The foregoing table shows a close agreement in average storm rainfall for the entire period at the several stations. Comparison of the figures for each storm will reveal no degree of uniformity nor any indication whatsoever as to the trend of storm intensity. The heaviest catch in each storm appears to be distributed without discrimination, first at one point of observation and then at another. The final result as summed up in the average shows that at all the stations, with the exception of Flamingo, Marco, and Observation Island, where the observations have been comparatively few in number, the mean storm rainfall is between 3 and 4 inches. Moreover, the difference in averages are so small that one may assume without liability to important error that the mean of observations made during any one storm reasonably represents the actual precipitation over the Everglades, and the figures so derived may be used without correction. This refers, of course, to the general storms taking place in the whole area and not to the showers which are of limited catchment area. It is true that one might, with the foregoing data, contrive and construct divers distribution schemes and spectacular weightings, but these would be, after all, an imaginative exercise unwarranted by the data and of no practical value in the conclusions.

It may be said with justification that the final results in the foregoing table are but crude averages; that at some stations the records are numerous and at other stations comparatively few; that records are missing in the several storms, now at one station, now at another, and therefore that the comparatively close agreement of means may be an accident—the algebraic sum of many badly weighted units. The point is sufficiently important to warrant a reasonable test. Therefore the following figures have been derived from thoroughly comparable records, which cover the same periods and in which no records are missing.

Comparison of 65 storms occurring at Orlando, Jupiter, and Fort Myers from January 16, 1899, to October 19, 1910:

	Orlando.	Jupiter.	Fort Myers.
Total fall	231.90	259.63	213.81
Mean	3.57	3.99	3.29

These three stations are located at the points of a triangle which covers the Lake Okeechobee and northern Everglades region. The first sums up the interior catch, the second that of the Atlantic coast, and the third that of the Gulf.

In a similar manner, and by quadrilateral location, the following stations encompass almost the entire district, and the results are the summation of 66 storms, extending from February 20, 1902, to November 22, 1912:

	Clermont.	Malabar.	Miami.	Fort Myers.
Total	206.72	199.41	221.22	203.73
Mean	3.13	3.02	3.35	3.08

The next comparison is a combination of six stations, two north, two east, and two west, consisting of 50 storms, extending from September 1, 1902, to November 22, 1912, which gives the following summation:

	Clermont.	Orlando.	Fort Pierce.	Hypoluxo.	Fort Myers.	Avon Park.
Total	151.25	153.10	152.59	158.36	141.16	160.81
Mean	3.03	3.06	3.06	3.16	2.82	3.20

Extending the comparison to cover all the long-term and continuously maintained stations, the following results cover 54 storms, from September 1, 1902, to November 22, 1912:

	Clermont.	Orlando.	Kissimmee.	Malabar.	Fort Pierce.	Hypoluxo.	Miami.	Fort Myers.	Avon Park.
Total	170.87	172.70	162.19	158.12	167.49	182.46	180.35	155.42	172.93
Mean	3.13	3.21	3.00	2.93	3.10	3.37	3.33	2.87	3.20

A final record includes the station at Arcadia, operation of which was started in July, 1907, and includes 29 storms.

	Clermont.	Orlando.	Kissimmee.	Miami.	Malabar.	Fort Pierce.	Hypoluxo.	Fort Myers.	Arcadia.	Avon Park.
Total	99.51	94.07	89.33	91.11	90.94	87.25	99.86	93.69	94.35	92.13
Mean	3.43	3.24	3.08	3.14	3.13	3.01	3.44	3.23	3.25	3.18

The general uniformity of average storm precipitation will be noted in the foregoing statements. Lest there should be some misunderstanding of their purport, the fact should be emphasized that the actual average values above reported have little or no significance. The whole purpose is to show by relative values, first, that, through a period of years, marked differences in general or extensive storm precipitation as measured at the several rainfall stations are largely compensated; second, that because of this fact the application of a system of weighting results to secure a weighted storm precipitation is not necessary; third, that in the absence of long-term precipitation records in the central Everglades the most reasonable and tenable assumption is that the direct means of all recorded storm catchments represents the general storm precipitation over the entire area. Finally it should be stated that the foregoing conclusions refer only to storm precipitation and not to long-term totals or averages.

EVAPORATION.

The measurement of evaporation is probably the most unsatisfactory and uncertain process in hydrometric work. The many experiments and series of observations that have been made throughout the civilized world apply only to the particular conditions governing each and are almost surely erroneous for every other condition. As the natural phenomena, consisting largely of temperature, wind velocity, barometric pressure, dew point, character of vegetative or other cover, vapor pressure, etc., not only vary from place to place but from hour to hour in the same place, the problem is exceedingly complex. Moreover, some of the factors governing the rate of evaporation are not as well understood nor as accurately measurable as they should be if good results are to be obtained. Therefore the best that can be done without the expenditure of practically unlimited time and money is to select a set of conditions which may roughly approximate the average and apply the results secured with a large measure of discretion.

The observations which have the closest application to the conditions prevailing in the Everglades are those secured at Crowley, La., by the Bureau of Plant Industry, United States Department of Agriculture, under the direction of Dr. Lyman J. Briggs, physicist in charge. These measurements were made from a free water surface in a circular pan 6 feet in diameter, which was sunk in the ground. The water level in the pan was maintained approximately at the level of the ground surface.

The results for the years 1910 to 1913, inclusive, are as follows:

	1910	1911	1912	1913		1910	1911	1912	1913
January	1.45	1.41	1.96	1.57	August	5.40	5.41	5.75	....
February	2.37	2.89	3.00	2.61	September	4.58	4.15	4.17	....
March	3.29	3.95	3.30	2.61	October	4.31	4.39	4.00	....
April	5.66	5.81	4.03	5.10	November	2.68	3.10	2.46	....
May	5.87	5.32	5.69	5.70	December	2.42	2.88	2.10	....
June	5.78	6.89	5.93	....					
July	5.56	5.56	5.08	....	Total	49.37	51.76	47.47	....

According to the foregoing table the annual evaporation at Crowley, La., is about 50 inches, with high months extending from April to August, inclusive. Review of the general climatic conditions at Crowley and in the Everglades region shows that while the two are at some variance, the differences are not sufficiently marked to make very wide departures in monthly evaporation. If the Crowley results apply even approximately to Everglades conditions it is apparent that the assumptions made for original State operations were more than twice too high.

Florida evaporation.—As soon as possible after the beginning of the present investigations, preparations were made to measure evaporation on the Everglades. The complexities of the problem are accentuated there by reason of the varying surface conditions. Lake Okeechobee presents a water surface of 730 square miles. In addition to this there is probably as large an aggregate water surface represented by other lakes and sloughs. At times almost the entire Everglades region is covered with water, and so the conditions vary from comparatively dry to entirely wet. The factors governing evaporation are therefore quite as variable.

In planning the work the commission was greatly assisted by the advice and counsel of Prof. Charles F. Marvin, now Chief of the United States Weather Bureau, and by Dr. Lyman J. Briggs, physicist of the Bureau of Plant Industry, United States Department of Agriculture. It was decided that in view of the unsatisfactory state of the science and the limited time at the commission's disposa!, the most purposeful course would be to secure that which would most nearly represent the average rate of evaporation. This condition appeared to be best satisfied by setting evaporation pans in the wet muck and operating them as has been described in the case of the Crowley observations. By courtesy of the United States Weather Bureau, two standard pans and measuring instruments were loaned to the commission and installed, one near the edge of Lake Okeechobee at Rita and the other near the South New River Canal at Zona. The results which appear in the following table are believed to be higher than the actual evaporation from the Everglades water surfaces and lower than that from the uncovered saw grass surfaces. It is especially to be regretted that the commission was obliged to prepare this report before a complete year of records was collected.

Evaporation at Rita and Zona, Fla.

