EVERGLADE LAND SALES COMPANY,
EVERGLADES LAND COMPANY,
EVERGLADES SUGAR AND LAND COMPANY
Miami, Florida.

Gentlemen:

The undersigned Board of Engineers was appointed by Mr. V. W. Helm, President of the Everglade Land Sales Company to examine the plans and works projected by the Trustees of the Internal Improvement Fund of the State of Florida, for the reclamation of the Everglades, and to report to you upon the adequacy and probable effect upon the Everglades of these works, with particular reference to the lands sold or controlled by your Companies. The Board has acted upon the following letter of instructions:

LETTER OF INSTRUCTIONS

EVERGLADE LAND SALES COMPANY

Chicago, July 23, 1912.

Mr. Daniel W. Mead,
Mr. Leonard Metcalf,
Mr. Allen Hazen,
Board of Engineers.

Gentlemen:

The State of Florida has undertaken to furnish all necessary main canals for the drainage of the so-called "Upper Everglades." Our Company now owns 70,000 acres, located as shown on the maps which have been furnished you, and we desire to determine whether or not the present system of canals as outlined by the State of Florida is sufficient to take care of the runoff from the "Upper Everglades" as a whole—and particularly of the 70,000 acres owned by us. If not, we desire to ascertain what amplification of the present system will be required to furnish drainage. We desire the Board to determine, in the event the State of Florida does not provide the necessary amplification of the canals as outlined, if it will be possible to dike our present holdings on the north and west in such a manner as to render them practically independent of the remainder of the Everglades, and what additional outlet canals will be necessary under such conditions in order to accommodate the runoff from the area involved.

We desire the Board to furnish us with specific information as to the canals, laterals, ditches, etc., which should be installed by our Company in order to properly drain our specific acreage, assuming that the necessary main canals to tide water will be installed. We desire the Board of Engineers to recommend such additional main canals and laterals as will be necessary for the purpose, and to designate the routes of such canals on maps to be submitted with the report.

Very respectfully yours,

EVERGLADE LAND SALES COMPANY
By V. W. Helm,
President.

FINDINGS UPON QUESTIONS SUBMITTED

In our judgment, the present system of canals as outlined by the State of Florida is not sufficient to take care of the runoff from the Upper Everglades as a whole.

We find that "to ascertain what amplification of the present system will be required to furnish a satisfactory drainage" will require a large amount of study and investigation, together with extended observations and surveys.

It is manifestly unfair that with your relatively small holdings, you should be required to meet the large expense of a full and comprehensive study of the drainage of the entire Everglades, and the Board has, therefore, investigated these matters more particularly with reference to the immediate condition and needs of your property, leaving the more detailed study of the larger problem for future investigation by the State, or by an association of all those interested in the reclamation of the Everglades.

We find that it will be possible to dike your present holdings in such a manner as to make them practically independent of the remainder of the Everglades, and we have determined what additional outlets and canals will be necessary in order to accommodate the runoff from the area involved.

We have, as far as practicable, without undertaking complete investigations and surveys, included in this report specific information as to the canals, laterals, ditches, etc., which should be installed by your Company in order to properly drain your specific acreage, assumming that the necessary main canals to tide water will be installed. Your Board of Engineers has also designated such additional main canals and laterals as will be necessary for the purpose, and, in a general way, the routes of such canals on maps submitted with this report.

GENERAL CONCLUSIONS

Without attempting to analyze and pass upon all of the details of the plans for the reclamation of the Everglades as outlined by the Engineers of the Trustees of the Internal Improvement Fund of the State of Florida, or to offer suggestions as to the lines on which the reclamation of the Everglades should be accomplished, certain conclusions can be drawn from the information secured which may be considered as fairly definite.

Your Board of Engineers has reached the following conclusions concerning the reclamation of the Everglades:

1. The drainage of the Florida Everglades is possible from an engineering standpoint. The various developments along the edge of the Everglades clearly indicate the great agricultural possibilities of the land, and we believe that the value of the land when drained and developed will much more than repay the cost of reclamation.

2. The work already done by the State, and at present definitely projected, is entirely inadequate for the drainage of the Everglades.

3. The canals now under construction and definitely projected will afford a more ready channel for the passage of flood water from the lake into the Everglades, and, while possibly benefiting to some extent the lands adjoining Lake Okeechobee, will undoubtedly aggravate the flood conditions along their lower reaches, both in amount and in duration, with the possible exception of certain lands favorably located in immediate proximity to the outlets of the canals. During dry seasons, the canals will assist materially in the drainage of the lands immediately adjoining them, but the flooding which will follow heavy rains will make the improved conditions during dry weather of little practical value.

4. It is, in the judgment of your Board of Engineers, financially inexpedient to attempt to complete the reclamation of the entire Everglades in the immediate future. On account of the great cost involved, and the large amount of land which would thus be thrown at once upon the market, this vast area cannot be sold and brought under successful cultivation with sufficient rapidity to meet the interest of the capital required and the maintenance charges.

5. The cost involved in the complete drainage of the Everglades will be so great as to render it difficult, if not impossible, even were it expedient, for the State of Florida to furnish the necessary funds for immediate develop-

ment, and consequently there is no hope for the completion of the work, as a whole, in the near future.

6. The magnitude of the possible future agricultural development of the Everglades will require a great and gradual readjustment of market conditions, railroad facilities, rate adjustments, and agricultural experiment work, which will involve much time, capital and labor.

7. For the reasons here given, the reclamation of the Everglades must, in our judgment, be a progressive development. Much of the work can be completed only after the earlier lands are drained and brought under successful cultivation.

8. The complete reclamation of the Everglades will require:

a. The control of Lake Okeechobee:
   To prevent its overflow and the flooding of the Everglades from this source.
   To provide storage for ultimate irrigation of the drained land.

b. The construction of numerous drainage canals or channels:
   For drainage purposes, and
   Ultimately, for the distribution of the stored waters of Lake Okeechobee for the irrigation of the drained land.

9. The drainage of Lake Okeechobee can be better accomplished by the construction of canals practically independent of the canals intended primarily for the drainage and irrigation of the Everglades.

10. The canals required for the drainage of Lake Okeechobee and the Everglades must have many times the capacity and will involve many times the cost of those at present under construction or projected by the State of Florida.

The canals should be much deeper than those under construction or projected by the State. The elevation above the sea of the land to be drained is not great, the available slopes in the canals in any event will be very slight, and the lowering of the ground surface by shrinkage of the soil when drained must be provided for. For effective drainage it is essential that the water level in the canals should be brought substantially to sea level at their mouths. This means that the canals must be deepened so that at their mouths the full discharging capacity will be reached in a prism that is below sea level. The State canals under construction and projected are particularly deficient in this respect, their bottoms being only a little below sea level, and their capacities being reached only with much higher water levels. Effective drainage of parts of the Everglades cannot be obtained by such shallow canals, however wide and numerous they may be.

11. It is apparent that the private lands now owned in the Everglades will not be effectually drained by the work now under way or projected by the State of Florida.

12. If the private lands are to be effectively drained within the immediate future, individual or collective effort will have to be exercised by the land owners. The work will be especially difficult on account of the fact that in most cases the State has sold alternate sections under which conditions any private drainage project will require the drainage of twice the land owned by private parties.

13. To accomplish effective reclamation work, a thorough and comprehensive study of this entire problem must be made. This study should involve a systematic study of rainfall conditions; the investigation of runoff and evaporation on the entire area considered; observations of the rise and fall of Lake Okeechobee, and the discharge of the various outlets from the lake; study and experiments on the agricultural possibilities of the muck lands; the necessary relation of the water table to the cultivated surfaces; the requirements of irrigation, land shrinkage, etc.; more detailed surveys and examination of various canal routes, especially from Lake Okeechobee to the sea. These data, together with many others which will be found desirable as the study of this great project progresses, will be found essential as a basis for the design of an effective reclamation system, and for the preparation of a comprehensive and adequate plan for the complete control of Lake Okeechobee, and the reclamation of the Everglades.

14. To assist in the immediate reclamation of at least a part of the private and public lands in the Everglades, the cooperation of the State is essential:

a. In the preparation of plans which will admit of progressive reclamation by a union of State and private effort.
b. In the passage of a sound drainage act.
c. In the exchange of lands to permit of the segregation of the holdings of private owners.

15. For practical reclamation work, the available resources of the State can best be devoted largely to the control of Lake Okeechobee, the enlargement of the natural outlets, and the construction of additional outlets from the Everglades to the Ocean, and to the progressive construction of adequate drainage channels from the outlets so provided into the interior of the Everglades.

You are face to face with the problem of reclaiming your own lands and those sold by you to others; we have therefore considered the problem primarily from this standpoint.

The conditions found by your Board of Engineers, the various data available, and the results of the study on which the above conclusions are based, are discussed at some length in the following pages.

FIRST MEETING OF THE BOARD OF ENGINEERS

The members of the Board convened at Jacksonville, Florida, on Saturday, August 3, 1912, where they were met by Mr. Henry H. Ralston, Vice President, and Mr. W. J. Kackley, Engineer of the Everglade Land Sales Company, and by Mr. J. O. Wright, Chief Engineer for the Trustees of the Internal Improvement Fund of the State of Florida.

EXTENT OF EXAMINATION BY THE BOARD

The party proceeded to Fort Myers on the west coast of the peninsula, arriving Saturday evening and leaving for Lake Okeechobee Sunday morning, August 4, by boat, upon the Caloosahatchee River. Sunday night was spent at La Belle. The party left LaBelle at six o'clock the following morning, passing to Lake Okeechobee by Flirt, Bonnet and Hicpochee Lakes and the Three Mile Canal. Both below and above LaBelle evidence of a recent heavy flood overflow was seen. (See photograph page 43).

A stop was made at Observation Island to secure recent rainfall and lake level data from Dr. F. K. Armstrong who has been making observations at that place for the U. S. Weather Bureau. (See appendix 1). From this place the party proceeded to Rita at the head of South New River Canal on Lake Okeechobee, where it arrived on Monday evening.

Tuesday morning, August 6, was spent in a trip down the South New River Canal to a point about 20 miles distant from Lake Okeechobee where hydraulic dredge No. 8 (see photograph page 19) was at work, removing muck from the bottom of the canal. Returning in the afternoon, the party examined the gardens at Rita (see photograph page 89) and paid a visit to Callahan's Nursery on the southern border of Lake Okeechobee at both of which points some of the agricultural possibilities of the Everglades' lands have been demonstrated.

On Wednesday, August 7, the party left the Bolles Hotel at Rita at 6 A. M., sailing easterly eight miles to the mouth of the North New River Canal, and thence, by the way of this canal to Fort Lauderdale. Various dredges and drill boats (see photograph pages 36, 38 and 39), at work completing the excavation of this canal, were passed and inspected on the trip.

Although still unfinished, this canal is now open to traffic throughout the entire length. The party arrived at Fort Lauderdale early in the evening of the 7th of August, Mr. Wright leaving at once for Tallahassee, the other members proceeding by automobile to Miami.

On Thursday, August 8, the Board, in company with Messrs. Ralston, Price, Miller and Kackley of the Everglade Land Sales Company, proceeded by boat up the Miami Canal about 20 miles to its present terminus, in proximity to the southern boundary of Tract No. 5 of the Company's land, near Section 31, Township 51 south, Range 39 east (see photograph page 21). In

the afternoon, the party visited the Snapper Creek Canal, about nine miles south of Miami, now under construction.

On Friday, August 9, with Messrs. Ralston and Kackley, the Board left Miami at 6 A. M., stopping at the orchard of Mr. Bryan near Dania and proceeding with Mr. Bryan to Fort Lauderdale, and thence by boat up the New River and South New River Canal to the Davie Farm (see photograph page 96) and the Royal Glade tracts (see photograph page 98), where the work already done and the conditions that prevail were examined.

