miguel to the south side of Culebra cut.............. 7
At Culebra ............................................. 14
At Empire ............................................. 16
At Las Cascadas ...................................... 3
At Obispo ............................................. 5
At Gatun ............................................. 2

47

In the present dry season these shovels were not exceeding an average of 350 yds. per shovel per day. In the wet season they will do not nearly so well, unless circumstances are greatly changed.

The immediate cause of the present low output per shovel, compared with results in the States in this dry sea-
son at Panama, is lack of cars and an apparent lack of system in train dispatching. It is quite a usual sight to see trains standing from 20 minutes to a half hour, waiting for signals.

Looking further for the insignificant output of machines that should be in the dry season, at least, very efficient, it is seen that the dumps are entirely inadequate and badly managed.

January was the red letter month on the Isthmus. All previous American outputs there were distanced. The work was better organized than ever before and everybody, except the men who actually manned and superintended these shovels and knew what they ought to do, was enthusiastic.

The supervisor of shovels at the main section stated that he had not half as many cars as he needed; that the shovels were frequently all of them idle, and that it was a common thing for them to stand hours at a time on this account. He was asked whether he laid the crews of the idle shovels off. No, he did not. They remained on the shovels or were kept busy somehow elsewhere. He could not lay them off. Shovel engineers are paid $210 gold and crane men $125 per month, nearly double the ordinary rate in the States. I saw one 95-ton shovel with the fire pulled, but the crew still on it. The engineer said he had been laid up a week and expected it would be another week before he could do any work.

Another engineer in Culebra cut told me that he had been on the Isthmus eight months and he had not put in an average of two hours real work a day. One engineer has a record of 25,000 yds., the best monthly output of any shovel on the Isthmus to date. (A 95-ton shovel working against a face 15 ft. high in clay, that had been loosened by powder.)

A supervisor of the — — — shovels told me that 240 cu. yds. a day, or 6,000 per month, was a fair average for the shovels on the Isthmus.

The record output for a day's digging of forty machines, he says, is 21,000 yds. He pointed to a shovel on the side of the great cut and said that he had seen that shovel stand one entire week, with a crew on it, waiting for a train. The transportation department is distinct from the operation of steam shovels.

One shovel on the Pedro Miguel section has been nine and a half months in a cut 2,100 ft. long, averaging 8 ft. deep and 30 ft. wide on the bottom. It handled 27,550 cu. yds. in all this time, an average of 2,000 yds. per month. The delay here was due largely to the fact that the rains make it very difficult for these machines to work in the soft clays. Many were unable to work during the rainy season in the upper soft clays, which become fluid mud.

A supervisor at another place pointed out one shovel which he had been able to start January 20. During the entire rainy season it had been idle. The rains begin again in April.
On January 30 I went through Culebra cut and counted 5 out of 14 shovels that were idle during the entire time that I was there. The other shovels were working intermittently. On January 31 I counted 6 entirely idle. I talked with many of the engineers in Culebra and Emperador. They were about a unit in declaring that two or three trains a day of 10 to 15 cars was an average output. The cars used are Western side dumps of 10 to 12 yds. capacity, flats of about 20 yds. capacity, and the old French side dumps. It takes one of the 95-ton shovels about 40 minutes to load the average train. All along the line wherever these machines are working the conditions are the same. At Bas Obispo I saw two operating attended by one train each of three cars (Western side dumps of 12 yds. capacity). The supervisor close to headquarters was the only one on the Isthmus with whom I talked who seemed to think that the Government was doing as well as could be expected and as well as any contractor would do. 

Such was the actual condition ten months ago. The interval has witnessed a complete change of dynasty and a gratifying increase in output. An official report dated October 16, 1907 states that in September, 1907, an average of 38 1/2 steam shovels handled 749,529 cu. yds., 70 per cent. rock and 30 per cent. earth, against 21 1/3 shovels in September, 1906, which excavated 291,452 cu. yds., 64 per cent. rock and 36 per cent. earth. The rainfall of this month in 1907 was nearly double that of the previous year. The increase is to be attributed to more cars and better train service. The largest part of the spoil still goes to nearby dumps.