	Rita.	Zona.
1913.	*Inches.*	*Inches.*
June 21	0.27	
June 22	.16	
June 23	.19	
June 24	.50	
June 25	.21	
June 26	.31	0.13
June 27	.17	.21
June 28	.28	.13
June 29	.21	.15
June 30	.21	
Total	2.51	.62
July 1	.24	.15
July 2	.22	.22
July 3	.19	.16
July 4	.22	.09
July 5	.24	.28
July 6	.18	.24
July 7	.21	.26
July 8	.15	.19
July 9	.23	.20
July 10	.17	.17
July 11	.23	.24
July 12	.19	.22
July 13	.17	.24
July 14	.04	.24
July 15	.26	.26
July 16	.24	.20
July 17	.20	.20
July 18	.19	.20
July 19	.21	.22
July 20	.22	.24
July 21	.24	.16
July 22	.19	.17
July 23	.16	.21
July 24	.22	.23
July 25	.09	.17
July 26	.11	.17
July 27	.24	.21
July 28	.21	.21
July 29	.21	.27
July 30	.19	.24
July 31	.20	.22
Total	6.06	6.48
August 1	.14	.37
August 2	.22	.15
August 3	.18	.08
August 4	.17	.23
August 5	.15	.10
August 6	.11	.06
August 7	.15	.16
August 8	.14	.16
August 9	.22	.22
August 10	.14	.21
1913.	*Inches.*	*Inches.*
August 11	0.20	0.17
August 12	.11	.20
August 13	.17	.20
August 14	.18	.23
August 15	.19	.19
Aug. 16	.22	.13
Aug. 17	.20	.32
Aug. 18	.26	
Aug. 19		.27
Aug. 20		.09
Aug. 21		.09
Aug. 22	.05	
Aug. 23	.21	.00
Aug. 24	.08	.09
Aug. 25	.18	.02
Aug. 26	.04	.18
Aug. 27	.09	.38
Aug. 28	.15	.24
Aug. 29	.13	.09
Aug. 30	.12	.17
Aug. 31	.15	.07
Total	4.35	4.87
Sept. 1	.29	
Sept. 2	.15	
Sept. 3	.18	
Sept. 4	.11	
Sept. 5	.06	
Sept. 6	.03	
Sept. 7	.05	
Sept. 8	.09	
Sept. 9	.21	
Sept. 10	.18	
Sept. 11	.23	
Sept. 12		
Sept. 13		
Sept. 14	.11	
Sept. 15	.12	
Sept. 16	.07	
Sept. 17	.15	
Sept. 18	.07	
Sept. 19	.17	
Sept. 20		
Sept. 21	.13	
Sept. 22	.25	
Sept. 23	.30	
Sept. 24	.20	
Sept. 25	.11	
Sept. 26	.07	
Sept. 27	.11	
Sept. 28	.17	
Sept. 29	.13	
Total	4.52	

The foregoing figures indicate a rate of evaporation similar to that at Crowley, La., during the summer months. Its significance in practical drainage plans will now be considered.

The highest recorded daily rate of evaporation in the above record is 0.50 inch at Rita on June 24; the next highest is 0.37 inch at Zona on August 1. The average rate is much lower. Emphasis should, however, be laid on the fact that so far as the local drainage of land is concerned, the average rate is not significant. As has already been expressed in the discussion of rainfall, the point to be considered is the individual storm. It is the storm run-off that must be carried away without prolonged overflow, and having provided sufficient canal capacity for this the average run-off will be amply provided for. Now during, and shortly after, storms it is apparent that the rate of evaporation must be at its lowest point. As a factor in modifying local storm run-off it is quite negligible. If evaporation on the Everglades were intense as it is, for example, in the Salton Basin of California, it would be a part of wisdom to make some allowances therefor. Inasmuch as on the days of high storm run-off it can hardly exceed and probably never equals 0.01 inch, the amount is relatively too small to warrant any allowance in the practical canal capacities adopted for the Everglades. In the original plans adopted by the State it was assumed that the greater part of the estimated run-off would be eliminated in this way, thereby greatly reducing the estimated necessary capacity of the drainage canals. There is no measure of justification for evaporation allowance in calculating storm run-off canal capacity of drainage ditches and none will be made in this report.

The control of Lake Okeechobee and its utilization as a storage reservoir necessitates consideration of evaporation. The case is unlike that discussed immediately above. In the drainage of lands for agriculture, the manifest effort is to get rid of surplus water. In storage considerations the purpose is to save all the water possible and to use it during dry seasons for navigation, water power, or irrigation. Therefore, in any such scheme due allowance must be made for that portion which is lost by evaporation. Evaporation losses are practically continuous and cumulative. It will therefore be necessary to determine what, if any, effect on ultimate storage utilization, evaporation will produce. Of course, no finally adjusted determination is possible because no adequate measurements have been made in the Everglades. Therefore, it will be necessary to make certain assumptions which shall be so conservative as to render safe the final conclusions.

Available information has already been set forth. Undoubtedly the recorded evaporation at Crowley, La., is not precisely the same as that which takes place in the Everglades. Nevertheless, the similarity of climatic and physiographic conditions, together with the relative agreement of the few coincident observations that have been recorded in both places justifies the assumption that the differences in rate of evaporation may not be large. If it be assumed in the present calculations that they are the same, and if the final results be interpreted broadly, the results should be satisfactory. Accordingly, the evaporation standards herein adopted are the monthly means of the results recorded at Crowley for the years 1910 to 1912, inclusive, averaged with a combination of the Crowley and Everglades records for the year 1913.

Examination of Table 1 (see pp. 19–22) containing the records of monthly rainfall for the past 25 years at the long-term stations surrounding the Everglades shows that the year 1898 is the lowest in the period. This year, therefore, presents the most severe evaporation loss conditions yet recorded. Estimates based on that year will certainly be conservative for any other year of record and the future will rarely, if ever, produce a year in which the rainfall is less.

In comparing evaporation with rainfall in any particular year, it is not sufficient to use that year alone because the hold-over storage or the rainfall in the year previous and in the year subsequent will usually affect the conclusions. The years 1897 and 1899 were years of large rainfall. To use these years in connection with the minimum year of 1898 would possibly make the result appear more favorable than true conservatism would warrant. Therefore, it will be assumed that the years previous and subsequent to the year of 1898 are years of average precipitation. Following the course of procedure, above discussed, the elements entering into the estimate are as follows:

	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
Evaporation	1.59	2.72	3.28	5.15	5.64	6.20	5.75	5.15	4.35	4.23	3.75	2.47
Rainfall, 1898	0.26	1.10	1.31	0.61	1.53	2.18	7.26	10.58	4.69	7.75	1.01	2.14
Mean rainfall	2.68	2.76	2.17	2.40	4.46	7.73	6.72	6.81	8.06	5.80	2.17	2.11

The foregoing factors have been plotted as mass curves on the accompanying diagram, entitled "Relation of rainfall to evaporation on Lake Okeechobee." The ordinates represent vertical inches of rainfall and evaporation. The abscissas represent monthly periods, the first and third being the average rainfall years, while the second is the minimum year of 1898. By this arrangement we have the minimum year set down between two average years. The evaporation curve is, of course, identical for all three years. The diagram shows that the evaporation is always in excess of the rainfall during the year 1898. The difference is, however, comparatively small. Indeed, the maximum excess of evaporation over rainfall, as shown by the longest ordinate between the two curves, occurs in June, 1898, and amounts to 1.4 inches. During a part of the three-year period the rainfall is in excess of the evaporation, and therefore has a certain compensating effect. It will now be necessary to determine what would be the maximum effect of this rainfall deficiency on practical storage evaporation.

One and four-tenths inches on 730 miles of Lake Okeechobee surface equals 2,375,000 cubic feet. The month of June has 2,592,200 seconds. Therefore, the average loss by evaporation for that month will be equivalent to 918 cubic feet per second. As will later be shown, the aggregate discharge from Lake Okeechobee during the low-water season of 1913 through the Three-Mile, North, Miami, and Hillsborough Canals was approximately 2,000 cubic feet per second. It is therefore apparent that if less than half of this amount were stored in the lake in 1898 the surface elevation thereof would have been held practically uniform so far as evaporation loss is concerned. The area tributary to Lake Okeechobee certainly contributes water in the driest seasons equal to at least three times that necessary for compensating evaporation losses. In view of the extreme conservatism used in the foregoing assumptions, it is believed that there need be no hesitation in concluding that in years of high rainfall sufficient water falls directly on the lake to amply compensate evaporation losses; that in the average year there is still an excess of rain; that in the year of minimum rainfall the maximum compensation for such losses is approximately 900 cubic feet per second, and this for only comparatively short periods.

EVERGLADES RUN-OFF.

The run-off characteristics of the Everglades are yet to be precisely determined. The work of this commission would, had it been allowed to continue for a period of years, have furnished a satisfactory basis for close determination. The necessity for an early closing of the investigations has rendered it impossible to present fixed conclusions. It is the commission's desire to urge with all possible emphasis that the honorable board provide liberally for the further maintenance of intensive hydrometric work. The successful drainage of this or any other area can be accomplished only when surplus water is conducted away from the land. It is therefore fundamental that the amount of water that must necessarily be so conducted be well determined. Then, and only then, can a canal system be so proportioned that it will surely fit the requirements. The only way to determine the amount of water is to measure it, and such measurements must be maintained over an extended period. The type of work is different from that of a land survey or the erection of a structure. In such cases completion can be hastened up to a certain degree by increasing the working force. In the determination of run-off, however, the work can progress only as fast as the seasons go by, and there is no assurance that any future season will produce the particular conditions of rainfall and run-off that will permit of rounding up the conclusions on the subject. The honorable board can proceed with intensive hydrometric work with a comparatively small expenditure, and there is no way by which it could expend money with greater ultimate benefit to the State.

The commission submits the foregoing emphatic statement because it has severely appreciated the difficulties occasioned by the lack of such data. It had no expectation in the beginning that it could, in the short period designated in its contract, determine finally the run-off characteristics of the Everglades. That which it did hope to do was to get certain fundamental factors by which it could directly determine with some reasonable degree of accuracy the necessary canal capacities, so that the State could with confidence proceed with its plans, assured that the only changes subsequently necessary would be the minor and inexpensive ones, advisable in consequence of more highly refined run-off data secured in consequence of later investigations. All things necessary to accomplish the purpose were arranged by the commission, but the contract period has not furnished the most necessary factors of all—heavy rains and high flood waters. The entire six months have been practically rainless. Against such a misfortune neither this commission nor any other that might be organized could prevail.