In the evening of August 9, the Board of Engineers left Fort Lauderdale, arriving in Jacksonville on Saturday morning, August 10, visited the U. S. Engineer's office and the U. S. Weather Bureau office in search of significant data, and spent the following day in conference at Jacksonville, discussing the general situation, the data acquired and desired, and the general lines on which report should be made.

August 12, Mr. Metcalf, and Mr. Ralston of the Everglade Land Sales Company, visited Tallahassee to confer with the Trustees of the Internal Improvement Fund, and their Engineer, Mr. J. O. Wright. Mr. Mead spent the day in Jacksonville with Mr. Kackley, securing data from the office of the U. S. Engineer's Corps and the U. S. Weather Bureau, and Mr. Hazen went to New York.

DESCRIPTION OF THE REGION

Sources of Information

The physical conditions that obtain in the Everglades and in those adjacent regions which, from their hydrological relations to the Everglades, must be considered in connection with any general reclamation project, are described in some detail in the various reports and papers included in Senate Document 89 of the 1st Session of the 62nd Congress. The following description of this region is drawn from this source as well as from maps and data secured from the U. S. Engineer's office at Jacksonville, through the kindness of Captain H. H. Slattery, from maps, profiles and data furnished by Major J. O. Wright, and from various other sources believed to be reliable.

Geology of the Everglades

The southern part of the peninsular of Florida, including the Everglades and the basin of Lake Okeechobee, is underlaid by a rough coraline limestone rock. The Everglades lie in a shallow basin of this limestone, confined within rock ridges or so-called "rims", roughly parallel to the Atlantic coast, which form a barrier three to five miles wide at its northern end opposite Lake Okeechobee, and ten to twelve feet higher than the bed rock in the center of the Everglades. This ridge disappears south of Miami, and the entire peninsula has here a rocky surface, dipping slightly to the southwest. On the west coast the rock rim is wider than on the east. The backbone of this ridge is west and south of Fort Thompson, twenty miles west of Lake Okeechobee, and extends in a southerly direction approximately parallel to the eastern rim. The "Everglades" consist essentially of the area enclosed by these rock rims and lying south of Lake Okeechobee, comprising a tract of land ninety miles long and forty miles wide.

Physical Conditions and Natural Drainage of the Everglades

"The Everglades of Florida cover an area of about 4,000 square miles, embracing more than half of the portion of the State south of Lake Okeechobee. The subsoil of this vast region is coraline limestone. Upon the surface of this which is very rough and irregular, lies an immense accumulation of sand, alluvial desposits, and decayed vegetable matter, forming a mass of quicksand, and soft mud, from 3 to 10 feet or more in depth, that overspreads all but a few points of the first stratum. Upon the mud rests a sheet of water, the depth varying with the conformation of the bottom, but seldom at dry seasons, greater than 3 feet. The whole is filled with a rank growth of coarse and rough grass, from 8 to 10 feet high, having a sharp, serrated edge like a saw, from which it obtains its name of saw grass.

"The difference of level between the highest and lowest stages of water is from 2 to 3 feet. The general surface of the Everglades is therefore, sub-

ject to great changes the character of marshy lake or mud flat predominating according to the wetness or dryness of the season. It is probable, that, sometimes more than one-half of the surface has no water upon it. Besides the mud islands, small keys are here and there met with which are dry at all seasons. Upon these the soil is very rich." (From Report of Lieutenant J. C. Ives, see page 71, Bulletin 89).

The land surface slopes gradually from Lake Okeechobee to the southern end of the peninsula at the rate of approximately three inches per mile. The surface of the Everglades westerly from Miami is about 8 feet above sea level.

The depth of muck varies considerably in different parts of the Everglades, and, in a general way, decreases from north to south. Broadly speaking, it ranges from 4 to 10 feet.

The growth of the Everglades proper, lying to the south of Lake Okeechobee, and beyond the fringe of custard apples, scrub oak and myrtle, which border this lake on the south, consists wholly of saw grass; and for miles to the south of the lake, as one passes through the canal to the seaboard, nothing is to be seen but one vast extent of saw grass.

On the border of the Everglades are found the myrtle and cypress, and back of these, the pine timber of the higher lands. Along the rock rim, more particularly on the eastern coast, the water has found or gradually developed natural outlets which afford local relief during flood water stages upon the Everglades; but the main flow of the natural drainage waters and of the overflow waters of Lake Okeechobee, is to the south along the center line or middle of the peninsula.

Lake Okeechobee

North of the Everglades lies Lake Okeechobee, roughly circular in outline and thirty miles in diameter. Into this lake flow the Kissimmee River from the north, and various smaller streams from the north, east and west. The total drainage area of the lake is about 6000 square miles. In its natural state, Lake Okeechobee had no definite and distinct outlet to the sea, and it was not until about 1884 that a canal was cut from the lake to the Caloosahatchee River, giving a direct connection with the Gulf of Mexico. Before that time it had been possible to enter the lake from the Caloosahatchee River only at times of high water. The Shores of the lake are not well defined except on the east coast, most of the shore being low and marshy and thickly covered with aquatic vegetation. On the southerly border of the lake are numerous small water courses, more or less distinct at the lake shore, but gradually losing themselves as they enter the Everglades. At high water in Lake Okeechobee, which is understood to be essentially at a level of 22 feet above the sea, these various water courses form an outlet for the overflow of Lake Okeechobee to the Everglades, and drain a portion of the Everglades to Lake Okeechobee during low water period. During high water or the rainy season, the lake discharges into the Caloosahatchee River and overflows its southerly border or margin into the Everglades; but during extreme high water in the Caloosahatchee River, when the lake itself is not at flood stage, a reversal of flow sometimes occurs during local storms of extreme severity on the Caloosahatchee drainage area, and then the Caloosahatchee River is found to discharge not only to the sea but also into Lake Okeechobee for a limited period of time. Such a reversal of flow occurred during the recent flood in June, 1912, and is shown in diagrammatic form in Drawing No. 2, Appendix 13.

The Kissimmee River

The Kissimmee River drains numerous lakes north of Lake Okeechobee as shown in Drawings Nos. 6 and 9, Appendix 13. This stream has a flood plain varying from 1½ to 2 miles in width, through which the river channel meanders during low water stages. The fall from Lake Tohopekaliga to Lake Okeechobee in approximately forty feet or ½ of a foot per mile. The banks of the stream are overflowed and the river bottom lands or plain are inundated during heavy storms.

East and west of the flood plain are extensive flat areas containing some pine lands, wire grass, swamps and sloughs. The whole drainage area here considered is covered with vegetation which retards flow, and is, therefore, detimental to adequate drainage. Vegetation is rapidly developed in

the waterways, the water hyacinth and other aquatic growths stopping and clogging the channels unless given frequent attention.

The Caloosahatchee River

The drainage basin of the Caloosahatchee River, which lies to the west of Lake Okeechobee, finds its natural outlet at Fort Myers and Punta Rassa. The river itself is shallow, varying in depth from 6 to 12 feet, more or less, and is sluggish and of meandering type. It is not an important factor in the drainage of Lake Okeechobee, since its river section and gradient are not sufficiently large to carry even its own storm waters without flooding its banks, and it therefore has not sufficient carrying capacity available for the effective relief of Lake Okeechobee.

LAKE OKEECHOBEE AS A FACTOR IN THE DRAINAGE OF THE EVERGLADES

It is clear that the drainage of the Everglades depends primarily on the control of Lake Okeechobee. Moreover, the lake and its storage will become of the greatest importance when the irrigation of these lands is undertaken in the future. Inundations of the Everglades from this lake must first be prevented, after which the drainage of the Everglades becomes a more simple problem. Owing to the comparative high temperatures of the winter season (during which season successful gardening operation is most profitable), the low rainfall for this period, and the character of the much soil, the irrigation of the reclaimed lands will later prove necssary, and Lake Okeechobee will then become of greater value as a reservoir for irrigation than as a reservoir for storm flow equalization purposes. From it, by means of properly designed canals, water may be rapidly discharged during the flood season, and drawn for irrigation purposes during the dry season.

DRAINAGE AREA OF LAKE OKEECHOBEE

The drainage area tributary to Lake Okeechobee has not as yet been determined with precision. Major J. O. Wright, formerly Drainage Engineer to the Board of Internal Improvement Fund of the State of Florida, fixes the drainage area at 6076.8 square miles, and the area of Lake Okeechobee at 710 square miles.

An appropriation was recently made by the government for the investigation of the feasibility of deepening the Caloosahatchee River and providing an outlet from Lake Okeechobee to the Atlantic coast for navigation purposes. A Board of Engineers was appointed, from the United States Engineer Corps, to investigate and report upon this subject. By courtesy of Captain H. H. Slattery, U. S. A. Engineer in charge at Jacksonville, we were furnished with a copy of a map of this region, as determined by the Engineers of the United States Engineer Corps. (See Drawing 6, Appendix 13).

Captain Slattery estimates the total drainage area tributary to Lake Okeechobee to be approximately 5366 square miles, as follows:

Kissimmee River	3,059	Sq. Mi.
Fish Eating Creek,	917	" "
East of Kissimmee River	373	" "
Area of Lake Okeechobee	733	" "
Allapattah Section	284	" "
Total Area	5,366	" "

Captain Slattery reports the area of Lake Okeechobee to be approximately 733 square miles.

In default of more exact information and wishing to make all estimates conservative, your Board of Engineers has assumed the drainage area tributary to Lake Okeechobee to be approximately 6000 square miles, including the area of the lake itself estimated at 710 square miles, or 454,000 acres.

AVAILABLE STORAGE IN LAKE OKEECHOBEE

The bottom of the lake slopes very gradually from the shore to a maximum depth of 20 feet, more or less; therefore, there are large areas of shoal water. The full lake level is at about 20.6 feet, and extreme high water at about 22 feet, both above mean low tide (sea level).

We understand that the United States Engineer Corps has for navigation purposes, set an elevation of 16 feet above mean low tide as a minimum limit, below which the lake level is not to be drawn.

The average storage capacity between elevations 16 and 19 is approximately 1,363,000 acre feet or 5,937,000,000 cubic feet, equivalent to four and one-quarter inches in depth over the entire assumed drainage area of 6,000 square miles.

The limit to which this storage, assumed to be available, must be discounted by reason of the uncertainty of meteorological conditions and forecasts, and the conflicting nature of the demands or necessities of drainage and irrigation, are discussed hereafter in this report.

PLAN OF THE STATE OF FLORIDA FOR THE DRAINAGE OF THE EVERGLADES

The drainage of the Everglades is under the jurisdiction of, and being actively carried on by the Trustees of the Internal Improvement Fund of Florida. This Board was created by a law passed January 6, 1855, which designated as "Trustees" the Governor, Comptroller, Treasurer, Attorney General, and Commissioner of Agriculture of the State, and their successors in office. The immediate supervision of the work for the last two years or more has been in charge of Major J. O. Wright, Chief Drainage Engineer to the Board.

Major Wright, as supervising engineer of the Board of Experiment Stations, United States Department of Agriculture, investigated the reclamation of the Everglades in the year 1907-1908. Later, he was appointed Chief Drainage Engineer to the Trustees of the Internal Improvement Fund of Florida, and continued in this capacity up to the time of his resignation in August, 1912.

While considerable work had already been done by the Trustees at the time of Major Wright's appointment, revised plans for the drainage of the Everglades were adopted shortly thereafter. The work definitely projected by the State of Florida up to this time was described in a letter received by the Board from Major Wright, under date of August 15, 1912, as follows:

Extract of Letter from Major J. O. Wright, Concerning Plans of the State of Florida for the Drainage of the Everglades

" The state is now engaged in cutting five outlets from Lake Okeechobee to tide water for the purpose of lowering the lake to an elevation of sixteen feet above sea level. The first of these enters into the Caloosahatchee River. This outlet is practically completed; the Government, however, requires that the channel be deepened in some places so as to have a uniform grade from an elevation of plus 11 at the lake to plus 1 at LaBelle, channel to be sixty feet wide on bottom.

"North New River Canal—This canal leaves the lake at an elevation of plus 12 and has a uniform fall of three inches to the mile to mean low tide at the junction of the North New River and South New River canals four miles west of Ft. Lauderdale.