The close of the dry season, April, 1907, recorded the best Culebra output so far attained—879,527 cu. yds. October, despite rain, has fallen but little short. The total output of this month is stated to have been 1,868,729 cu. yds. But of this 42% was the easiest possible dredging of light sand in front of Colon and seaward of La Boca, where the new channel is exposed to endless resiling and the gain is not permanent. The removal of this 783,404 cu. yds. cost possibly $75,000 while the remainder, 1,085,325 cu. yds.—58%—is chargeable with the monthly outlay of approximately $2,750,000 or about $2.50 per cubic yard. This is five times the average estimate of dry excavation allowed by the experts and three times their allowance for Culebra work. Practically the dry work cost twenty-five times the dredging. It is the steam shovel system which requires the vast labor forces, the Railroad plant and the building, sanitary and miscellaneous expense.
CHAPTER XXI.

CULEBRA CUT.

The original summit of the Culebra cut measured 333 ft. above sea on the centre line, 300 ft. at the lowest place to one side. The French dug it down to 157 ft. A report early in 1907 from one especially fitted to know reads:

"There has been no deepening of the cut below the bottom grade left by the French. The President was misled into thinking that the Culebra had been lowered 65 ft. by the American forces, when, as a matter of fact, only two small narrow ridges carrying some cross-over tracks have been taken out. The ex-chairman in his farewell speech reiterated this deluding assertion. The executive was misled in many other ways, according to current accounts."

A member of the Advisory Board and other Boards, writes to the "Harvard Engineering Journal," June, 1907:

"The question is often asked, when will the canal be completed? The works near Gatun and the cut through the continental divide fix the probable limit. In estimating the duration of the latter it is not uncommon to divide the total volume by the assumed annual output of the whole number of steam shovels provided. This is far from correct, for the real cause of delay is concentrated in about a mile of deepest cutting and the number of shovels possible to employ becomes less and less as the depth increases. Meantime, the greater part of the eight miles of cut will have been completed and much of the plant will have been standing idle. The official estimate of time of completion taking all circumstances into account was nine years and we are now just beginning."

All the work done has been confined to widening the section and removing land slides.

The sliding in the Culebra is thus far confined to the upper red and yellow clays, and is most evident in the high slopes of Gold Hill, though in a smaller way it is taking place also at other points along the cut. This phase of the Culebra problem is receiving considerable attention. The centre line of the cut has been shifted to the west at Gold Hill, so that the sliding clays may be disturbed to the least degree. This throws the line into Contractor's Hill, said to be composed of the hardest material in the divide. Underneath gray-black hardened volcanic mud, water-bearing sands and gravel are visible in some openings which have been made.

Slopes Continually Sliding in.—The south slope of Gold Hill is composed of red clay, and the slopes left by the
French are continually sliding in, just as they did in former times. A slide from the north side of this hill took place not long ago, carrying away the tracks and trestles on the terraces and landing in the cut below. From the face of Gold Hill smaller masses have dislodged recently.

On the south side of the hill, there is now a persistent movement of the slope toward the cut which extends back at least half a mile. The natural incline of this mass is about 6 to 1 for several hundred feet back to the slope line; beyond that the incline rises more rapidly. Great faults in the surface mark this movement all the way back. A steam shovel worked during the daylight hours at the foot of the constantly moving slide in February, 1907, and was withdrawn every evening to avoid being overwhelmed during the night. The "Canal Record" of October 23, 1907, has this "Note of Progress":

"The Cucaracha Slide."