It has therefore been necessary to construct the run-off portion of this report—first, with the few hydrometric facts that could be obtained; second, by taking advantage of every correlated and confirmatory incident that has occurred in the past; third, by generalizing and specializing broadly from experience and observation in other places; and, finally, by approaching all conclusions in a conservative way, making due allowances for all apparently incomplete and unknown facts. The commission believes that its conclusions are as safe as could be made with the data at hand. It presents them with all due confidence and would not hesitate to proceed with the work along the course laid down. In so doing, however, it would reserve the right to pursue hydrometric investigations at least throughout a high-water season and modify its first plans accordingly. Therefore, the commission can not and does not guarantee the correctness of the run-off findings here presented. Such a guaranty would merely be an assumption of infallibility and a violation of truth. It is almost inevitable that further hydrometric studies, which the honorable board is in duty bound to make, will dictate some modifications of this report's conclusions. We think those modifications will be small, but there can be no assurance that they may not be fairly wide. So far as the run-off conclusions in this report are subsequently confirmed by actual data, and only so far, does this commission defend them. This statement can not be made too emphatic.

Unusual run-off factors in the Everglades: There is probably no more difficult place on this continent in which to determine run-off than in the Everglades. Its general inaccessibility, its lack of perceptible grade, its practically unknown geology, the variability of its muck cover, and the unexplored influence of Lake Okeechobee on underground flow, all present grave uncertainties. The underground water problem is an unknown factor; whether through the porous and probably cavernous limestone that underlies the Everglades the waters of Lake Okeechobee have access, and if they do, how extensive is their journey, are vitally important points which will require years of study and observation. More important than all else, however, is the fact that in the day when Everglades muck is drained and cultivated the rate at which it will give up its water into canals and ditches will be markedly different from that which now prevails. The virgin muck is a coarsely fibrous substance; after cultivation has taken place for several seasons it becomes a fine-grained soil of almost unexampled productivity. Thus the run-off factors that we are now able to determine will, after cultivation, not apply to the new conditions. Happily there is every evidence that the soil will be more retentive of water after cultivation than it is now. Therefore the canals that will be necessary to drain the Glades in the first instance will be ample for subsequent conditions. In view of all of the above, let no one vainly imagine that this report or the report of any commission similarly instructed can be the last word on the subject. On the contrary, such a report can be only the beginning of information. Patient and continuous study by the State's officers, and especially by the farmer, must proceed for a generation. Concerning all soil, the farmer has much to learn, but especially concerning muck soil. This commission in its goings about the Everglades has gathered from old residents and from apparently reputable observers and experimenters more contradictory information about muck than the commission's members have confronted about any other subject in all their professional lives. Confusion seems to be unbounded, and about every disputed point there turns a factor affecting run-off.

Plan of hydrometric investigations.—In laying out the work of measuring run-off the two familiar Everglades problems presented themselves, viz, control of Lake Okeechobee and the local drainage of muck lands. For the first it became necessary to determine the amount of water contributed to Lake Okeechobee; for the second the need was to ascertain the relation of rainfall to run-off in the Everglades. Obviously the most direct way to measure the amount of water flowing into a lake is to observe the flow of its tributaries and apply a determined factor to the area that contributes directly. This course proved impossible in the present instance because the directly contributing area was not determinable in the time and with the funds available to the commission. More important than this, however, was the fact that the streams tributary to the lake, and especially the principal one, Kissimmee River, afford no suitable measurement section where the channels are sufficiently uniform and the banks are high enough to carry the extreme floods. Therefore it became necessary to determine this factor from the other end, viz, to measure the water flowing out of well-defined channels from the lake. Accordingly measurement stations were established at the heads of the four canals leading from the lake—Three-Mile, Miami, North New River, and Hillsborough. The canal last named has not, at the date of writing, been cut through to the coast, yet, as figures subsequently given will show, it has a large discharge, the water probably flowing out over some of the lower glades or into convenient sloughs. All of the discharge from the lake up to the point of broad overflow is measured at these stations, except the unknown but probably relatively constant amount that seeps out to the south underground.

The amount of water discharged from Lake Okeechobee is shown by Table No. 4.

TABLE NO. 4.—*Discharge from canals leading from Lake Okeechobee.*

[Cubic feet per second.]

Date.	Three-mile Canal.		South New River Canal.		North New River Canal.		Hillsborough Canal.		Total from lake.
	Gauge height.	Discharge.	Gauge height.	Discharge.	Gauge height.	Discharge.	Gauge height.	Discharge.	
1913.									
May 15	20.00	708	20.00	555	20.00	625	20.00	437	2,325
16	19.97	678	19.97	546	19.97	616	19.97	435	2,295
17	19.93	685	19.93	532	19.93	605	19.93	432	2,254
18	19.91	679	19.91	524	19.91	600	19.91	431	2,234
19	19.90	675	19.90	521	19.90	596	19.90	430	2,222
20	19.88	669	19.88	514	19.88	591	19.88	429	2,203
21	19.87	666	19.87	510	19.87	588	19.87	428	2,192
22	19.86	663	19.86	507	19.86	585	19.86	428	2,183
23	19.88	669	19.88	514	19.88	591	19.88	429	2,203
24	19.93	685	19.93	532	19.93	605	19.93	432	2,254
25	19.97	698	19.97	546	19.97	616	19.97	435	2,295
26	20.00	708	20.00	555	20.00	625	20.00	437	2,325
27	20.01	712	20.01	560	20.01	628	20.01	438	2,338
28	20.00	708	20.00	555	20.00	625	20.00	437	2,325
29	19.99	706	19.99	552	19.99	622	19.99	436	2,316
30	19.98	702	19.98	549	19.98	620	19.98	435	2,306
31	19.93	685	19.93	532	19.93	605	19.93	432	2,254
Total	....	11,716	....	9,104	....	10,343	....	7,361	38,524
Mean	....	689	....	535	....	608	....	433	2,266
Maximum	....	712	....	560	....	628	....	438	2,338
Minimum	....	663	....	507	....	585	....	428	2,183

TABLE No. 4.—*Discharge from canals leading from Lake Okeechobee*—Continued.

Date.	Three-mile Canal.		South New River Canal.		North New River Canal.		Hillsborough Canal.		Total from lake.
	Gauge height.	Discharge.	Gauge height.	Discharge.	Gauge height.	Discharge.	Gauge height.	Discharge.	
1913.									
June 1	19.95	691	19.95	538	19.95	611	19.95	434	2,274
2	19.92	682	19.92	528	19.92	603	19.92	431	2,244
3	19.87	666	19.87	510	19.87	588	19.87	428	2,192
4	19.84	656	19.84	500	19.84	580	19.84	426	2,162
5	19.84	656	19.84	500	19.84	580	19.84	426	2,162
6	19.80	644	19.80	485	19.80	568	19.80	424	2,121
7	19.81	646	19.81	489	19.81	571	19.81	424	2,130
8	19.84	656	19.84	500	19.84	580	19.84	426	2,162
9	19.87	666	19.87	510	19.87	588	19.87	428	2,192
10	19.93	685	19.93	532	19.93	605	19.93	433	2,255
11	19.97	698	19.97	546	19.97	616	19.97	435	2,295
12	19.86	663	19.86	507	19.86	585	19.86	428	2,283
13	19.96	694	19.96	542	19.96	614	19.96	434	2,284
14	19.93	685	19.93	532	19.93	605	19.93	433	2,255
15	19.87	666	19.87	510	19.87	588	19.87	428	2,192
16	19.86	663	19.86	507	19.86	585	19.86	428	2,183
17	19.78	637	19.78	479	19.78	562	19.78	422	2,100
18	19.75	627	19.75	468	19.75	554	19.75	420	2,069
19	19.75	627	19.75	468	19.75	554	19.75	420	2,069
20	19.71	614	19.71	454	19.71	542	19.71	418	2,028
21	19.68	605	19.68	444	19.68	534	19.68	416	1,999
22	19.67	601	19.67	440	19.67	531	19.67	415	1,987
23	19.63	588	19.63	426	19.63	519	19.63	412	1,945
24	19.59	575	19.59	411	19.59	508	19.59	410	1,904
25	19.58	572	19.58	408	19.58	505	19.58	409	1,894
26	19.59	575	19.59	411	19.59	508	19.59	410	1,904
27	19.58	572	19.58	408	19.58	505	19.58	409	1,894
28	19.59	575	19.59	411	19.59	508	19.59	410	1,904
29	19.61	582	19.61	418	19.61	513	19.61	411	1,924
30	19.64	591	19.64	429	19.64	522	19.64	413	1,955
Total	....	19,058	....	14,311	....	16,832	....	12,661	62,862
Mean	....	635	....	477	....	561	....	422	2,095
Maximum	....	698	....	546	....	616	....	435	2,295
Minimum	....	572	....	408	....	505	....	409	1,894
July 1	19.64	591	19.64	429	19.64	522	19.64	413	1,955
2	19.64	591	19.64	429	19.64	522	19.64	413	1,955
3	19.64	591	19.64	429	19.64	522	19.64	413	1,955
4	19.62	585	19.62	422	19.62	516	19.62	412	1,935
5	19.60	578	19.60	415	19.60	510	19.60	411	1,914
6	19.58	572	19.58	408	19.58	505	19.58	409	1,894
7	19.59	575	19.59	411	19.59	508	19.59	410	1,904
8	19.60	578	19.60	415	19.60	510	19.60	411	1,914
9	19.61	581	19.61	418	19.61	513	19.61	411	1,923
10	19.61	581	19.61	418	19.61	513	19.61	411	1,923
11	19.63	588	19.63	426	19.63	519	19.63	413	1,946
12	19.62	585	19.62	422	19.62	516	19.62	412	1,935
13	19.61	581	19.61	418	19.61	513	19.61	411	1,923
14	19.59	575	19.59	411	19.59	508	19.59	410	1,904
15	19.57	569	19.57	404	19.57	502	19.57	409	1,884
16	19.59	575	19.59	411	19.59	508	19.59	410	1,904
17	19.60	578	19.60	415	19.60	510	19.60	411	1,914
18	19.57	569	19.57	404	19.57	502	19.57	409	1,884
19	19.54	559	19.54	394	19.54	494	19.54	407	1,854
20	19.56	565	19.56	401	19.56	499	19.56	408	1,873
21	19.52	552	19.52	387	19.52	488	19.52	405	1,832
22	19.49	543	19.49	377	19.49	479	19.49	403	1,802
23	19.51	549	19.51	384	19.51	485	19.51	405	1,823
24	19.52	553	19.52	387	19.52	488	19.52	405	1,833
25	19.52	553	19.52	387	19.52	488	19.52	405	1,833
26	19.53	556	19.53	390	19.53	491	19.53	406	1,843
27	19.49	543	19.49	377	19.49	479	19.49	403	1,802
28	19.44	527	19.44	358	19.44	465	19.44	400	1,750
29	19.43	523	19.43	355	19.43	462	19.43	399	1,739
30	19.39	511	19.39	339	19.39	450	19.39	397	1,697
31	19.36	501	19.36	329	19.36	442	19.36	395	1,667
Total	....	17,478	....	12,370	....	15,429	....	12,637	57,914
Mean	....	563	....	399	....	497	....	407	1,868
Maximum	....	591	....	429	....	522	....	413	1,955
Minimum	....	501	....	329	....	442	....	395	1,667