"South New River Canal—This canal leaves the lake at an elevation of 12 and has a fall of 0.2 per mile to tide water at the junction of the North New River and South New River four miles west of Ft. Lauderdale.

"The Miami Branch leaves South New River forty-five miles from Lake Okeechobee at the grade of this canal at that point, and has a fall of 0.2 per mile to tide water in the Miami River.

"Hillsboro Canal—This canal leaves the lake at an elevation of twelve feet above sea level and has a fall of 0.2 per mile to within about four miles of its mouth at which point grade increased to practically one foot per mile to tide water in the Hillsboro River.

"The length, bottom width, depth of flow, depth of cut of the several portions of these canals are shown in a tabulated statement attached thereto.

"The upper portion of these canals for a distance of twenty miles south of the lake is wholly in muck and the bank slopes are ½ horizontal to 1 perpendicular. The lower portion of these canals is usually in muck two to seven feet deep underlaid with rotten lime stone. In some places near the lower end of these canals the rock comes to the surface of the ground. Where

the muck is underlaid with rock the bank slope of the rock is ½ to 1, and the slope of the earth, above the rock, varies from ½ to 1 to 1-½ to 1 owing to the character of the material.

"West Palm Beach Canal—The contract for this canal has not yet been let and it has not been determined definitely what width it will be made.

"I am enclosing, herewith, a profile of the Calooashatchee River and a condensed profile of the Hillsboro canal and the West Palm Beach Canal.

"In my original investigation of this drainage area I concluded that it would be necessary to remove from the lake 3938 cu. ft. per second by means of the canals during the rainy season. On further investigation of the subject I reached the conclusions that a discharge of 3200 cu. ft. per second would be ample to control the lake except possibly in extraordinary storm periods which might occur at rare intervals. By reference to Senate Document No. 89, page 168, you will note I have provided for two canals not embraced in the plans now being constructed. It is the purpose of the Trustees, as explained to you, to cut other canals as they have the means, that may be found necessary to prevent the overflow of the lake and to furnish outlets for lateral drains.

"In computing discharge of the above canals I have allowed the maximum depth of flow in the Caloosahatchee River to be eight feet, and in the other canals seven feet.

"Shrinkage of muck soil—This is a matter about which there is more or less speculation. From my observation and experience I have concluded the shrinkage in the Everglades will range from 25 to 33-1/3% of the depth of the muck above the plane of the soil water held in the "Glades" when the land is drained. By means of suitable locks and dams the level of the water can be held at the elevation that experience shows to be best suited for the growth of crops. From the experience of the truck growers on the Davie Experimental Farm and in the vicinity of Miami and Fort Lauderdale, it seems that from thirty to thirty-six inches below the surface is a level for the soil water that gives the best results. The soil of the Everglades is not wet but is simply overflowed and I think it would be an easy matter to overdrain it. The proper depth below the surface to hold the soil water can be determined by experience only.

"Owing to the lack of reliable data concerning rainfall, evaporation and runoff there is necessarily more or less uncertainty as to the discharge capacity of the canals required. The Trustees not having an unlimited capital at their command have felt that it was wiser to build this system of drainage by degrees as they had means to do the work rather than undertake an elaborate system with much more carrying capacity in the canals than would be needed. If money is wasted in useless excavation it cannot be recovered; if on the other hand additional canals are found by experience to be necessary they could readily be constructed."

DIMENSIONS OF CANALS UNDER CONSTRUCTION

North New River Canal

Miles	Bottom Width	Depth of Flow	Depth of Cut
1 to 10	50 ft.	7 ft.	10.0 ft.
10 to 20	55 ft.	7 ft.	9.5 ft.
20 to 30	60 ft.	7 ft.	9.5 ft.
30 to 40	65 ft.	7 ft.	9.0 ft.
40 to 56	65 ft.	7 ft.	8.75 ft.

South New River Canal

1 to 10	50 ft.	7 ft.	10.0 ft.
10 to 20	55 ft.	7 ft.	9.25 ft.
20 to 30	60 ft.	7 ft.	8.75 ft.
30 to 40	65 ft.	7 ft.	8.25 ft.
40 to 45	70 ft.	7 ft.	8.00 ft.
45 to 57	60 ft.	7 ft.	8.50 ft.

Miami Branch

1 to 10	50 ft.	7 ft.	8.50 ft.
10 to 20	55 ft.	7 ft.	8.25 ft.
20 to 26	60 ft.	7 ft.	8.50 ft.

Hillsboro Canal

1 to 10	50 ft.	7 ft.	10.0 ft.
10 to 20	55 ft.	7 ft.	10.0 ft.
20 to 30	60 ft.	7 ft.	10.0 ft.
30 to 40	60 ft.	7 ft.	11.5 ft.
50 to 60	60 ft.	7 ft.	13.0 ft.

CAPACITY OF CANAL SYSTEM AS NOW PROJECTED

We understand that the five outlet canals from Lake Okeechobee as projected have been assumed to have a joint capacity of 3200 cubic feet per second at the lake, with the depth of flow specified in the table. Under the assumption made we estimate this capacity with the water surface in Lake Okeechobee at elevation 19, at approximately 2700 cubic feet per second, assuming that the West Palm Beach Canal is to have a width of 50 feet, or 2850 cubic feet per second if the West Palm Beach Canal is excavated to a width of 75 feet.

It is to be noted, however, that these flows are calculated on the basis of maintaining the level of Lake Okeechobee at 19 feet above sea level, and the water in the canals at a level too high for satisfactory agricultural use. As a shrinkage or fall in the muck or ground surface of two feet, more or less, should be anticipated after successful drainage of these lands, the water surface in the main canals should ordinarily be kept from two to three feet below the ultimate surface of the ground.

The maximum capacity of the projected canals should therefore be calculated on the basis of a depth of not over five feet, with a resulting capacity at Lake Okeechobee of from 1300 to 1900 cubic feet per second depending upon the extent to which relief may be had from the Caloosahatchee River. These quantities are made up approximately as follows:

North New River Canal	257	cu.	ft.	per	second
South New River Canal	230	"	"	"	"
Hillsboro Canal	230	"	"	"	"
West Palm Beach Canal (75′ wide)	550	"	"	"	"
Total	1267	"	"	"	"
Caloosahatchee River	610	"	"	"	"
Grand Total	1877	"	"	"	"

It is to be noted further that these capacities are based upon an assumed free outfall in the canals, a condition which cannot be realized in fact by the projected canals, inasmuch as they will of necessity receive, all along their courses, flood waters from the drainage areas tributary to them. Backing up of water in the canals must inevitably result after heavy rainfalls, which will seriously reduce their surface slope and hence their available capacities. in any event, it is clear that the practical carrying capacity of the canals projected by the State has been largely over estimated.

PRESENT CONDITION OF CANALS

Upon drawing 3, Appendix 13, are shown the canals projected by the State, and the extent to which the canals had been opened on July 1, 1912. A considerable amount of rock still remains to be taken out from the bottom of the canals which have been opened up.

The South New River Canal is being built southward from Lake Okeechobee, the head of the excavation being about 30 miles south of the lake. The surface muck has been removed for this entire distance, and suction dredge No. 8 (see photograph page 19) is now pumping the lower muck from the canal at a point about 20 miles south of the lake.

The North New River Canal is open from Lake Okeechobee to New River, most of the muck having been removed, although two dredges are still working upon the excavation of this material. Two drill boats (see photographs page 38) and a dredge (see photograph page 39) are working upon the rock about 30 miles southerly from the lake. Your Board of Engineers traversed the North New River Canal on the trip through the Everglades. It was observed upon this trip, which was made some time after the maximum high water, that in many places south of the point where the rock excavation

was still uncompleted, and where the discharge was substantially obstructed, the water flowed at an elevation of eight to twelve inches or more above the adjoining land, and found vent into the Everglades at many points.

The Miami branch of the South New River Canal was begun at the Miami River and has been carried north to the north line of Township 52 S., Range 39 E. (See Drawing 3, Appendix 13). Although this canal has not yet been cut through to the lake, merely running from the seaboard into the Everglades a distance of about 20 miles at the present time, and though the high water stage had already passed when the examination was made by us, yet this canal was full to overflowing (see photograph frontispiece page 1), and the land at the end of the canal in proximity to your property was submerged to a depth of at least one foot. (See photograph page 21). While the completion of the West Palm Beach Canal and the Hillsboro Canal would, if of sufficient capacity, intercept a certain amount of the flow-off water from the north and thus prevent its reaching the North New River Canal and the Miami branch of the South New River Canal, yet it was apparent, from the conditions found along this canal, that the Miami Canal is totally inadequate to provide proper drainage for the land adjacent to its course, and will be still less serviceable to you when it is cut through to Lake Okeechobee than it now is

CANAL OUTLETS

The Miami River (see Drawing 11, Appendix 13) which serves as an outlet to the Miami branch of the South New Canal, has a section fairly satisfactory for present conditions. Measurements made under the direction of the United States Engineer Corps (Drawing 12, Appendix 13) show that under normal conditions the fall from the head of the river to the sea is small, yet that the river will take care of the drainage at present reaching it without undue flooding of the adjacent lands. The bed of the river has already become somewhat silted up by operations upon the Miami Canal, and the United States Engineer Corps has demanded that the Trustees of the Internal Improvement Fund dredge out the bed of the river and re-establish the conditions existing prior to the beginning of the canal work. It is doubtful however if the carrying capacity of this river will prove adequate to handle the increased amount of water resulting from the projected plans of the State.

The New River was found very greatly congested by the water reaching it from the North and South New River Canals on the date of our visit, although the water in the Everglades was much below its maximum elevation. It is apparent that this outlet, the mouth of the New River (see Drawing 10, Appendix 13), will be entirely inadequate to care for the added flood water flow from the projected canals, and that it will have to be very materially enlarged to pass without damage the drainage water which it is intended to receive. Enlargement will also be necessary to care for the water pumped from your lands under the plans suggested by us for draining presently your own lands.

Two small canals, the Snapper Creek Canal, now under construction, and the Snake Creek Canal, which the State has projected to connect with the Royal Glade Canal, now under construction by the Everglade Land Sales Company, are designed to have a bottom width of 20 feet, and a depth of 8 feet. The capacity of these canals, also, will be too small to pass the water which must reach them.

A canal has already been constructed from Lake Okeechobee to Fort Thompson, to connect the lake with the Caloosahatchee River, although this canal still remains to be deepened under the terms of assurances given to the United States Government by the State. When your Board passed through this canal, there was a slight current outward from the Lake. It should be noted, however, that during the flood of June, 1912, in which the maximum rainfall was concentrated on an area west of Lake Okeechobee (see Map page 82), the Caloosahatchee River, unable to carry the flow from its drainage area, not only overflowed its banks (see photograph page 43) but actually reversed its flow from Turner P. O. west of Fort Thompson to Lake Okeechobee (see profile, Drawing 2, Appendix 13), and thus discharged from this point in opposite directions, both easterly into the lake and westerly into the Gulf.

It is evident that the carrying capacity of the Caloosahatchee River is not sufficient to care for the normal flood flow from its own tributary drainage area excluding the Lake shed, and that it cannot therefore be considered as affording during rainy season an important outlet to Lake Okeechobee, for there will undoubtedly be times, as heretofore, when the river will occasionally discharge into, rather then from the lake, thus contributing to the flood water conditions in the lake, rather than assisting in relieving them. It will undoubtedly be essential to regulate the flow between Lake Okeechobee and this river by the construction of a lock and controlling works near the point where it, or the canal built in extension of it, leaves the lake. It may also be necessary in the future to control other outlets in a similar manner.