"During the past week the work of removing the material cast in Culebra Cut by the Cucaracha Slide has continued with undiminished energy. Electric arc lights have been erected at the slide and the work has been carried forward day and night with three steam shovels. The effect of this has been to gain slowly but gradually on the slide and it is hoped that within ten days or two weeks the movement of material trains through
It is a comparatively simple matter to excavate the material within a much shorter time than that allowed for the work, even on the supposition that all of it except the clay near the surface must be shattered by preliminary blasting. The whole difficulty attending this part of the construction of
the canal is attached to the removal of the material from the shovels or other excavators to the spoil banks. This problem of transportation is in reality the substance of the problem of building the trans-isthmian canal, and in treating this part of the project the Board realizes and has considered the large amount of railroad track and the extensive transportation organization required for the disposition of the waste material. It is probable, as has been estimated, that not less than three miles of standard track will be required for each shovel employed, making a total of 300 miles of trackage for 100 shovels.

It is to be assumed that 100 shovels are available for continuous work, there being a sufficient surplus above that number undergoing repairs, whenever necessary to maintain the working complement, it can be demonstrated that as much as 20,000,000 cu. yds. of material classed as rock may be annually removed from the summit cut.

The time required to remove this great mass of material, by far the greater part being soft and hard rock, will depend greatly upon the efficiency of the method of operation and the organization of force and plant, all of which must be ultimately the result of most careful consideration of all the factors, including those of climate and character of labor available.

Where does it go? Not to Panama breakwaters to stop the endless dredging of unprotected approaches or to reclamation of the Panama tide lands, making a useful property, of many times in extent the area occupied by the present city itself. The Rio Grande valley is pre-empted for the care of its watershed, whence 8,000 cu. ft. per second must some time run off.

A Riddle and a Mystery.—What a travesty this of pretense at solving the Isthmus problems while leaving spoil distribution, so far as they enlighten, a riddle and a mystery.

It was stated December 17, 1906, that the Culebra spoil is to go to the dams—the dams! There remained to be excavated under the 85-ft. plan 53,800,000 cu. yds. from the Culebra section, to say nothing of over 14 million cu. yds. right adjacent. Nowhere in the International or Commission reports is it told what they propose to do with this spoil. The late chief engineer testified that it would be a good thing to mix it with the mud batter that is to go into the Gatun dam, but he tells not how much. He would also put some "below Bohio," in his testimony before Senate Committee. It is understood that he proposed to haul half each way somewhere from the centre of the great cut. We must assume, in tracing what is intended, that about 27,000,-
CULEBRA CUT.

000 cu. yards are to be carried toward the Pacific. Apparently (p. 245) there go to—

<table>
<thead>
<tr>
<th>Description</th>
<th>Cu. Yds.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Back filling and embankment, Pedro Miguel</td>
<td>300,000</td>
</tr>
<tr>
<td>Dam, Pedro Miguel</td>
<td>1,100,000</td>
</tr>
</tbody>
</table>

This, however, is nearly offset by the excavation from mile 39.60 to 41.47.

The Minority seem likewise to have:

<table>
<thead>
<tr>
<th>Mile 41.47 to 45.08</th>
<th>Cu. Yds.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Excess from Sosa lock</td>
<td>220,000</td>
</tr>
<tr>
<td>Outside the lock</td>
<td>480,000</td>
</tr>
</tbody>
</table>

Total: 6,080,000

The Ancon-Sosa, Ancon-Coroal or Sosa-Coroal and La Boca dams require some 11,697,000 cu. yds. It is unlikely that over 1,280,000 cu. yds. from the above 6,030,000 cu. yds. would go into the dams; around 17,000,000 cu. yds. must go somewhere outside of “Lake Sosa.” Possibly it is intended that part may go into the area east of the Sosa-Coroal dam and be lifted high in the air, providing the drainage of the Juan Diaz and Puente creeks is properly cared for—another thing which the experts overlooked. A considerable area is drained by these creeks, but no provision was apparently made for their run-off. There remain millions and millions and again millions of cubic yards still to go—where? Far to sea by barges? This would be a grave waste of opportunity to make breakwaters to the islands, to stop littoral drift and resulting or to make reclamations, serving useful and valuable commercial or military purposes.