Table No. 4.—*Discharge from canals leading from Lake Okeechobee*—Continued.

Date.	Three-mile Canal.		South New River Canal.		North New River Canal.		Hillsborough Canal.		Total from lake.
	Gauge height.	Discharge.	Gauge height.	Discharge.	Gauge height.	Discharge.	Gauge height.	Discharge.	
1913.									
Aug. 1	19.38	508	19.38	336	19.38	448	19.38	396	1,688
2	19.39	511	19.39	339	19.39	450	19.39	397	1,697
3	19.41	517	19.41	348	19.41	456	19.41	398	1,719
4	19.46	533	19.46	366	19.46	470	19.46	401	1,770
5	19.47	536	19.47	370	19.47	473	19.47	402	1,781
6	19.47	536	19.47	370	19.47	473	19.47	402	1,781
7	19.48	540	19.48	373	19.48	476	19.48	403	1,792
8	19.45	530	19.45	362	19.45	468	19.45	401	1,761
9	19.40	514	19.40	344	19.40	453	19.40	397	1,708
10	19.37	505	19.37	332	19.37	444	19.37	395	1,676
11	19.35	498	19.35	325	19.35	439	19.35	394	1,656
12	19.32	488	19.32	314	19.32	430	19.32	392	1,624
13	19.32	488	19.32	314	19.32	430	19.32	392	1,624
14	19.31	485	19.31	310	19.31	427	19.31	391	1,613
15	19.31	485	19.31	310	19.31	427	19.31	391	1,613
16	19.33	491	19.33	318	19.33	433	19.33	393	1,635
17	19.33	491	19.33	318	19.33	433	19.33	393	1,635
18	19.32	488	19.32	314	19.32	430	19.32	392	1,624
19	19.31	485	19.31	310	19.31	427	19.31	391	1,613
20	19.31	485	19.31	310	19.31	427	19.31	391	1,613
21	19.24	462	19.24	284	19.24	408	19.24	387	1,541
22	19.30	481	19.30	306	19.30	425	19.30	391	1,603
23	19.28	475	19.28	298	19.28	419	19.28	389	1,581
24	19.28	475	19.28	298	19.28	419	19.28	389	1,581
25	19.31	485	19.31	310	19.31	427	19.31	391	1,613
26	19.38	508	19.38	336	19.38	448	19.38	396	1,688
27	19.37	505	19.37	332	19.37	445	19.37	395	1,677
28	19.40	514	19.40	343	19.40	453	19.40	397	1,707
29	19.42	520	19.42	350	19.42	459	19.42	399	1,728
30	19.41	517	19.41	347	19.41	456	19.41	398	1,718
31	19.41	517	19.41	347	19.41	456	19.41	398	1,618
Total	....	15,573	....	10,334	....	13,729	....	12,242	51,878
Mean	....	502	....	333	....	443	....	395	1,673
Maximum	....	540	....	373	....	476	....	403	1,792
Minimum	....	462	....	284	....	408	....	387	1,541
Sept. 1	19.37	505	19.37	332	19.37	444	19.37	395	1,676
2	19.33	491	19.33	318	19.33	433	19.33	393	1,635
3	19.32	488	19.32	314	19.32	430	19.32	392	1,624
4	19.30	482	19.30	306	19.30	425	19.30	391	1,604
5	19.28	475	19.28	298	19.28	419	19.28	389	1,581
6	19.29	478	19.29	302	19.29	422	19.29	390	1,592
7	19.32	488	19.32	314	19.32	430	19.32	392	1,624
8	19.32	488	19.32	314	19.32	430	19.32	392	1,624
9	19.37	505	19.37	332	19.37	444	19.37	395	1,676
10	19.37	505	19.37	332	19.37	444	19.37	395	1,676
11	19.38	507	19.38	338	19.38	448	19.38	396	1,689
12	19.35	498	19.35	325	19.35	439	19.35	394	1,656
13	19.34	495	19.34	321	19.34	436	19.34	393	1,645
14	19.28	475	19.28	298	19.28	419	19.28	389	1,581
15	19.26	468	19.26	291	19.26	413	19.26	388	1,560
16	19.21	452	19.21	276	19.21	400	19.21	385	1,513
17	19.21	452	19.21	276	19.21	400	19.21	385	1,513
18	19.18	442	19.18	267	19.18	390	19.18	383	1,482
19	19.19	446	19.19	271	19.19	393	19.19	383	1,493
20	19.24	462	19.24	284	19.24	407	19.24	387	1,540
21	19.30	482	19.30	306	19.30	425	19.30	391	1,604
22	19.34	495	19.34	321	19.34	436	19.34	393	1,645
23	19.38	508	19.38	338	19.38	448	19.38	396	1,690
24	19.37	505	19.37	332	19.37	444	19.37	395	1,676
25	19.29	478	19.29	302	19.29	422	19.29	390	1,592
26	19.22	454	19.22	279	19.22	402	19.22	385	1,520
27	19.15	433	19.15	260	19.15	381	19.15	381	1,455
28	19.30	482	19.30	306	19.30	425	19.30	391	1,604
29	19.07	407	19.07	240	19.07	359	19.07	375	1,381
30	19.06	404	19.06	238	19.06	356	19.06	375	1,373
Total	....	14,250	....	9,031	....	12,564	....	11,679	47,524
Mean	....	475	....	301	....	419	....	389	1,584
Maximum	....	508	....	338	....	448	....	396	1,690
Minimum	....	404	....	238	....	356	....	375	1,373

For the purpose of determining the amount of water draining from Everglade lands, stations were established as follows: North New River Canal, at a point midway between head and foot, or about 30 miles from the lake (locally designated as "Everglades station" because of the fact that the barge *Everglades* is moored there); North New River Canal, at the lock; South New River Canal, at Zona; Miami Canal, 8 miles above Miami (locally designated as "Barkley's"). The increase of flow measured at these stations over that measured at the head of the canals would, it was originally believed, give the increment due to Everglades run-off. The results are given in Table No. 5.

TABLE No. 5.—*Flow of Everglade canals.*

[Cubic feet per second.]