PRESENT PLANS OF THE STATE OF FLORIDA FOR THE RECLAMATION OF THE EVERGLADES

Up to the present time the State authorities have committed themselves to the control of the flood waters of Lake Okeechobee, and to completing following canals: The North New River Canal, the South New River Canal, the Miami branch of the South New River Canal, the Hillsboro Canal and the West Palm Beach Canal, (see Drawing 3, Appendix 13). The State officers have not apparently given formal notice that these works would drain the Everglades; but it appears that the Trustees of the Internal Improvement Fund have been led to hope that they might be sufficient, and the public generally has quite definitely assumed this to be the case. It is hardly conceivable that the individual owners of small tracts of land in the Everglades, who probably number from 20,000 to 30,000, would have bought their holdings had they not presumed that the works now under construction by the State would accomplish the reclamation of the Everglades and make their land tillable.

WORK UNDER CONSTRUCTION INADEQUATE

It appears to us that the works now under construction by the State are totally inadequate to accomplish the necessary drainage. Probably eight to twelve or more times as great carrying capacity will be required than is provided by the above mentioned canals. The work now under way is exceedingly limited in view of the magnitude of the work actually required.

FURTHER INVESTIGATION NEEDED

It is of the utmost importance, in order to advance the practical reclamation work, that the present plans be revised and added to, and that the work be undertaken on a scale of much greater magnitude than has heretofore been contemplated.

The first step in such a revision is securing information and data upon which to form a sound basis for the design of this great work. We have collected such information and data as we were able within reasonable limits of time and expense. To secure additional data in sufficient detail for the formation of sound and reliable estimates as to the most desirable plans for reclaiming the Everglades, would involve too great an expense and too great a loss of time in connection with the preparation of this Report.

It is manifestly unfair that the Everglade Land Sales Company should be required to meet the large expense of a full and comprehensive study of the drainage of the entire Everglades, and we have, therefore, investigated these matters only with reference to the immediate conditions and use of your own property, leaving the more detailed study of the larger problem for future investigation by the State, or by an association of all those interested in the reclamation of the Everglades.

We venture to suggest that the Trustees of the Internal Improvement Fund could most appropriately undertake this investigation, and we believe that no better use could be made of so much of their funds as may be reasonably necessary for this purpose.

OPINIONS OF OTHER ENGINEERS ON THE DRAINAGE OF THE EVERGLADES AND ON THE REQUIRED CANAL CAPACITIES

The question of the required capacities of the canals necessary to drain the Everglades is of the utmost importance. The views of your Board of Engineers on the required capacities of these canals differ substantially from those heretofore expressed in certain published reports. As the uncertainties involved by the problem may well result in substantial difference in opinion, in view of the rather meagre data available upon which to base final conclusions, it seems desirable to quote in some detail at this point, from the published reports upon this subject.

EXTRACTS FROM SENATE DOCUMENT NO. 89 "EVERGLADES OF FLORIDA" REPORT OF MAJOR J. O. WRIGHT, PAGE 164 ET SEQ.

"The drainage of the Everglades involves the consideration of two problems:

"First. The best means of controlling the water in Lake Okeechobee, so that it will not overflow its banks during the rainy season and yet will retain sufficient water to irrigate the lands when needed, and also to maintain a sufficient stage of water in the outlet canals for navigation.

"Second. To provide adequate and proper drainage for the lands when protected from the overflow of the lake.

"The character of the soil in the Everglades is such that a constant supply of moisture is required to support and mature plants. During the winter and spring months the precipitation in southern Florida is not sufficient to supply the need of growing crops if the ground water is too far removed. In order to develop the fertility of the Everglades and make them sufficiently productive, water should be stored in Lake Okeechobee to supply the deficiency to the land during the dry period and provision should be made to remove the excess water so as to prevent overflow. This can best be accomplished by a system of outlet canals, provided at the upper end with gates, to regulate the flow of water into them.

"The watershed drained by Lake Okeechobee, including the area of the lake, is approximately 4,000,000 acres. There is no authentic record of the rainfall in this area except at Kissimmee, in the northern portion, but it will be safe to assume that the rainfall at this station represents fairly accurately that of the entire watershed. The average annual rainfall at Kissimmee for the past nine years was 53 inches, with a minimum of 40.22 inches in 1902, and a maximum of 70.92 inches in 1899. This amount of rainfall is not uniformly distributed throughout the year but is excessive during the summer and fall, often exceeding 12 inches in a single month. In the months of July and August, 1905, the total rainfall recorded at Kissimmee was 27.95 inches. During the same period there were but 20 inches at Jupiter, 24 inches at Fort Myers, and 25 inches at Miami. This would seem to indicate that the rain at Kissimmee was due to some local influence, and that probably the rainfall over the entire drainage area for that time did not exceed 26 inches. As a fall of 26 inches in any other two consecutive months is the nearest approach to this amount, it is safe to conclude that 26 inches in two successive months is an extraordinary rainfall, not likely to occur except at rare intervals. Since a rainfall, of 18 to 22 inches in two consecutive months has occurred three times during the last decade, we may reasonably expect the same amount in the future. In order to have a margin of safety, it will be assumed in these considerations that the maximum rainfall upon the entire watershed in two consecutive months is 24 inches.

EVAPORATIONS

"Rainfall disappears in two forms: (1) Run-off or free water which flows away in streams, and (2) evaporation, which includes water taken up by growing plants as well as that which passes into the atmosphere as vapor.

"No observations have been made in southern Florida to determine the loss by evaporation in that latitude. Careful experiments, however, have been carried on in some of the Northern States, in the arid West, and in Europe,

to determine what percentage of the rainfall is run-off and what percentage is evaporation. While the results obtained vary with the local conditions some general laws have been established by these experiment from which we may deduce fairly accurate conclusions. The most complete, as well as the best known series of observations on the evaporation from the surface of the soil are those made by Gilbert and Lawes at Rothamstead, England 1870 to 1890. The English experiments show that in June, July, August, and September 76 per cent of the total rainfall during these months was removed by evaporation. Prof. E. F. Ladd, of the Agricultural College at Fargo, N. D., conducted a series of experiments in 1902 to 1905 to determine the loss by evaporation from a water surface. The average daily evaporation as shown by his report is as follows: May, 0.17; June, 0.21; July, 0.26; August, 0.24; and September, 0.11 inch.

"Croton River watershed in New York for a period of 32 years shows a mean annual evaporation of 25.74 inches, or 53 per cent. of the rainfall, the greater portion of this evaporation occuring during the months of June, July, August, and September. At least 70 per cent. of the total rainfall during these months is evaporated.

"The volume of water which is taken up by vegetation during the growing season is large. Prof. F. H. King showed in experiments at Madison, Wisconsin, which were made to determine the amount of water required to produce a pound of vegetable dry matter, that some crops use water equivalent to 25 inchs of rainfall in the growing season.

"Experiments made at Emdrup, Denmark, and quoted by J. T. Fanning, show the following relative evaporation from water and long grass as determined by observations during a period of 10 years: From water surface, mean for June and July, 10.5 inches; from long grass, mean for June and July, 17 inches.

"Mr. Fanning quotes experiments made in Lancashire, England, and at Whitehaven, England, to determine the evaporation from bare earth. At the former place, the amount in June and July was 7.8 inches, and at the latter, 8.3 inches.

"A study of the details of numerous experiments of this character leads to the conclusion that where the surface is wet or covered with water, or with dense vegetation, and where the temperature is high—80° to 95° F.—and the percentage of humidity is less than 85, the conditions are favorable for high rate of evaporation. It also shows that the evaporation from land covered with dense, short vegetation is much greater than from a water surface or from bare earth.

"Turning to the area under consideration, during the months of July and August, 1905, when 28 inches of rain fell at Kissimmee (see Table, page 146), the following conditions prevailed over the peninsula of Florida: The ground was either saturated or covered with water. The mean temperature was 79° F., the average wind velocity 8.5 miles per hour, and the humidity of the atmosphere 82 per cent. Under this condition of the atmosphere, and a dense vegetation covering a large part of the area, the evaporation was at least 0.3 inch per day during the entire period. This would be 9 inches per month, or 75 per cent of the rainfall for the months of July and August, which passed off as evaporation from the watershed of Lake Okeechobee.

"The difference between rainfall and evaporation is the runoff or drainage that must be provided for. It is estimated that the maximum rainfall that is likely to occur in July and August is 24 inches, or a mean daily precipitation of 0.387 inches. The difference between this amount and 0.3 inch, the estimated amount of evaporation, is **0.087 inch, which is the estimated mean daily run-off from the entire watershed.**

"The effect of the run-off from the land into the lake will be as follows: The land surface which discharges its runoff into the lake is seven and one-half times the area of the lake. The run-off being estimated at 0.087 inch per day, the lake would be raised 7.5 times that amount, or 0.65 inch per day, or 40.45 inches during July and August. The daily evaporation from the lake being estimated at 0.25 inch and the rainfall 0.387 inch, there remains 0.137 inch of water in the lake, or 8.49 inches, which, added to the run-off from

the land, makes 48.94 inches, the amount which the level of the lake would be raised during July and August should the banks be high enough to retain it.

"From the above facts it appears that the most feasible way to control the level of Lake Okeechobee is to dig canals from the lake to tidewater of sufficient capacity to reduce its level to an elevation of 16 feet just before the rainy season sets in, and allow a storage capacity for 36 inches of the run-off. There will then remain to be romoved through the canals 13.94 inches during the 62 days, or 0.2088 inch in 24 hours. To accomplish this will require canals having an aggregate discharge of 3,938 cubic feet per second."

The report then goes on to a discussion of "Size and Arrangement of Canals". In brief, it may be said that the plan shown in the report, contemplated the construction of seven canals in addition to the improvement of the Caloosahatchee River, the proposed canals being as follows: North Canal, Hillsboro Canal, North and Middle New River Canals, having a joint outlet above Fort Lauderdale; South New River Canal, Miami Canal, and West Canal, which latter was to find an outlet in the lower Everglades. (See Drawing 4, Appendix 13).

It may be noted that while the plans under which the drainage work is now being carried forward by the State of Florida provide for the construction of five, instead of eight canals, as originally provided by Major Wright in addition to the improvement of the Caloosahatchee River, their carrying capacity is estimated by Major Wright to be substantially the same as that of the canals contemplated in the earlier project.

The hydraulic elements, estimated capacities, and amounts of excavation involved by these proposed canals are shown in the tabulation following:

VIEWS OF MR. C. G. ELLIOTT

While the report referred to above, and written by Major J. O. Wright, was prepared under the authority of Mr. C. G. Elliott, then Chief of the Drainage Bureau, United States Department of Agriculture, and received, we understand, pertunctory endorsement, Mr. Elliott subsequently concluded that the proposed capacity of the canals was inadequate, and made certain changes in the basic figures contained in Major Wright's report, which were published later as a part of Exhibit B of No. 5 in the "Hearings before the Committee on Expenditures, in the Department of Agriculture."

We quote from Mr. Elliott's published statement (see page 33 et seq.):

"Examinations of this great area have not been made in sufficient detail to secure the facts that are necessary to an intelligent design of a drainage plan for the Everglades. The area has distinctive characteristics and in many respects is unlike any reclamation project which has been completed. Since it has no counterpart, the plan must be worked out by comparing the conditions which have been found in localities where drainage has been successfully accomplished with those which are known to exist in the Everglades. The discussion of the drainage problem therefore, will be confined necessarily to the consideration of the factors which relate to it, and to suggestions regarding their use and value in formulating a practical plan.

"The problem has three elements which require separate examination:

"First: The area of land lying north of Lake Okeechobee, estimated at 5,500 square miles, which discharges its drainage into the lake through the Kissimmee River and several smaller streams.

"Second: The lake, comprising an area of 733 square miles, which receives the entire runoff from the land before described and when filled relieves itself westward through the Caloosahatchee River and southward over the Everglades.

"Third: The upper Everglades, comprising a plain of approximately 2,981 square miles, for which there is no natural drainage.