Like the Line Around Lake Baikal.—We have heard much of the French transporting Culebra spoil up hill, but it is not recalled that they were ever guilty of proposing to carry 10,000,000 cu. yds. down hill and then to hoist it into huge 80-ft. dams overhanging Panama or to haul 20,000,000 cu. yds. to Gatun and lift them then growingly to 135 ft. Further we have the new railway embankments of the experts across the arms of Gatun lake. The profile of this extravagant proposal looks much like the line around the shores of Lake Baikal in Siberia—a succession of vast fills, deep cuts, tunnels and bridges and ram’s-horn curves. It will take plenty of dirt and gold to grade this railway around and across Lake Gatun at 85 ft.

Where is the spoil going? An engineer’s report in February, 1907, summarizes:

**Dumps**—“For the Pedro Miguel, Culebra and Emperador sections there are five short, low dumps on the east side of the Panama Railroad tracks between Corozal and Pedro
Miguel. In addition to this there is the La Boca track extension, which has so far absorbed a large portion of the spoil of these sections.

Part of the material from Emperador goes with that from Las Cascadas and Obispo to the short dumps, four in number, scattered between Las Cascadas and Mamei, or to the larger dump which is being extended east of the Panama Railroad into the swamps at Tavernillo. The Bas Obispo cut has two small dumps on the east side of the excavation, not over 1,000 ft. long.

The spoil from the Gatun lock excavation is being put a little distance east of the lock site on a very short but fairly high bank, which, like all the others, has one blind siding on it and accommodates but one train.

The dumps are all too short, all too low, and all so arranged that but one train at a time can be accommodated on them. Thus the minimum of service is obtained from the trains operating, because of the long delays to which these are subject whenever they endeavor to get on to the spoil areas.

Tracks on these are always in bad condition, and are often impassable, especially in the rainy season, because it is necessary to be constantly shifting them on account of the lowness of the dumps. Gangs of 50 to 100 men are contin-
CULEBRA CUT.

uously employed for track moving, where a gang of ten on a properly selected and developed dump would take care of the disposal of five times the material.

Owing also to their shortness, these places accommodate but one small train, and make it necessary for the cars to go in and out at the same point and thus hold all other trains waiting.

Spoil tracks are installed at Corozal, apparently for the new substitute dam across the swamp to Sosa Hill, but the borings for this dam are just begun. One good dump on the tide flats west and south of Panama City, properly arranged so that trains might enter or leave without interference with each other, and with unloading devices of a well studied character, would easily dispose of twice the material that is spoiled now on the fourteen or fifteen dumps and at one-fourth the dumping cost."

It is sufficiently clear that in order to get a record under stress of pressure, the record sought to justify the expectations of the country, no spoil was going to the dams. They are too far away. None was going to the railway embankments around the lake-to-be; none was going to the breakwaters or valuable reclamation; none to raise Colon. Where? Just to the nearest places, without reference to anything but disposing of the output. The putting of tens of millions of cubic yards of spoil into dams and embankments is a very different proposition from the procedure of this record-striving exhibition. The dump at Tavernillo is greatly to be deprecated, from the standpoint of a lake lower than 85 ft., since it may unnecessarily limit the navigated widths. The "Canal Record," September 18, 1907, has this official item:

DUMP-GROUND RECORDS.

The following is a statement of the amount of material handled from the Culebra Cut at the different dump grounds during the month of July:

La Boca .................................................. 90,510 cu. yds., or 12 %
Sosa-Corozal dam ......................................... 42,714 cu. yds., or 5½ %
Corozal .................................................. 62,383 cu. yds., or 8 %
Pedro Miguel ............................................ 32,240 cu. yds., or 4½ %
At inside dumps from Paraiso to Bas Obispo ......... 210,698 cu. yds., or 28 %
Gorgona .................................................. 15,673 cu. yds., or 2 %
Juan Grande ............................................. 48,106 cu. yds., or 6½ %
Mamei ..................................................... 33,471 cu. yds., or 4½ %
Tabernilla ................................................ 218,363 cu. yds., or 29 %

This table shows that there is still being dumped on the inside or those dumps close to the Division, the largest per cent. of the excavated material, the dumps north of Bas Obispo taking only 42 per cent of the total output."