Date.	North New River Canal at dredge Everglades.		North New River Canal at lock.		South New River Canal at Zona.		Miami Canal at Barkleys.	
	Gauge height.	Discharge.	Gauge height.	Discharge.	Gauge height.	Discharge.	Gauge height.	Discharge.
1913.								
May 12							8.35	365
13			3.05	970	2.25	448	8.35	365
14			3.1	985	2.1	420	8.35	365
15			3.05	970	2.1	420	8.25	355
16			2.95	950	2.1	420	8.2	350
17			2.08	910	2.0	405	8.2	350
18			2.85	920	1.85	383	8.1	340
19			2.85	920	1.65	358	8.1	340
20			2.75	900	1.75	370	8.1	340
21			2.8	910	1.6	353	8.05	335
22			2.5	835	1.45	338	8.05	335
23			2.45	820	1.6	353	7.92	322
24			2.75	900	1.85	383	8.22	352
25			3.2	1,010	2.3	458	8.55	385
26			3.75	1,185	2.85	606	8.6	390
27			3.65	1,150	2.65	549	8.58	388
28			3.5	1,095	2.65	549	8.5	380
29			3.42	1,070	2.5	507	8.45	375
30			3.35	1,050	2.4	481	8.4	370
31			3.25	1,020	2.25	448	8.33	363
Total				18,570		8,249		7,165
Mean				977		434		358
Maximum				1,185		606		390
Minimum				820		338		322
June 1			3.3	1,035	2.15	429	8.26	356
2			3.28	1,030	2.0	405	8.22	352
3			3.25	1,020	2.1	420	8.43	373
4			3.08	980	1.95	398	8.63	393
5			3.05	970	1.95	398	8.73	403
6			3.18	1,005	2.1	420	8.81	411
7			3.15	1,000	2.0	405	8.73	403
8			3.25	1,020	2.15	429	8.75	405
9			3.68	1,160	3.0	650	8.85	415
10			3.8	1,205	3.25	722	8.83	413
11			3.92	1,255	3.3	737	8.8	410
12			3.92	1,255	3.35	752	8.81	411
13			4.05	1,305	3.4	766	8.85	415
14			4.02	1,295	3.46	780	8.8	410
15			3.98	1,280	3.4	766	8.78	408
16			3.88	1,240	3.3	737	8.73	403
17			3.78	1,200	3.3	737	8.7	400
18			3.72	1,175	3.15	694	8.65	395
19			3.58	1,130	3.0	650	8.7	400
20			3.48	1,100	3.0	650	8.83	413
21			3.4	1,065	3.0	650	8.85	415
22			3.35	1,050	2.95	636	8.86	416
23			3.25	1,020	2.9	621	9.05	435
24			3.30	1,035	2.98	644	9.15	445
25			3.35	1,050	3.1	679	9.13	443
26			3.40	1,065	3.15	694	9.17	447
27			3.40	1,065	3.2	708	9.25	448

TABLE No. 5.—*Flow of Everglade canals*—Continued.

[Cubic feet per second.]

Date.	North New River Canal at dredge Everglades.		North New River Canal at lock.		South New River Canal at Zona.		Miami Canal at Barkleys.	
	Gauge height.	Discharge.	Gauge height.	Discharge.	Gauge height.	Discharge.	Gauge height.	Discharge.
1913.								
June 28			3.40	1,065	3.1	679	9.23	453
29			3.40	1,065	3.05	664	9.22	452
30			3.40	1,065	3.05	664	9.17	447
Total				33,205		18,584		12,397
Mean				1,110		619		413
Maximum				1,305		780		455
Minimum				970		398		352
July 1			3.6	1,130	3.05	664	9.12	442
2			3.5	1,095	2.95	636	9.03	433
3			3.42	1,070	2.85	606	8.92	422
4			3.32	1,040	2.65	550	8.9	420
5			3.32	1,040	2.6	535	8.92	422
6			3.22	1,015	2.7	563	9.02	432
7			3.45	1,080	2.8	592	9.2	450
8			3.35	1,050	2.7	563	9.23	453
9			3.1	985	2.8	592	9.3	460
10			3.1	985	2.7	563	9.23	453
11			3.1	985	2.65	550	9.2	450
12			3.0	960	2.5	507	9.15	445
13			3.0	960	2.4	481	9.13	443
14			2.95	950	2.35	470	9.07	437
15			2.9	935	2.3	458	9.18	448
16			2.9	935	2.25	448	9.15	445
17	2.5	552	2.82	915	2.45	494	9.1	440
18	2.5	552	2.75	900	2.5	507	9.05	436
19	2.4	542	2.72	890	2.5	507	9.03	433
20	2.4	542	2.7	885	2.1	420	9.02	432
21	2.4	542	2.68	880	1.9	390	8.95	425
22	2.4	542	2.62	865	1.9	390	8.9	420
23	2.4	542	2.55	850	1.85	383	8.83	413
24	2.4	542	2.5	835	1.8	376	8.82	412
25	2.45	547	2.42	815	1.65	358	8.78	408
26	2.4	542	2.32	795	1.45	338	8.7	400
27	2.4	542	2.28	785	1.55	348	8.65	395
28	2.4	542	2.22	775	1.45	338	8.6	390
29	2.35	537	2.25	780	1.4	334	8.52	382
30	2.3	532	2.4	810	1.4	334	8.5	380
31	2.3	532	2.45	825	1.3	325	8.42	372
Total		8,130		28,820		14,620		13,152
Mean		542		930		472		424
Maximum		552		1,130		664		460
Minimum		532		775		325		372
Aug. 1	2.3	530	2.45	825	1.3	325	8.40	370
2	2.25	527	2.45	825	1.38	333	8.37	367
3	2.2	522	2.75	900	1.85	383	8.4	370
4	2.2	522	2.85	930	1.9	390	8.4	370
5	2.2	522	2.7	885	1.9	390	8.4	370
6	2.15	517	2.95	950	1.9	390	8.4	370
7	2.3	532	3.18	1,005	2.2	438	8.5	380
8	2.3	532	3.15	1,000	2.3	458	8.5	380
9	2.25	527	3.1	985	2.25	448	8.45	375
10	2.2	522	3.0	960	2.1	420	8.4	370
11	2.2	522	2.9	935	2.0	405	8.37	367
12	2.2	522	2.78	905	1.9	390	8.33	363
13	2.1	512	2.65	870	1.85	383	8.25	355
14	2.1	512	2.65	870	1.85	383	8.23	353
15	2.1	512	2.8	840	2.0	405	8.2	350
16	2.1	512	3.05	900	2.1	420	8.37	367
17	2.2	522	3.12	920	2.15	429	8.77	407
18	2.3	532	3.05	900	2.3	458	8.87	417
19	2.3	532	3.1	915	2.35	470	8.85	415
20	2.28	530	3.05	900	2.3	458	8.8	410
21	2.25	525	3.08	910	2.3	458	8.75	405
22	2.58	560	3.1	915	2.65	549	9.02	420
23	2.58	560	3.22	945	2.7	563	9.07	420
24	2.55	557	3.3	965	2.6	535	9.05	423
25	2.62	564	3.3	965	2.5	507	9.08	427
26	2.65	567	3.2	940	2.45	494	9.02	420

Table No. 5.—*Flow of Everglade canals*—Continued.

[Cubic feet per second.]

Date.	North New River Canal at dredge Everglades.		North New River Canal at lock.		South New River Canal at Zona.		Miami Canal at Barkleys.	
	Gauge height.	Discharge.	Gauge height.	Discharge.	Gauge height.	Discharge.	Gauge height.	Discharge.
1913.								
Aug. 27	2.62	564	3.2	940	2.4	481	8.97	415
28	2.6	562	3.2	940	2.3	458	8.88	406
29	2.58	560	3.2	940	2.25	448	8.8	398
30	2.56	558	3.1	915	2.1	420	8.78	396
31	2.52	554	3.0	890	2.2	438	8.72	390
Total	....	16,593	....	28,475	....	13,527	....	12,051
Mean	....	535	....	919	....	436	....	389
Maximum	....	567	....	1,005	....	563	....	427
Minimum	....	512	....	825	....	325	....	350
Sept. 1	2.522	530	3.0	890	2.15	429	8.63	381
2	2.5	552	2.9	865	2.05	412	8.6	378
3	2.49	551	2.85	850	1.95	398	8.57	375
4	2.45	547	2.78	835	2.0	405	8.6	378
5	2.44	546	2.8	840	1.95	398	8.57	375
6	2.44	546	2.8	840	2.1	420	8.78	396
7	2.49	551	3.0	890	2.15	429	8.98	416
8	2.52	554	3.05	900	2.25	448	8.95	413
9	2.5	552	3.12	920	2.3	458	8.9	408
10	2.48	550	3.0	890	2.15	429	8.83	401
11	2.48	550	3.12	920	2.0	405	8.75	393
12	2.5	552	3.25	950	2.35	470	8.80	398
13	2.5	552	3.4	990	2.8	592	8.93	411
14	2.54	556	3.42	995	2.8	592	9.1	428
15	2.5	552	3.3	965	2.7	563	9.03	421
16	2.5	552	3.3	965	2.6	535	9.12	430
17	2.48	550	3.4	990	2.6	535	9.13	431
18	2.49	551	3.38	985	2.5	507	9.07	425
19	2.48	550	3.28	960	2.48	502	9.03	421
20	2.5	552	3.3	965	2.4	481	9.0	418
21	2.5	552	3.32	970	2.45	494	8.98	416
22	2.52	554	3.4	990	2.65	549	8.98	416
23	2.5	552	3.4	990	2.55	521	8.9	408
24	2.46	548	3.6	1,045	2.75	578	8.92	410
25	2.5	552	3.68	1,075	2.9	621	9.0	418
26	2.49	551	3.68	1,075	2.75	578	8.97	415
27	2.42	544	3.62	1,050	2.65	549	8.9	408
28	2.41	543	3.50	1,015	2.55	521	8.88	406
29	2.35	537	3.35	980	2.45	494	8.8	398
30	2.35	537	3.25	950	2.3	458	8.8	398
Total	....	16,490	....	29,425	....	14,771	....	12,190
Mean	....	550	....	981	....	492	....	406
Maximum	....	554	....	1,075	....	621	....	431
Minimum	....	537	....	835	....	398	....	375

Several points of uncertainty should be recognized in connection with the results in Table 5. There has been at all times during the period of investigation a considerable flow from the surface of the Glades into the North Canal and out of the North across to the South Canal. Whether or not all of this water may be truly accounted as Glades drainage is questionable because a part of it may be surface water from the overflow of the Hillsborough Canal.