"The rainfall of the interior part of the State is fairly represented by the record of the Weather Bureau station at Kissimmee, from which it appears that a precipitation of 15 inches in one month occurs occasionally, but rarely exceeds 24 inches in two consecutive months. This amount may fall during two consecutive months in the summer or early fall on any portion of southern Florida, so that it will be used as a basis for computing the probable run-

off that should be provided for. The actual runoff from either the Lake Okeechobee watershed or the Everglades has not been determined. Lacking this specific information, the amount of drainage may be estimated by comparing the runoff areas which are somewhat similar to southern Florida in surface and climate, giving due weight to the difference in conditions which are known to exist.

"A comparison of the actual runoff from large areas as given by the records of stream gauging shows a wide range of results, due to differences in the character of the rainstorms, the temperature, the topography, and the soil surface. The ratio between rainfall and runoff can be determined only by reliable measurements of both. Data of this kind for areas similar to southern Florida can not be secured, but by consulting the records of the gauging of several streams in the South, and the corresponding rainfall, it appears that the runoff for two consecutive summer months varies between 20 and 30 per cent. of the rainfall for that time. Taking into consideration the difference in areas for which runoff has been measured and the watershed of Lake Okeechobee, it is thought that 22 per cent of the rainfall which may be expected in two consecutive months will pass into the lake. Assuming 24 inches as the rainfall for 62 days, the depth of run-off will be 5.28 inches. Since the area discharging its water into the lake is seven and one-half times larger than the lake, the lake surface would be raised 39.6 inches by the inflow. Assuming the same rainfall upon the lake, and the same loss by evaporation as we assumed for the land surface, the total rise in the lake due to a rainfall of 24 inches during 62 days will be 44.88 inches, should there be no discharge during that time.

Lake Okeechobee as a Storage Reservoir

"It is proposed to control the flow from the lake and from the land which discharges its drainage into it by storing in the lake a part of the water which falls during months of heavy precipitation, and permitting it to flow through ditches to the ocean during the dry season of the year. The water may also be used during the season by renewing the supply in the Everglades. The lake will be lowered by the ditches to an elevation of 16 feet and may rise to an elevation of 21 feet before it overflows. It is proposed to allow the lake to rise 3 feet under the conditions of rainfall and runoff previously discussed, and to provide ditches with controlling gates at the lake ends to carry the remainder.

"The statement of the problem is as follows:

"Twenty-two per cent. of 24 inches of rainfall in 62 days on the Lake Okeechobee watershed—5.28 inches.

	Inches
Surface of lake raised by this inflow 5.28 inches 7-½	39.60
Depth of rainfall on the lake after deducting evaporation	5.28
Total depth collected on the lake in 62 days	44.88
Storage depth in the lake (733 sq. miles)	36.00
Depth to be removed by ditches	8.88

"Allowing 68 days for this amount to be discharged the depth per day will be 0.1306 inch and will require canals with a capacity to remove 2.572 feet per second. This plan of preventing the overflow of the lake requires that its level be gradually reduced during the dry season to an elevation of 16 feet. During the rainy season, assumed to be two consecutive months in the summer or fall, the water will rise to an elevation of 19 feet, during which time the flow through the ditches will increase as the depth of water becomes greater, reaching a maximum discharge when the level of the lake reaches the highest stage. It will be necessary to maintain either a natural or artificial bank along the south border of the lake to prevent the waves from breaking over the adjoining land.

"The foregoing examples indicate the prevailing drainage practice with respect to runoff from reclaimed lands. They are of assistance in planning drains for the Everglades insofar as the efficient conditions are intelligently

compared. The rainfall will at times be not less than 24 inches in two consecutive months, with possibly 15 inches in a single month. There will be no relief except through the ditches which finally discharge into the sea. While muck soils when dry absorb a large volume of water, they also require a large permanent supply where a thrifty growth of vegetation is desired. It is further observed that the total amount of drainage required for turf lands does not differ materially from that of other permeable or open soils. This is found to be true in central Wisconsin, where muck lands resting on a sand subsoil are being reclaimed. It may be safely assumed, however, that more water will be used by plants, and that the evaporation from the surface will be greater in the Florida climate than in more northern sections.

"With reference to the shape and size of the drainage units in the Everglades, it should be observed that the entire area should be divided by parallel ditches into drainage sections, each limited by the several outlet ditches of the system. Instead of being a large valley, with tributary streams which collect the water from the entire basin and finally discharge it into one stream, it will be a collection of drainage areas not exceeding 100 square miles each.

"Taking into acount such differences as now appear between areas which have been successfully drained and the Everglades, it is thought best to design the main ditches of sufficient **capacity to remove one-fourth inch in depth of water in 24 hours, which is equivalent to 6.72 cubic feet per second per square mile.** In the nature of the problem there is an uncertainty in this matter which can only be removed by constructing a series of drains which will be to some extent experimental. It is believed, however, that the drains should have greater capacity rather than less, in order to meet all the requirements of the land.

Ditches Required

"The ditches shown upon the map are designed to conduct water from the lake to tidewater and also to furnish outlet drainage to a strip of land one mile wide on each side. Additional ditches should be constructed parallel to these at intervals of 2 miles with sufficient capacity to care for the drainage of land for a mile on each side of them. Cross ditches one mile apart should connect these, thus dividing the land into blocks 1 mile wide by 2 miles long. This arrangement will permit interior drainage to be accomplished by ditches which need not be longer than one mile. The main drainage should not be considered complete until these ditches have been provided. The 2-mile canals should extend to the lake and there be furnished with gates by means of which water can be admitted for subirrigating the land during dry seasons. The height of the water in the ditches can be regulated by temporary dams and the supply be increased when desired by admitting water to them from the lake.

Cost of Excavation

"But little is known regarding the amount of rock that will be encountered in excavating the canals. The material excavated by the State dredges on the New River Canal near Fort Lauderdale is composed of about 20 per cent rock and 80 per cent muck. The cost of such work, as shown by the latest report of operations upon that ditch, is 8 cents per cubic yard for rock and 4 cents for muck. The rock is cheaply blasted and removed by the dredges. The estimates herein given are based upon these figures. It should be understood that the estimates of the amount of excavation and of the cost of work are based upon extremely meagre information concerning the material that will be encountered and contingencies which may arise during the execution of the work.

"A few further observations upon matters relating directly to the reclamation of the Everglades may profitably direct attention to certain contingencies which will modify the effectiveness of the system. The mean velocity of flow in the ditches will be so small that winds having a direction contrary to the current will have a very appreciable retarding effect upon their discharge. The maintenance of the ditches will be an important item because of the rapid growth of aquatic plants which are indigenous to that region. Unless these are removed at timely intervals, they will render the ditches partially or wholly inoperative. While the surface of the Everglades

is generally a plane and has been treated as such in the drainage plans which have been proposed, there are in reality runs or depressions in the Everglades probably 18 inches or more below the general surface which will not respond so easily to the drainage system as the lands of the general level. Occasional low islands also occur, which will suggest the propriety of deflecting the course of certain ditches which may be projected before a complete examination of the ground has been made.

"Brief mention has been made of the facilities for irrigating the land by using the water which will be stored in the lake. The water which will be stored during two months of large rainfall may be used the remainder of the year for mantaining a desirable height of water in the ditches, and in that manner subirrigate the land. For example, the precipitation at Miami during September and October, 1909, was 44.45 inches, an exceptionally large amount. Should such rain occur after the reclamation works have been constructed, the system would be taxed to its greatest capacity. The rainfall for February and March 1907 was only 0.88 inch, and frequently does not exceed 3 inches during those months, which conditions suggest the necessity for irrigation. Light muck soils dry easily and fail to produce well unless the supply of moisture is maintained quite uniformly during the growing season. The variation in monthly rainfall in Florida is as great as it is in the regions having heavy loam soils, yet the power of Florida muck to retain moisture is much less. The irrigation feature in connection with drainage should not be neglected, especially where it can be so easily secured.

"The plans and estimates herein given are only suggestive. The data and specific information which are necessary for the development of a thoroughly reliable plan of drainage have not yet been obtained, nor can such information be secured without a more complete examination of the Everglades, and a further investigation of the runoff conditions which are peculiar to southern Florida. The object of this report is to present a discussion of the various phases of the problem, to point out the factors which enter into it, and to direct attention to the manner in which the entire subject should be treated."

DISCUSSION OF MAJOR J. O. WRIGHT'S REPORT

An examination of Major Wright's report upon the drainage of the Everglades, in U. S. Senate Document 89, leads to the conclusion that not only were the basic data contained therein incomplete and inadequate, but data actually available were not utilized. Thus the exceedingly valuable and most significant rainfall records kept by the U. S. Weather Bureau were apparently overlooked. Certainly no weight was attached to them. Monthly records were given for but two stations, and no investigation was apparently made of the actual monthly distribution of rainfall over the Everglades through the available records of various other stations in southern Florida, nor of the distribution, duration and intensity of individual storms with reference to the Everglades, upon which the drainage plans must so largely depend. The data on evaporation which were given in the report were at least inapplicable under flood conditions, and the conclusions drawn from them were unwarranted either by the data discussed or by any other data with which your Board is familiar. Runoff data from similar low areas upon the Gulf or coast were unconsidered. Observed and recorded discharges from other drainage districts in the southern United States, of comparative value though not directly comparable, were unmentioned. The deductions as to the probable runoff were based upon unsound reasoning.

The uncertainties involved in basic data, upon which the report was predicated, were not clearly brought out, and the reader was left to infer that the conclusions were based upon sufficiently accurate data for the development of this great project, involving the expenditure of millions of dollars.

DISCUSSION OF REPORT AS MODIFIED BY MR. C. G. ELLIOTT

In the report as modified by Mr. Elliott, while but few additional data were presented, a clearer conception of the magnitude and uncertainties of the problem appears,—"The plans and estimates given are only suggestive;"

"The data and specific information which are necessary for the development of a thoroughly reliable plan of drainage have not yet been obtained."

Mr. Elliott called attention to current practice in other drainage works, and based his estimates of runoff and necessary ditch capacity upon the results of successful practice in other localities. He quoted discharge statistics from Southern rivers, and used those data as a basis for the plan of drainage which he presents, and this, a tentative one only. He showed his appreciation of his lack of data and exact knowledge, and impressed the reader with the urgent need of more comprehensive study and investigation of the subject before the preparation of final plans for the reclamation of the Everglades.

It is unfortunate indeed for the State of Florida, for the land companies interested in the sale of these lands, and for the numerous puchasers of small tracts that the warning conveyed in the Elliott revision of the original Wright report was not promptly published by the Department of Agriculture and thus made available for their information.

Cautious as the Elliott report is, we are of the opinion that it is still too optimistic, and that the capacities therein suggested are not as great as the available data indicate to be necessary for the final success of the work.

DISCUSSION OF AVAILABLE DATA RELATIVE TO THE DRAINAGE OF THE EVERGLADES

Your Board of Engineers fully recognize the lack of reliable information and the urgent necessity for full and careful investigation of many of the phases of this great problem; nevertheless, there is available much information which has apparently never been considered in detail in the discussion of the Everglades' problem. We have therefore attempted to collect and make a brief study of the more important of these data and have endeavored to point out some tentative conclusions, which seem warranted by the known facts, not only to make clear the magnitude of the problem and the great need of a comprehensive and exhaustive study of it, before an attempt is made to determine the most practicable method of draining the entire Everglades, but also to arrive at sound conclusions as to the best method for draining promptly your own lands.

RAINFALL

The average annual rainfall of the United States is shown on the map on page 59, from which it will be seen that the peninsula of Florida is within the broad area of maximum rainfall in the United States (50" to 60"), excepting only a few limited areas subject to still greater rainfall, shown by the full dark blue color on the map. The average annual distribution of rainfall in Florida is shown by the map on page 3. The annual rainfall on the Everglades (averaging 53 inches) is subject to much variation from year to year (36" to 65"). (See Tables Appendix 3). The total annual amount of rainfall is, however, not as important in the consideration of drainage problems as are its distribution, the character of the rainy season, and the frequency, distribution, magnitude and intensity of individual storms.