Conclusions relative to such run-off can not be derived from the South New River Canal and from the Miami Canal records because of the uncertainty concerning the area to the westward. It is apparent that the "western edge of the Everglades" is an imaginary line so far as drainage direction is concerned. Therefore, we are unable to assume any reliable watershed factor with which to compute unit run-off.

In the North Canal, conditions should be more favorable, inasmuch as we may safely assume that the watershed limits extend approximately halfway to the Hillsborough Canal on the one side and to the Miami and South New River Canals on the other. The figures in Table 5 indicate the following:

Drainage area between Lake Okeechobee and dredge *Everglade*, 102 square miles; between dredge *Everglade* and lock, 227 square miles.

Mean flow in cubic feet per second.

	May.	June.	July.	August.	September.
Head of canal	608	561	497	443	419
Dredge Everglades	....	....	542	535	550
Difference	....	....	45	92	131
Difference per square mile	....	....	0.44	0.90	1.28
Dredge Everglades	....	....	542	535	550
Lock	977	1,110	930	919	981
Difference	....	....	388	384	431
Difference per square mile	....	....	1.49	1.49	1.9
Head of canal	608	561	497	443	419
Lock	977	1,110	930	919	981
Difference	369	549	433	476	562
Difference per square mile	1.12	1.67	1.31	1.44	1.71

The foregoing data are not especially significant. While they show a certain increment of flow between the stations named, the condition is abnormal. The canal was practically bank full the entire period, because of the influx of Lake Okeechobee water. It is unquestionable that the Everglades contribution would have been considerably greater had there been any space in the canal into which local drainage water could go.

Southern Louisiana run-off.—Having for reasons above discussed failed to secure flood run-off data in the Everglades, it becomes necessary to use the run-off results observed on a selected area, which compares as closely as possible in physical conditions with the Everglades, as a basis of estimate. Hydrometric work in regions of this character appears to have been generally neglected. It happens, however, that since July, 1909, intensive studies have been maintained by the Office of Drainage Investigations, United States Department of Agriculture, in cooperation with certain plantations in southern Louisiana. The results, which consist of observations of rainfall and run-off, have been compiled to December 31, 1912, and distributed in mimeograph form by that office. They have been used in part for the deductions made in this report.

The only series directly applicable is that made on the tract of the New Orleans Land Co., 1,080 acres in extent, lying within the northern city limits of New Orleans and fronting on Lake Pontchartrain. The outfall from this tract is by way of the New Basin Canal, which borders it on one side. City pumping station No. 7 is located close by and by pump operation the water level of this canal has, during the entire course of the investigation, been kept well below the level of the New Orleans Land Co.'s tract. The run-off measurements have been made over a sharp-crested weir and the head of water over the weir crest has been recorded by an automatic gauge. This arrangement affords a constant record of the discharge from the tract.

The records on other tracts in southern Louisiana, though valuable in general work, do not furnish a continuous history of actual run-off. On those plantations the drainage water is artificially elevated from the canal basins by pumps. These pumps are not started until the water in the basins rises, after storms, to a certain height and operation is discontinued when the water level is again lowered below that point. While these records show the amount of water necessarily removed to maintain a soil sufficiently dry for agricultural operations, they do not constitute a record of actual run-off. They are rather a record of necessary pump operation. The tables show that there are, in some dry seasons, periods of one month or more in which no pumping is necessary. It is clear that during those months some small amount of run-off would, under natural conditions, be derived from these plantations. Moreover, there is no record of the speed with which the water entered the pumping basins from the canals. Pump discharge need not, and undoubtedly does not, conform in rate to that at which the water is contributed to the basin from the land. Therefore, though the records from these plantations are useful in determinations of total run-off, they are quite valueless in all comparative computations in which the time element is an important factor. For this reason only the records secured on the tract of the New Orleans Land Co. are valuable for this investigation.

Consideration will be given only to those periods of record in which heavy rainfall has occurred. The important periods are given in the following table:

Date.	Rainfall.	Run-off.	Date.	Rainfall.	Run-off.	Date.	Rainfall.	Run-off.
1909.	*Inches.*	*Inches.*	1910.	*Inches.*	*Inches.*	1911.	*Inches.*	*Inches.*
June 19	0.00	0.007	May 19	2.83	0.079	Apr. 28	0.00	0.73
20	.23	.013	20	.00	.058			
21	1.26	.023	21	.27	.065	1912.		
22	.00	.029	22	1.57	.082	Mar. 20	.00	.09
23	.00	.028	23	1.25	.114	21	.05	.08
24	1.35	.048	24	.30	.138	22	3.60	.24
25	.00	.057	25	.00	.116	23	2.40	1.09
26	.00	.059	Aug. 25	.00	.035	24	.00	1.78
Oct. 18	.00	.035	26	2.85	.146	25	.00	.84
19	.91	.066	27	.22	.131	Apr. 9	.00	.06
20	1.17	.143	28	.00	.001	10	.15	.06
21	.11	.128				11	.26	.07
22	.00	.102	1911.			12	1.39	.07
Dec. 11	.00	.059	Apr. 7	.00	.08	13	.21	.17
12	2.74	.120	8	4.03	.69	14	2.10	.71
13	.00	.337	9	.00	.98	15	.00	1.42
14	.80	.331	10	.00	.47	16	1.60	1.08
15	.00	.320	Mar. 21	.00	.015	17	.00	.69
			22	3.80	.336	Dec. 2	.00	.03
1910.			23	.00	.623	3	.25	.04
Mar. 9	.00	.053	24	.00	.374	4	.90	.04
10	3.11	.096	Apr. 23	.00	.11	5	1.00	.05
11	.00	.184	24	1.05	.11	6	3.00	.20
12	.00	.50	25	.00	.11	7	.00	1.36
May 17	.00	.000	26	2.72	.58	8	.00	.45
18	.00	.025	27	.50	.81			

The foregoing table records nearly all the heavy storms which produced a high run-off during the period June, 1909, to December, 1912, inclusive. It will be noted that the record in each case is discontinued shortly after the beginning of recedence of run-off. A general perusal of the figures shows the usually observed condition, viz, that a small amount of rain on a well-saturated ground will produce a higher run-off than a larger amount of rain on a ground less saturated. Note, for example, that the 2.74-inch rain on December 12, 1909, fell when the run-off on the previous day was 0.059. The flood wave on the day following this rain represented 0.337. On May 19, 1910, a rainfall of 2.83 on a ground discharging 0.025 produced a run-off of only 0.079. On the other hand, comparison of the storms of December, 1909, and March, 1910, shows that in the latter case the much higher rainfall on a ground apparently nearly as well saturated as in the former does not produce as high a run-off. Therefore it is apparent that many physical conditions other than soil saturation influence the ratio of rainfall to run-off. Of course one of the most important of these conditions is intensity of rainfall. Many similar and instructive circumstances may be discovered in the table.

We are particularly interested in the three highest rates of run-off, viz, March 24, 1912—1.78 inches, April 15, 1912—1.42 inches, and December 7, 1912—1.36 inches. The first two came during a period of unusually copious rainfall, when the entire lower Mississippi Valley was in the midst of an historically violent flood. During the previous December, January, and February the rainfall had been 4.43, 4.48, and 3.70 inches, respectively, while the fall in March previous to the 22d had been 3.27 inches. The soil probably held its maximum amount of capillary water and was, at the outset of the March storm, yielding surplus drainage water to the canal system at the rate of 0.08 inch per day. Six inches of rain fell on March 22 and 23. By dividing the depth by the number of days duration we derive a factor which we will call rainfall intensity. This gives an intensity of 3, producing a run-off of 1.78 inches.

The second heavy storm took place April 12–14, 1912. The same generally wet conditions continued up to the beginning of this storm, the ground held its maximum capillary water and was yielding drainage water in the amount of 0.07 inch per day. From the 12th to the 14th there fell 3.70 inches of rain. We, therefore, have an intensity of 1.25 producing a run-off of 1.42. From December 4–6, 1912, there fell 4.9 inches. The intensity is, therefore, 1.63 and the run-off 1.36 inches per day. This storm took place after three months of rather low rainfall, viz, September, 2.88; October, 1.72; and November, 2.17 inches. On the 1st and 3d of December there fell a total of 0.88 inch. The drainage water yielded by the land to the canals at the beginning of the storm was 0.04 inch per day, or only one-half that which preceded the storm previously discussed. This fact explains in large part the higher intensity factor and lower run-off than those in the April storm.

Summarizing the foregoing we have:

Storm.	Intensity.	Run-off.
1912.		*Inches.*
March	3	1.78
April	1.25	1.42
December	1.63	1.36

EVERGLADES RUN-OFF.

The task now remains to apply these results to the Everglades. Before doing so we must consider and make all possible allowance for the difference in physical conditions in the two places. Land surface grades are practically the same. The Louisiana country is probably somewhat more flat than the Everglades, though the latter has so little grade that it is negligible in these particular considerations. The two places have comates so nearly alike that the difference can not be accounted for in comparing rates of percolation. We have therefore to appraise the muck cover in the two places.

The soil cover on the New Orleans Land Co.'s tract is principally a "tree muck." The upper foot is of fine loose texture, mixed with a considerable portion of roots and fibers. The second foot is similar to the first except that the fibers and roots form a greater portion and the earth contains numerous passages, both vertical and horizontal, which are caused by root decay and by the burrowings of crayfish and mice. Below this is a stratum 3 or 4 inches thick, consisting principally of roots and fibers, with very little soil or muck. Finally there is a stratum of mixed clay and silt through which the rate of percolation is extremely low. These observations, which were made and reported to the commission by Mr. John L. Porter, director New Orleans water filtration plant, were not carried below the clay stratum because, as will be shown below, the purposes of the inquiry were satisfied by the upper 3 feet. It will readily be seen that practically all of the drainage water is discharged from this tract into the canals over the top of the fine clay layer, the root and fiber stratum especially furnishing a ready lateral exit over the whole tract.

Soil cover on the Everglades is a "grass muck," overlying rock in some places and marl at others. In texture it is coarsely fibrous. Over the greater part of the 'Glades it is over 5 feet in thickness, reaching in some places to 12 or 13 feet. To the south the muck thins out and in some places is less than 2 feet deep. As a result of the proposed canalization the water table may be lowered to an average depth of about 3 feet. Heretofore the rate of percolation to be considered concerns only that of the muck.

In order to compare the relative porosity of the soil in the two places, experimental boxes were constructed by Mr. Porter in New Orleans, into which both kinds of muck were placed to a depth of 3 feet. Every precaution was taken to preserve the stratigraphy of the muck and to place it in the boxes at about the same degree of compaction as existed in the natural conditions. The only artificial compaction given to the muck in either case was that occasioned by the shaking which the boxes received in transit on wagons. A screen was placed in the bottom of the box, and this, together with 0.5 inch of gravel and a like thickness of sand supported the overlying muck. An artificial water table 2.5 feet from the surface was created by setting the filters in tight boxes, filled with water to a point of overflow corresponding with the desired height of water table. Overflow outlets were placed in the filters at the muck surface elevation, and water was allowed to flow over the surface at a rate sufficient to run slowly from these overflows. This insured a supply of water quite constant in amount and always sufficient to supply the maximum percolation demanded.

The operation of the two filters showed maximum rates of percolation as follows: New Orleans, 0.9 foot per hour; Everglades, 4.5 feet per hour. It should here be emphasized that the actual rates shown have no significance. The point to be remembered is that under conditions as nearly uniform as can be made the rate of percolation through Everglades muck, as evidenced by the experiments described, is five times that through New Orleans muck. Thus inferentially, Everglades muck, under good drainage conditions, offers little resistance to the passage of the rain from the soil surface to the canals. The Louisiana storm of March 22–23, 1912, certainly would have produced a daily run-off of 3 inches on the Everglades muck had the capacities of the drainage canals been sufficient to carry that amount, and the muck would not, even then, have been taxed to its utmost capacity.

In view of this discussion of Everglades muck, the question will naturally arise in considering the plans presented by this commission—what good purpose will be accomplished by the construction of locks on the now existing canals and those in the process of construction or under contract? Will not the water flow freely around these locks? Though porous, as our experiments show, water does not flow as freely through this muck as it does in an open channel. This is shown by the lock on the North Canal; at this canal there is a wide channel around the east side of the lock through which there is a rapid flow of water and yet there is a decided difference in elevation of water between the upstream and downstream end of the lock; all of the usual operations of closing valves in the upstream and downstream gates of the lock have to be performed before those gates will function in proper sequence.

In a newly dug channel the outflow into adjacent muck lands will be greater in its early use than it will be later after the porosity of its sides and bottom has been diminished by silting up almost to the extent of imperviousness. Lake Okeechobee itself is an illustration of the manner in which this sealing of sides and bottom by unfiltered silt has taken place and left it a reservoir; its shores are no longer sieves since silting up has made them retentive.

Having established this general relation, it now becomes necessary to appraise storm rainfall in the Everglades.

Review of the daily rainfall records during the 14 years from 1899 to 1912, inclusive, at the stations in and surrounding the Everglades shows that the average daily rainfall, as measured at the several stations at the time in operation, may be classified as follows:

In excess of—	Days.	In excess of—	Days.
2.0 inches	12	1.2 inches	50
1.9 inches	16	1.1 inches	59
1.8 inches	23	1.0 inches	69
1.7 inches	24	0.9 inch	98
1.6 inches	27	0.8 inch	123
1.5 inches	35	0.7 inch	171
1.4 inches	41	0.6 inch	234
1.3 inches	46	0.5 inch	322

The determination of the proper capacity of any drainage system is finally a matter of economics. Storms and consequent run-off vary greatly in amount and intensity. Very great storms are comparatively rare; moderate storms are common; small storms usually occur several times each month. To provide a drainage system sufficient to carry, without overflow, the largest storms would require canals of enormous capacity. Their cost, including maintenance, and the great aggregate area which they occupy, which area is, of course, made forever unavailable for agricultural operations, would undoubtedly render the Everglades project impracticable. The question is, therefore, one of dollars and cents. The damage caused by overflows that may occur only once or twice in a year aggregates, in flat country, only a small part of the cost of providing channels large enough to carry those floods. It is a well-established fact that agricultural land is not damaged by occasional overflows if the water does not remain long upon the surface and if the drainage outlets are of sufficient capacity to reduce within a reasonable time the moisture in the soil to a degree favorable for crop growth.

Indeed, many lands are benefited by these overflows. Unless the overflows be too deep or descend with violence, the principal damage is that of temporary inconvenience. Practically every great agricultural region in the humid parts of the United States occupies relatively flat country, subject now and then to overflow. Even in rolling country, the lower lands, usually considered the most valuable for agriculture, have their occasional inundations. Therefore, according to standards that prevail almost universally, a drainage system is not considered inadequate if it fails to carry the largest floods. In the Everglades violent floods are inconceivable; the very flatness of the country and the absence of tributary uplands of high slope makes it certain that overflows occur by the quiet and gradual rise of water, without torrential characteristics. The farmer on the Everglades will instinctively take all of these things into account. His houses, barns, and all structures and equipment subject to more or less damage by water will be raised above and diked off from the temporary overflow of a few inches depth. In the case of houses and stables the requirement is a good one for hygienic reasons alone, even if no overflows occur. Roads and highways would, under intelligent administration, be raised above the general level in any event. Therefore, even during temporary overflows the farmers' means of egress would not be cut off.

In addition to the foregoing considerations there is the fundamental question of overdrainage. A certain amount of moisture must be retained in the soil. It is readily apparent that even under a perfectly adapted drainage system irrigation must be practiced in the Everglades. The high porosity of the soil, the long dry periods, and the plenteous water demands of the crops that are apparently the most profitable in this region, all portend a great irrigation necessity. For these and for many other familiar reasons overdrainage would be fatal. It therefore appears that a drainage system that is too small to carry the highest floods is not only desirable from the financial standpoint, but necessary for agricultural reasons.

In determining upon the best canal capacity, it should be noted that the foregoing figures as to the depth of storms are made up of averages of all observations at the rainfall measurement stations. They hold true for the Everglades as a whole, but it is known that at particular points during each storm the precipitation is much greater than the average. Local catchment in excess of 9 inches per day has been observed. Clearly a drainage system designed to carry the average of, say, 0.6 inches would be inadequate for the area over which the 9-inch storm fell. We know, however, from intensive observations made elsewhere that areas of enormous rainfall occupy narrow limits. It has been observed that great differences in precipitation may occur even at points less than 1,000 feet apart. Here in Florida the records at Clermont, Kissimmee, and Orlando reveal extreme differences in storm catchment, notwithstanding the fact that these places are located in the same general region. These areas of high local precipitation do nevertheless enter into the problem. They raise canal capacity requirements above those which might be considered satisfactory if the maximum catchment did not exceed the average.

Considering all of the foregoing, in connection with the tabulated statement of storm depth and distribution, the commission believes that local drainage capacity equivalent to a depth on the surface of 0.6 inch per day is best suited to the demands and financial considerations. As has already been stated this decision is subject to confirmation by subsequent intensive hydrometric studies, without which no hard and fast conclusions can ever be drawn. This is equivalent to a discharge of 16 cubic feet per second per square mile. This applies to each individual square mile. Of course, by reason of time and distance elements the necessary capacity of the larger canals will be less.

In arriving at this decision that canal capacities must be equivalent to a run-off of 0.6 inch per day, the commission wishes again to emphasize its previous declaration concerning final acceptance of the premises used. It can not in truth and does not in fact guarantee the absolute accuracy of the run-off findings. Nevertheless, the commission has sufficient confidence in them to advise immediate procedure with the plans here proposed.