THE RAINY SEASON IN FLORIDA

The distribution of the rainfall during the year varies considerably upon the Florida peninsula. In general, 50% or more of the annual rainfall occurs within the three to four months' time included in "the rainy season". The rainy season, generally comprised within the months of June, July, August and September, often includes the months of October, especially along the Atlantic seaboard. (See Diagram page 62). Maps of the average monthly distribution of rainfall for June, July, August and September are shown in Appendix 5.

The annual rainfall of the peninsula equals in quantity the annual rainfall of Louisiana (see map, page 59), but its distribution is not so uniform (see Diagram page 62 and Table page 63), and a larger proportion occurs within the months mentioned, and that in greater intensity and in a distribution more difficult to handle by drainage work (see Mass Curves, Appendix 9).

NUMBER OF MONTHS OF HEAVY RAINFALL EXCESSIVE

If the rainfall records are examined in detail, it will be seen that the number of months of rainfall in excess of 10 inches is very much greater in Florida than in Louisiana. It should also be noted that usually months of heavy rainfall succeed each other with greater frequency in Florida than in Louisiana.

From the Table on page 65 it will be seen that between the years 1886 and 1912 there were at New Orleans 19 months in which the rainfall was ten inches or more, while during the same period the number of months of similar rainfall were 41 at Ft. Mead, 36 at Ft. Myers and 28 for Miami.

EXCESSIVE TWENTY-FOUR HOUR STORMS NOT EXPERIENCED IN UNUSUAL NUMBERS

In individual heavy rainstorms, of 2.50 inches per day and over, a greater number occur at Louisiana stations (as represented by New Orleans) than at the Florida stations investigated (see Table on page 66).

For the period, from 1900 to 1911 inclusive, the following number of storms of 2.5″ or more occurred at the stations investigated:

New Orleans	48
Ft. Mead	39
Ft. Myers	16
Miami	46

The Florida storms noted in this list frequently last for longer periods (several days), and hence, result in more adverse drainage conditions.

IN INTENSITY OF RAINFALL, FLORIDA STATIONS EXCEED MOST OTHERS IN THE UNITED STATES

In intensity of rainfall, both for one, two and three consecutive days, and for one, two and three consecutive months, the rainfall at various stations in Florida (see Table on page 68) is believed to be equaled or exceeded by few localities in the United States. In rainfall for brief periods, two hours or less, the records of Florida stations also show excessive amounts, especially when the brief time for which records are available is considered.

Many stations in the United States have recorded rainfall intensities as great as those at the Florida stations, but these are found in seventy year records. The ordinary probable maximum for other stations is much below the Florida record (see Curves B, C and D on the Diagram on page 69). The two-hour record at Key West, and the five and ten-minute record at Tampa, have been equaled by but few stations in the eastern United States. (See Apendix 8).

STUDY OF RAINFALL AFFECTING THE EVERGLADES SHOULD BE MADE FROM MAPS SHOWING THE RAINFALL DISTRIBUTION

The rainfall data from single stations are somewhat misleading as they indicate the local condition only. The extent of the storm producing the local record, can be determined only by a comparison of the simultaneous conditions at other stations.

In order to obtain a more definite idea of the actual distribution of rainfall throughout the Everglades, the total rainfall for the three months of maximum rainfall for each year from 1891 to 1911 inclusive, has been platted. (See Appendix 6).

The daily rainfall at the various stations on the peninsula of Florida (see Appendix 7) has also been studied in relation to certain specific storms, and platted on a series of maps as isohyetals or lines of equal rainfall, which are believed to give a better idea of the distribution of rainfall over the Everglades than can possibly be obtained from any simple examination of statistics.

EVAPORATION

Very little reliable information is to be had upon the evaporation from water or soil surfaces. Most of the experiments upon evaporation have been

made upon such a small scale and under such artificial conditions, as to lead to the suspicion that they do not correctly reproduce or represent the actual or natural conditions.

EVAPORATION DATA OF LITTLE VALUE IN RUNOFF CALCULATIONS

It is the opinion of your Board that, while evaporation is known to have a substantial effect upon runoff, the data available concerning its amount and variation under any conditions, are too meagre and too inadequate to warrant their use as a basis for even an approximate estimate of runoff. Moreover, if provision for the drainage of the Everglades must be made in large measure independent of storage in Lake Okeechobee, in consequence of the necessity for holding this storage for ultimate irrigation purposes, the comparatively small amount of available storage, and the impossibility of forecasting meteorological conditions, the effect of evaporation in reducing runoff will be of little importance, by reason of the excessively heavy rainfalls occurring in this region in periods of from three to ten days (3″ to 23″) and the fact that during the storms or the periods when the air is nearly saturated with water vapor, the actual evaporation is at a minimum and negligible in amount.

EVAPORATION MEASUREMENTS BY U. S. WEATHER BUREAU

In 1887 and 1888 the United States Weather Bureau made certain temperature observations with wet and dry bulb thermometers, from which the attempt was made to determine the variations in evaporation from water surfaces throughout the United States. The results of these experiments have been platted and are shown on Map on page 71. The information contained upon this map is by no means exact but rather comparative, indicative of the variations found in various parts of the country.

The estimates of the United States Weather Bureau for the total monthly evaporation in inches at Florida stations is as follows:

EVAPORATION IN INCHES AT CERTAIN FLORIDA STATIONS

(As Computed by the U. S. Weather Bureau from Wet and Dry Bulb Thermometer Readings)

	Jackson-ville	Titus-ville	Cedar Keys	Key West	Pensa-cola
Jan.	2.9″	3.5″	3.3″	3.8″	2.9″
Feb.	2.6	2.6	2.8	3.7	2.8
Mar.	3.8	3.3	4.0	3.8	4.1
Apr.	4.3	3.8	4.6	4.5	4.0
May	4.6	3.8	4.5	4.4	4.3
June	5.3	4.3	5.1	4.8	4.6
July	5.0	3.8	5.0	5.1	5.0
Aug.	4.7	4.3	5.5	5.1	5.4
Sept.	3.8	4.0	4.5	4.7	5.2
Oct.	3.6	4.1	4.1	4.3	4.5
Nov.	3.0	3.6	3.5	3.8	3.6
Dec.	2.1	3.1	2.6	3.6	2.4
	45.7″	44.2″	49.5″	51.6″	48.8″

EVAPORATION IN ARID REGIONS

In the arid regions where the rainfall is slight and where the humidity is very low, conditions favorable to maximum evaporation occur and the evaporation is consequently high. The results obtained under such conditions compare well with the evaporation assumed by Major Wright, but they are not at all applicable to Florida conditions.

Mr. Charles H. Lee (see Engineering News, October 12, 1911) made certain experiments of the soil evaporation near Independence, California, and

determined the evaporation in inches, from month to month, and the average precipitation to be as follows:

(Tables omitted)

These records are of importance only as showing that the maximum amount of evaporation is coincident with high temperature and low rainfall at the station.

MAJOR WRIGHT'S DISCUSSION OF EVAPORATION

In regard to the evaporation statistics quoted in his report (see page 47) it should be noted that Major Wright's deductions, based on conditions in other localities, are fallacious inasmuch as he takes the average of the observations during a number of months without making note of the corresponding temperature and hygrometric conditions, and of the amount of rainfall which occurred during the period considered. The Fargo, North Dakota, observations for May to September inclusive, over a period of four consecutive years, averaged 24″ for the five months stated, the July average reaching as high in amount as 8″. Elliott states that during the period the average monthly rainfall amounted to 16.8″ or 45 per cent. less than the observed evaporation, and the records show that for each month the average evaporation was greater than the rainfall. It is also known that during some of the periods covered by these observations, the season was so excessively wet that crops were injured by the lack of drainage.

The observations on the Croton River watershed in New York have little significance for Florida conditions. The 70% of the average annual evaporation which occurs from June to September inclusive, occurs there at a season when evaporation is at a maximum and with a low rainfall as compared with the rainy season in Florida. Similar observations made at Boston, Massachusetts, and Rochester, New York, are no criterions for Florida conditions.

The experiments on the consumption of water by crops, made by Reisler, Harrington and King deal with general averages in other latitudes and under climatic conditions differing largely from those prevailing in Florida, and they cannot therefore be applied to Florida conditions, under which maximum runoff must be determined for times of maximum rainfall and under conditions unfavorable to large evaporation.

RUNOFF

The runoff from any area, which may appear either as the flow of streams in definite channels or the broad surface flow resulting from flood conditions, is the direct result of rainfall distribution, modified by geological, topographical, and physical conditions which space will not permit us to discuss. A brief examination of the rainfall data already presented shows that the heaviest storms, which would naturally produce large runoff, are concentrated in limited areas, and it follows from these conditions that the runoff from small areas must be much greater, per unit of area, than from large areas. Extended observations upon numerous streams have clearly indicated the general law, to which there are few exceptions. This condition is well illustrated by the Kuichling diagram shown on page 77, upon which appear the actual maximum discharges observed upon various American (chiefly northeastern United States) and foreign rivers. A curve of limiting maximum flood discharges is also drawn, showing graphically the law held to apply under the conditions considered by him.

METHOD OF STUDY OF MAXIMUM RUNOFF

The intelligent study of the maximum runoff from the Everglades, or from any given drainage area, necessitates the determination of the law applicable to the region under question and this local law will be found to vary greatly with the particular conditions that there obtain. Thus note the curve in red placed by us on the Kuichling diagram for tentative use in Florida and for further example see Diagram on page 79 which shows two curves prepared by Mr. C. G. Elliott, the upper one developed by him for application in the Little River District of Arkansas, the lower for drainage ditches, swamps

and low lands in the Upper Mississippi Valley; a similar curve developed by Mr. Arthur E. Morgan as a basis for the estimate of the maximum discharge from ditches in Drainage District No. 9, Mississippi County, Arkansas; a curve prepared by us roughly indicating current practice in Louisiana; and finally a curve suggested by us for tentative use in the region of the Everglades. The first four of these curves are the result of study and actual observed runoff from districts where somewhat similar physical conditions prevail. The determination of a similar law for any given district must involve a study of all the rainfall and other physical conditions which there obtain.

THE RUNOFF PROVIDED FOR IN LOUISIANA

In certain drainage districts of Louisiana, which perhaps most nearly parallel the conditions found in the Everglades, the ditches and pumping plants built for drainage purposes are usually based upon a maximum runoff from ¾" to 1" in the 24 hours (see Appendix 12), or from 21 to 27 cubic feet per second per square mile of drainage area for areas of ten square miles or more.

In many of these districts the lagoons and bayous along the Mississippi River and its tributaries afford considerable storage reservoir capacities equivalent to from one to two inches or more over the entire area of the district. Under these conditions the pumping and main canal capacities need not be so great as when no storage is available; then the ditches and pumps must be able to handle the maximum rate of flow from the given area, as would be the case in the Everglades.

VALUE OF STORAGE

It should be noted that storage of this kind, where it already exists within a drainage district, while of distinct advantage in reducing the necessary pumping installation, yet it is seldom if ever of sufficient advantage to warrant the creation of such storage by new excavations. The cost of the necessary lands and of excavation is usually much greater than is warranted by the resulting benefit.

RUNOFF CONDITIONS IN THE EVERGLADES

Runoff conditions in the Everglades have practically not yet been determined and need further observation, investigation and study. The flows of various Southern rivers have been examined by us (Appendix 11), and while the observations upon these rivers are not strictly applicable, they are of some assistance in determining the conditions which may be anticipated. The intensity of the rainfalls which prevail lead us to believe that the runoff in the Everglades will be greater than in Louisiana.

RUNOFF OF THE CALOOSAHATCHEE RIVER

Calculations of the approximate flow of the Caloosahatchee River at Olga during the flood of October, 1910, were made by the U. S. Engineer Corps office at Jacksonville, and the discharge at that time was estimated at approximately 12,000 cubic feet per second. The flood of June, 1912, was occasioned by heavy rainfall (see Map on page 82) upon the drainage area contiguous to the Caloosahatchee River. The flood of that date was somewhat greater than the flood of October, 1910. The flow of the river was reversed (in the 1912 flood) from a point below Fort Thompson to Lake Okeechobee (see Drawing 2, Appendix 13), and the resulting discharge at Olga, which must have been greater than 12,000 cubic feet per second, seems to have been contributed from an area (see Drawing 6, Appendix 13) of about 500 square miles, so nearly as we can judge, which would be equivalent to about 24 cubic feet per second per square mile, or 0.9 of an inch per 24 hours, and this continued for a period of more than one day. The data, especially as to the area from which the drainage waters were discharged, are only approximate. They are clearly indicative, however, of a high rate of flow from this territory.

RUNOFF FROM DRAINAGE AREA OF LAKE OKEECHOBEE

In the same storm, June 1912, the level of Lake Okeechobee rose 12 inches in seven days from June 7 to 14 (see Appendix 1), and continued to

rise at a less rate for some time. Estimating the drainage area tributary of Lake Okeechobee at 6,000 square miles, and the area of the lake at 710 square miles, the average discharge from this area was 710 x 12 / 6,000 x 7=0.2 of an inch per day over the entire drainage area for a seven day period. As the above discharge was the average for a seven day period, the maximum discharge must certainly have been as much, at least, as 1¼ inch per 24 hours, and it is not improbable that it was substantially greater.

In this connection it should be noted (see Map page 82) that the center of the storm was west of Lake Okeechobee, and that its drainage area therefore probably did not discharge the maximum that must be anticipated.

The partially completed South New River, North New River, and Hillsboro Canals, and possibly other outlets, were discharging water from the lake during the rise, while the canal from the Caloosahatchee River was discharging water into the lake. Whatever this outward flow may have been it would augment the intensity of runoff computed above and might increase the latter from 5 to 10%.

RUNOFF FROM MUCK LANDS

Much stress has been laid upon the porosity of the muck soil of the Everglades, and its ability to absorb quantities of water. It must be remembered, however, that when the Everglades are successfully drained and thoroughly cultivated, a change will take place in the character of the muck, and that the soil above the water table will become different in character, more impervious and less absorbent. As pointed out by Mr. Elliott, it has not been found under Wisconsin conditions that the quantity of drainage from peat and muck lands is greatly different from similar districts with other soils, and it seems probable that no marked difference in the quantity of runoff can be anticipated in the long run on account of the character of the soil of the Everglades.

TENTATIVE CONCLUSIONS AS TO NECESSARY CANAL CAPACITIES FOR EVERGLADES LANDS

We conclude tentatively, therefore, that for complete drainage, when the areas are fairly concentrated, the ditch or canal capacities should provide for a discharge of about **1½" per 24 hours, or 40 cubic feet per second per square mile of drainage area on land tracts of 50 square miles or less; not less than ¾" per 24 hours, or 21 cubic feet per second per square mile on tracts of about 200 square miles; not less than ½" per 24 hours or 14 cubic feet per second per square mile on tracts of about 750 square miles;** and that if the whole drainage discharge of the Everglades were concentrated in a single canal, it would not be safe to estimate upon a capacity at its outlet of less than **¼" in depth of runoff per 24 hours, or 7 cubic feet per second per square mile of drainage area.**

For immediate construction purposes, it will probably be undesirable to design ditches for the smaller land areas for more than one inch capacity in 24 hours. This will probably afford ample drainage under most conditions but may result in limited overflow during occasional heavy storms.

MAXIMUM FLOOD NOT PROVIDED FOR

We do not consider it necessary to provide drainage facilities to remove the largest floods that may be expected in a long term of years. To do this would involve an investment in canals and other facilities not justified to avoid floods that occur only at long intervals. The intention throughout this report has been to provide drainage for floods likely to recur with sufficient frequency so that it was advisable to provide for their complete removal. The data upon which to estimate these quantities are extremely meagre. It must be recognized that experience in the actual operations of drainage will modify them as the years go on. For the present we have intended to keep in mind moderate figures which would certainly provide a degree of drainage sufficient to demonstrate the possibilities of the project and probably sufficient to meet all reasonable requirements for early years. The question of whether additional facilities, and if so to what degree, would be required for

the ultimate development, may appropriately be left for determination after actual experience is available. All the figures hereinafter mentioned for the capacity of canals are to be understood in this way, and it must be recognized that occasionally at times of very heavy rains, there will be floods that will probably overtax the works now suggested.

STORAGE FOR IRRIGATION OR FOR STORM FLOODS IN LAKE OKEECHOBEE

There can be no doubt that the greatest value of Lake Okeechobee lies in its future availability for irrigation purposes. The storage capacity between the limits of 16 and 19 feet (above sea level) projected by the State would give a total storage of 3 feet upon 710 square miles, or 1,363,000 acre feet to irrigate two million or more acres of land. An examination of the rainfall and temperature records shows that during the dry winter months the rainfall is so slight and the evaporation necessarily so considerable, that the quantity of water available even with a full reservoir, would be insufficient for proper irrigation of the area which, judging from results of practice in irrigated regions elsewhere, would perhaps require from 12 to 18 inches in depth of water during the crop growing season. It is probable, therefore, that ultimately it will be advantageous to meterially increase the maximum level of Lake Okeechobee by the construction of adequate dikes along the low western and southern margins of the lake. This possibility should receive thorough study and investigation.

LAKE OKEECHOBEE SHOULD BE CONTROLLED BY INDEPENDENT CANALS

It is our opinion that the flood waters from Lake Okeechobee must practically be controlled by a canal or canals constructed essentially for that purpose, and that it is impracticable to accomplish this control by long canals designed for both drainage of the lands of the Everglades and for the control of Lake Okeechobee.

The importance of irrigation must be recognized, and the system of drainage canals for the Everglades should be so designed or supplemented with additional canals that the irrigation waters from the lake may be brought to the lands for that purpose.

PROBABLE RUNOFF FROM LAKE OKEECHOBEE

It is the opinion of your Board that the amount or water to be removed from Lake Okeechobee during floods will not be less than one-fourth of an inch of runoff per 24 hours, and that it may be, in fact, considerably greater in exceptional rains; but during a considerable period of years, while the development of the Everglades is taking place, and during which the water of the lake is not used for irrigation, it will be possible to ordinarily hold the lake level at a low stage, and to use the storage in the lake temporarily for flood waters. Under those conditions half the flood flows, more or less, may be stored temporarily, and canals having a smaller capacity, or perhaps not more than one-eighth of an inch runoff per 24 hours, may suffice.

CAPACITY OF CANALS NEEDED TO CONTROL LAKE OKEECHOBEE

Upon this basis the flood flow to be ultimately provided will be 40,000 cubic feet per second, requiring a channel from Lake Okeechobee to the seaboard upon the shortest practicable route, approximately 1000 feet wide and 15 feet in depth below elevation 18 at the lake and 15 feet below sea level at the point of discharge. For immediate requirements, with storage capacity in the lake utilized for storing flood flows, to be discharged as soon as possible, without holding them for use in irrigation, 20,000 cubic feet per second must be provided for, requiring a canal 500 feet wide, and of the depth previously mentioned.

These quantities refer to the control of Lake Okeechobee, and are independent of the drainage district lying south of the lake.

CANALS NEEDED FOR THE DRAINAGE OF THE EVERGLADES

Without attempting to outline a practical plan for drainage and irrigation of the Everglades, it may be of interest to consider the approximate size and distribution of a series of canals which would be sufficient. If, for example, the Everglades were to be drained by a system of canals running east from the west side of the Everglades and provided with proper outlets to the seaboard, and if these canals were spaced three miles apart, allowing each to drain the territory one and one-half miles on each side of it, these canals would drain an area three miles wide and an average of about 50 miles in length, or a total of 150 square miles.

Upon such a long narrow strip, the distribution of the rainfall would probably be such that a runoff of not more than one-half inch per 24 hours need be anticipated. On this basis, the main canal for draining each of these areas should have, at the outlet, a capacity of 150 sq. mi. x 13.44 cu. ft. per sec. per sq. mi. = 2100 cu. ft. per sec.

Such canals would have a mean slope of about 0.2 foot per mile, and for the capacity estimated should have at their outlets water sections about 110 feet wide and 12 feet in depth.

In the actual plans for reclamation, fewer and larger outlets would naturally be used by the union of a number of these canals into a common outlet. The above calculation will, however, give some conception of the magnitude of the problem and of the extensive system of canals necessary for the final reclamation of the Everglade.

ULTIMATE SUCCESS ASSURED

No one can carefully examine the results already achieved on the lands on the borders of Lake Okeechobee at the Callahan nursery, in the gardens at Rita, in the experimental station at Miami, and in the various developments along the Everglades near Miami and Fort Lauderdale, without feeling confident of the ultimate agricultural success which will result from the reclamation of the Everglades lands. These lands have the advantage of a great market within much less distance than the irrigated lands of the West, and have the advantage of a climate that will permit the growth of agricultural produce at a time when it is not available elsewhere. As the problem of supply and demand becomes progressively adjusted by development of transportation facilities, by rate adjustments, by a thorough knowledge of agricultural possibilities and practicabilities, as determined in the light of all these factors, there can be no doubt that the entire Everglades can and will be successfully reclaimed. Conservative optimism must admit, however, that the safe and sane development of this vast tract will require a large expenditure of time and money in agricultural experimentation, in the development of suitable markets, and in the adjustment of agricultural supply to the market demand.

TIME REQUIRED FOR DEVELOPMENT OF TRANSPORTATION FACILITIES

Even were it financially possible to complete the drainage of the Everglades promptly, it must be remembered that years will be required to build up transportation facilities needed to move the crops involved in the cultivation of this large tract of land. The marked development in winter market gardening in the vicinity of Ft. Lauderdale and Miami, now carried on along the edges of the Everglades, while of comparative limited extent, has resulted in freight congestion and heavy losses on account of inadequate transportation facilities, and time only will permit of equipment sufficient to meet a still more marked development along this line. The area is so great and the possibilities so large that other and more extended transportation facilities will have to be provided through and from the Everglades.

TIME REQUIRED FOR AGRICULTURAL AND COMMERCIAL DEVELOPMENT

The successful agricultural development of two million acres, farmed in ten acre tracts, for market gardening and the production of easily perishable produce, seems entirely impracticable. The bulk of the Everglade lands

must be developed in large tracts for citrus orchards, sub-tropical fruits, sugar cane or other produce for which these lands are adapted and which in their nature are not readily perishable.

Parallel with agricultural must come commercial development. The development of the canning industry, the establishment of sugar factories, and of other industries dependent upon agriculture, must parallel the agricultural development of the land. The complete agricultural development of the country will require extensive construction of houses and increase in facilities and conveniences, along lines always entailed by growth in population. Under the best of conditions, such growth must be slow:

DANGER OF GROWTH OF JUNGLE DUE TO TOO RAPID DEVELOPMENT

It is evident by the luxuriant growth of vegetation that has rapidly followed the progress of canal construction southward from Lake Okeechobee, that if the land was successfully drained long prior to its agricultural ulitization, a jungle would soon develop which would be more difficult and expensive to subdue and bring under cultivation than the saw grass lands which at present constitute almost the only vegatation of the Everglades.

DANGER FROM FIRES DUE TO TOO RAPID DEVELOPMENT

The rapid draining of the Everglades, far in advance of agricultural development, would also entail a still greater danger from the probability of the total destruction of large areas of the newly drained muck lands by fires. The newly drained lands must be carefully guarded from this danger until the muck has decomposed and is beyond the danger of destruction from this cause. The frequent fires in northern peat bogs during unusually dry seasons, and the impossibility of controlling them, demonstrates this danger.

BAD RESULTS FROM FORCED DEVELOPMENT

A too rapid growth will result in congestion, extravagance, loss and disappointment. Ill-advised attempts at too rapid development, while possibly profitable to the few, must result in great loss to the many, and mean injury to the development of the State. Real progress, and the greatest good to the State itself, will come from slow, substantial, progressive development which is the most certain, the safest, and ultimately the best for all concerned. When the great financial investment is considered, such development is the only practical way in which the problem of the reclamation of the Everglades can be accomplished.