The figure 0.6 inch per day is essentially derived from two premises: (1) That the Everglades muck is shown by experiment to possess five times the rate of percolation that is shown in the New Orleans muck. From the run-off ratings actually observed in the latter it is manifest that the former should in times of heavy rain deliver run-off equivalent to 3 or 4 inches per day; (2) that, in our judgment, based on financial and agricultural considerations, the Everglades must sustain occasional overflows of short duration, in common with agricultural lands in other regions, both naturally and artificially drained; further, that the rainfall records show that during the past 14 years there have been 234 storms averaging in excess of 0.6 inch per day or about 17 per year, and that this does not take account of the more intense and deep precipitation that prevails over limited areas and which for the time being requires more drainage capacity than that represented by the average.

Now, it may possibly be proved by subsequent observation that the percolation rate shown by experimentation will for various and sundry reasons not persist under natural conditions. We believe that it will, but admit the possibility that the actual figure may be less. Against this possible discrepancy, however, and to compensate any errors involved thereby, we place our allowance of 14 overflow storms per year. This does not necessarily mean that the days of actual overflow resulting from these storms will be limited to 14. Under severe storm conditions the overflow periods might aggregate

30 days or even more, though not in one consecutive stretch. This we believe to be an over-liberal allowance, or in other words somewhat more overflow than the lands should, under ideal conditions, be called on to sustain.

Therefore, if there be any complaint of over-liberality in our percolation factor in the one direction, let the complainant contemplate our over-liberality as to flood sufferance in other direction. We are all persuaded by the weight of evidence as it meets our several interpretations. In the present case the basis for hard and fast conclusions does not exist. The real question is not whether our percolation factor is too high, or our flood sufferance factor is too liberal, but whether, all things being considered, our ultimate capacity factor of 0.6 inches is justified. We believe that, under present state of knowledge, it is.

CONTROL OF LAKE OKEECHOBEE.

The contract of April 30 last, under which we are proceeding, calls for investigations, conclusions, and estimates of cost within the existing drainage district. Since that date the legislature has extended the boundaries of the district, but the change does not materially alter the area to be considered nor require any greater research on our part. At the conference between your honorable body and our chairman, on September 2, you requested that we consider the effect of the proposed lowering of the lake upon the problem of draining the lands in the Kissimmee Valley and give expression to our views relating thereto.

In our judgment the major element in the reclamation of the lands south of Lake Okeechobee is the prevention of their overflow by the flood waters sent down from the Kissimmee watershed. Also, in our judgment, the successful reclamation of a large portion of the lands in the Kissimmee Valley is dependent upon the lowering of the lake, as contemplated in the present project. We believe that the logical way to control the lake is by the excavation of a canal of suitable size to the nearest ocean outlet, and such canal should be excavated along a course where local drainage problems are at a minimum. From so vast a problem of lake control and operation every conflicting detail should be eliminated or simplified. An outlet canal designed solely or primarily for lake control surely presents operation difficulties enough; such difficulties should not be multiplied by distributing them among many canals or by complicating them with local drainage. There is here suggested two types of canal; the first for the discharge of lake water and the control of lake levels, in which local land drainage is merely incidental; the second solely or primarily for agricultural land drainage, in which the discharge of lake water is either limited or is dictated by the urgency of a great flood.

The boundaries of the Everglades drainage district are located arbitrarily. Men may establish and extend lines as suits their fancy, but they can not by so doing change any natural laws or fundamental necessities. Such laws and necessities were established in the area tributary to Lake Okeechobee many thousand years before man conceived such things as boundary lines. Though the northern limit of the drainage district is set between township 36 and 37 south, the necessities of all the land lying to the north still remain. The improvement afforded by the control of Lake Okeechobee and the lowering of its surface can not be confined to the legally established district boundaries. Unless man intervenes to prevent, all of the country in the basins of Kissimmee River and Taylor's and Fish-eating Creeks will be greatly benefited. Moreover, it would be practically impossible to suitably drain these basins without the contemplated improvement in Lake Okeechobee. Even under present conditions, Kissimmee River in time of flood overflows wide areas of country. Drainage of swamp lands means quicker run-off. Therefore drainage can not be accomplished in this valley unless a greater slope and a greater velocity is given to Kissimmee River. Logically the mouth of the river must be lowered, and this is precisely what will be accomplished.

Whenever a city constructs a sewerage system, it builds large outlets to carry the combined flow of all the lateral sewers. These large outlets must be paid for, even as are the laterals. No city ever proposed to tax the owners of property lying along the course of the outlet sewers and leave free from taxation those owners of similar property which happened to lie along the lateral sewers. Such a proposition would be justly condemned and would be promptly reversed by the courts. Each property owner within any city limits is expected to pay his just share for sewer-outlet benefits. This principle is so familiar that no argument is required in its support.

Upon Everglades property the present State plan proposes to place the burden of the outlet sewer and leave free from obligations the beneficiaries in the country to the north and west. The commission therefore declares that the property beyond the district borders tributary to the lake should bear its just outlet-cost burdens; that so far as these outlet costs are concerned the legislature should pass suitable laws extending the district boundaries to the marginal limits of the three streams above mentioned, so that these just burdens may be legally imposed. And with equal emphasis we call attention to the fact that the progressive drainage of these lands benefits the entire acreage of the district even though the immediate effect upon the more remote areas is not physically visible.

We have been furnished with a copy of House Document No. 137, Sixty-third Congress, first session, the same being a report on the improvement of the Kissimmee and Caloosahatchee Rivers for navigation. A 3-foot navigation is recommended for the Kissimmee River, to be obtained at a cost of $37,000 and an annual charge of $6,000 for maintenance. On page 29 occurs the following:

> "If the State's drainage operations are successful and the level of the lake (Okeechobee) is lowered as contemplated, the State should be required to construct at its own expense a lock and dam at the mouth of the Kissimmee River and to dredge at its own expense a channel from this lock to the 6-foot curve in the lake. The height of the spillway of the dam should be placed at about elevation 22. At high-water stages the water would flow around the ends of the lock and dam, but this would have no great effect upon navigation, as the function of the dam is merely to hold up the surface of the water in the lower river to the same elevation as now exists during low-water stages in the lake."

Should Congress adopt this recommendation, the Kissimmee Valley would be barred from realizing any benefit from the lowering of Lake Okeechobee, and the cost to the State of Florida of maintaining the paltry navigation that would be possible in such a channel would not merely consist of the cost of the lock and dam and the channel improvements mentioned in the report of the engineer officers, but it would be equivalent to the value of more than 1,000,000 acres of the richest lands within Florida borders, because they would thus be condemned to remain swamp lands, producing little except reptiles and miasma, whereas they should, under reclamation, have a selling value of at least $100,000,000. A 3-foot waterway for navigation is certainly not worth this price.

LAKE OKEECHOBEE RUN-OFF.

Plans for the control of Lake Okeechobee necessitate as accurate knowledge of run-off from the contributing area as do plans for local drainage in the Everglades. In the former case, however, we are fortunately possessed of fairly accurate information, according to which certain well-attested conclusions may be drawn. Since March 13, 1912, lake levels have been observed at Observation Island by or under the direction of Dr. L. K. Armstrong. Rainfall records in and surrounding the Everglades are available, as has previously been explained. Finally, a lake survey, mentioned in another section of this report, affords the remaining necessary information. This lake survey, with its accurately established contours at elevations 16 and 20 above tide, affords information as to the capacity of the lake between these two levels; and by reason of the uniformity of land slopes above elevation 20 the same capacity factors may, without appreciable error, be applied to this portion up to the point of overflow. The record of lake levels furnishes the factor for determining the volume of inflow or outflow at any time, and the rainfall records demonstrate the underlying cause of lake fluctuations.

Rainfall and lake levels are represented graphically by the accompanying diagram entitled "Record of rainfall in region tributary to Lake Okeechobee and of levels of lake, January 1, 1912–September 30, 1913." The rainfall records are the means of recorded observations at Clermont, Kissimmee, Orlando, Malabar, Fort Pierce, Fort Meade, Bartow, Arcadia, Avon Park, Okeechobee, Observation Island, Ritta, and Head North Canal. The original records of lake level have been modified to compensate for wind effects. Water elevation at any given point in the lake is greatly influenced by velocity and direction of wind. Ordinary daily fluctuations vary from 0.1 to 0.2 foot. The changes of true level in a lake so large as this must, except during a very violent flood, be very slow. Nevertheless, recorded daily variations at Observation Island of 0.3 foot are not uncommon. If this were the true variation it would represent an increase or a decrease of 6,000,000,000 cubic feet. This, in the absence of any well-defined cause, is of course preposterous and must be almost wholly due to wind action. To eliminate in a broad way this element and to give to the record an appearance in keeping with the unquestionable facts the records have been expressed as "progressive averages," i. e., each day's record on the diagram is the mean of that day, the two previous, and the two succeeding days.

The diagram largely relates its own story. Attention is called to two important points. (1) From June 6–11, 1912, rain fell to a depth of 8.04 inches. This occasioned one of the most rapid and extensive lake rises within the memory of those familiar with the region. The maximum level attained was 21.7 feet. Did this storm cause the lake to overflow? If not, it furnishes an acceptable basis for calculation of run-off and storage.