LOGICAL SYSTEM FOR THE DEVELOPMENT OF THE EVERGLADES

It follows logically that if the drainage of the Everglades is to be successfully accomplished, the lands adjacent to centers of population and to transportation facilities, and which also are close to natural or artificial outlets, should be the first to be reclaimed.

The ultimate lines of development should, however, be thoroughly canvassed, and plans should be matured on such a comprehensive scale that future complications will be avoided and final success assured.

IMMEDIATE EFFECTIVE DRAINAGE OF LANDS DEPENDENT ON INDIVIDUAL EFFORT

From our study of this problem, we are forced to conclude that in no cases which have come under our notice can the owners of land within the Everglades expect effective drainage, so far as their individual lands are concerned, from the work now under way or projected by the State of Florida; nor can it be anticipated that the State will be able to give early relief from the conditions that obtain. In our judgment, the available funds of the State can best be applied at the present time to a thorough study of the entire problem, to furnishing adequate outlets to the ocean through artificial and enlarged natural channels, and to the control of Lake Okeechobee. If the funds

that can be raised by the State of Florida are sufficient to accomplish these results, it is believed to be all that can be anticipated at the present time.

In our judgment, therefore, the successful reclamation of the private lands within the Everglades is largely dependent upon private effort. Without works of your own, we believe that the various lands controlled by you will be subject to frequent inundation which will make continuous agricultural operations upon them impracticable.

SEPARATION OF LANDS UNFORTUNATE

The method adopted by the State of Florida of selling alternate instead of contiguous sections of land is unfortuate, inasmuch as it makes the problem of drainage by individual effort much more difficult.

STATE DRAINAGE ACT NECESSARY

We were advised by the Trustees of the Internal Improvement Fund that a drainage act would probably be passed at the coming session of the legislature.

Obviously such an act will be necessary if property owners are to act independently or in groups upon the problem of draining their lands without waiting for final action by the State. The passage of such an act is of importance as it will simplify the obtaining of consent to proceed with effective private drainage, and should make possible co-operation with all of the land holders who will be benefited by any improvement work which may be projected.

DRAINAGE OF THE LANDS SOLD OR CONTROLLED BY THE EVERGLADE LAND SALES COMPANY AND ASSOCIATED COMPANIES

Fortunately, certain of your lands are contiguous so that they can in any event be drained in four tracts.

EXCHANGE OF CERTAIN LANDS DESIRABLE

It would be of distinct advantage if exchange of certain of your lands could be effected so as to bring your property into one or two areas, thus reducing to a minium the cost of diking, ditching and canalization.

The co-operation of the State, and perhaps of individual property owners or corporations holding large tracts of land, will be necessary to accomplish this; but it seems likely that the Trustees of the Internal Improvement Fund will assist in such an exchange of lands as far as possible in view of the conditions under which these lands have been purchased from the State, and as a means of assisting in the earlier development of this territory, thus benefiting the State as well as the individual, by the increase in value of real estate which will inevitably result, and which will make it possible for the State to realize increasing returns upon the lands which may sell hereafter.

It has been assumed in our report that such exchange of lands could, and would be effected by you, and our studies of drainage have been made on certain alternative schemes involving the segregation of all of your lands in one, two and four parcels.

PRESENT CONDITION OF YOUR LANDS

With the exception of certain sloughs, the lands of the Davie Tract lie about 5½ feet above mean low water in Biscayne Bay. The lands in the other tracts owned by you are apparently 8 feet and less above the same datum.

About May 15, of the present year, all of these lands were overflowed as a result of an early and severe rainy season.

At the seven mile post of the North New River Canal at the point where this canal is joined by the Royal Glade Canal, now under construction, the water elevation has been approximately as follows:

	Ft. above Mean Low Tide
February 14,	6.2
June 27,	9.4
July 22,	8.8

August 1,	8.6
August 15,	8.4
September 1,	8.2
September 15,	8.0
October 1,	8.0

At the time of the visit of the Board (August 8 and 9), very little of the middle tract, as viewed from the north end of Miami Canal (see photograph page 21) seemed to be above water, and the lands of the Royal Glade Tract (see photograph pages 98 and 23) were practically submerged.

On the same dates, the Davie Tract, on account of its location near the junction of the canal with the South New River (see photograph page 96) was partially free from water, and it was wholly so on October 6, on the occasion of a subsequent visit of Mr. Mead (see photographs page 100 and 101), although the lands of the Royal Glade Tract were still largely submerged.

We are informed that, excepting certain sloughs, the lands adjacent to the eastern edge of the Everglades are commonly free from water during the winter season, and many of these lands are then utilized for the raising of garden produce. This condition holds for all or most of the land owned by you.

Mr. H. D. Miller, of the Everglades Land Sales Company, informed the Board that in the last 16 years the Everglades Lands near Miami and Ft. Lauderdale had been flooded three times during the period of winter cropping, and that these same lands were always flooded during the rainy season.

POSSIBLE METHODS OF RECLAIMING THE LANDS OF THE EVERGLADE LAND SALES COMPANY AND ASSOCIATED COMPANIES

Inasmuch as the projected canals of the State of Florida can not successfully drain your lands, we have investigated the following different methods for draining these lands independent of the action of the State.

1. By gravity, by the construction of a large canal discharging at the Atlantic Seaboard.
2. By pumping
3. By a combined scheme for drainage in part by gravity, in part pumping.

DIKING OF LANDS NECESSARY

Whatever scheme is adopted by you for the drainage of your lands, independent of the territory surrounding them, it will be necessary to construct dikes or embankments around your lands to prevent their being flooded during the season of high water in the Everglades.

The underlying Coraline rock, which is at a depth varying perhaps from 5 to 15 feet or more below the surface of the ground, is covered, at least under some of your property, by layers of marl and fine sand upon which rests a layer of muck varying in depth from two to six feet, more or less. As the character and the depths of the materials overlying the rocks vary considerably, we have suggested the construction of the embankment or dike in the following manner, the suggested cross section being shown on the sketch on page 104.

It is suggested that a narrow trench, four feet, more or less, in width, be excavated first on the center line of the proposed embankment, the material being taken there from being dumped within the lines of the proposed embankment, and that this trench be backfilled with the best available material taken out of the canal adjacent to the embankment, the construction of which will be carried on at the same time. In this manner a core can be built in the embankment, of the most impervious material available, without greatly increasing its cost. The rest of the embankment work will then be completed from the material removed from the canal. While the material in the embankment will be compacted in considerable measure by the process of construction, it will probably be necessary to build it two feet, more or less, above the final surface decided upon, which has been placed tentatively by us at an elevation of five feet above the present ground surface in order to allow for subequent shrinkage.

An embankment section sixteen feet in width on top, with side slopes

1½ horizontal to 1 vertical, and with an eight foot berm on the inside of the embankment adjacent to the canal, is suggested. The side slopes of the canal may have to be varied, according to the character of the material traversed by it, but can probably be built as steep as 1 to 1, as we found the embankments of a considerable portion of the canals traversed by us were standing successfully on a slope of ½ horizontal to 1 vertical.

The final height necessary for the dikes or circumferential embankments will, of course, have to be determined after a careful study of the extreme high water levels prevailing in the Everglades, with allowance for the influence of the canals which have recently been constructed by the State, or which may be added hereafter.

SHRINKAGE OF MUCK LANDS

Specific data are lacking as to the probable amount of shrinkage in the muck soil of the Everglades. We interviewed a number of men upon this subject during our stay in Florida, among them Major Wright, and Captain Rose, Chemist of the State of Florida, who has had considerable experience with the soils of this region and who was in charge of the St. Cloud sugar plantations in the Kissimmee Valley at the time of its development by Mr. Disston in 1885. The consensus of opinion seemed to be that a shrinkage of at least thirty per cent and perhaps as much as forty per cent should be provided for in that portion of the soil lying above the ground water level after drainage. From experience in other parts of the country with peat and other similar soils, we are of the opinion that a shrinkage of at least fifty per cent in the depth of the drained soil should be provided for even though this shrinkage may not exceed thirty percent more or less during the first few years. Continued cultivation will gradually change the character of the top soil and result in its further compacting and settlement.

Therefore in our plans we have made allowances for shrinkage to about this limit (40%) not only in the embankment, but also in the surface of the ground, with reference to its effect upon the water level which may be maintained successfully in the ditches and canals.

LATERAL DITCHING

The lateral ditches, for which provision has already been made by you in your contemplated development of these lands, and which are nine feet in width and five and one-half feet in depth, with side slopes one to one, and built one-fourth of a mile apart, will be sufficient for the purpose of lateral drainage and will successfully serve the strips of land adjacent to them for a distance of two miles, measured along the line of the ditches. The ditches must, of course, be kept free from organic growth and other obstructions.

The four foot ditches projected by you for certain localities are not recommended on account of the shrinkage of ground and consequent reduction in carrying capacity.

WATER LEVELS IN DITCHES AND CANALS

We have assumed that, for agricultural purposes, the water in the main canals should be kept ordinarily about three feet below the final elevation of the surface of the ground; and as shrinkage of the muck, resulting from drainage and cultivation, will lower the ground level by approximately two feet, the normal carrying capacity of the main canals has been calculated with the water level five feet below the present surface of the muck.

We have assumed, however, that during exceptional floods the water level at the end of the lateral canals may rise temporarily two feet or to a level one foot below the assumed ultimate ground surface without injury to the trees and crops. This may cause the water level at the extreme end of some of the lateral ditches to rise occasionally for a brief period to the surface of the ground. The raising of the ground water level to such a degree, occasionally, during the rainy season or times of heaviest storm, we are assured by those who have worked in this region and soil, will not permanently injure the fruit groves or crops.

DRAINGE BY GRAVITY

We have outlined and investigated a project for the drainage of your lands by gravity. The general plan suggested is shown upon page 108 and the profile on Drawing 1, Appendix 13. This project involves the exchange of certain of your present holdings for lands that will lie within one rectangular strip, comprising approximately 186 square miles, although the property controlled by you amounts to but two-thirds of this area, approximately 121 square miles.

It is suggested that the location of the portion of the South New River Canal not yet built should be modified so as to run along the northern boundary of your property, or that such portion of this property as lies upon the northern side of the proposed canal should be exchanged for lands lying south of it; and that the land comprised in your southerly tract should be exchanged for land contiguous to the other tract within the rectangular tract suggested.

It is further proposed that the easterly boundary of this rectangular tract shall be upon the highland lying east of the Everglades. Plans showing the proposed arrangement of main canals, profiles, cross and typical sections and the estimate of cost of drainage by this project have been outlined in some detail in our preliminary report of September 14, 1912.

Suffice to say, with reference to this gravity drainage project, that the elevation above the sea level is adequate and the method is a desirable one if practicable and not too expensive. The objections to this plan are that it involves obtaining from the State, authority to exclude from the main outlet canal all drainage water other than those coming from your lands, and to close that portion of the Miami Canal which under the projected plans will traverse your lands diagonally. It involves also the purchase of the necessary right-of-way for the construction of the outlet canal, and very high cost of installation resulting in high fixed charges, in large measure regardless of the extent to which the lands drained may be cultivated or opened up.

We are of the opinion that this plan is the least attractive of the three general plans considered.

DRAINAGE BY PUMPING

Two general projects for the drainage of your properties by pumping have been considered. The first of these, shown on the sketch on page 110, involves the segregation of your land in two parcels by the exchange of the southerly tract, No. 5, for lands lying between and connecting with the westerly end of Tracts Nos. 3 and 4. The second, shown on the sketch on page 112, involves the drainage of four different parcels of land, essentially as they now exist.

Three general methods of pumping have been considered, outlined and estimated upon:

1. Electrical pumping with a central power plant located at Ft. Lauderdale, with high tension electric transmission and separate motor driven pumps at the various pumping stations upon the different tracts of land.
2. Individual pumping plants, driven by steam engines.
3. Individual pumping plants, driven by oil engines.

A pumping capacity, capable of handling a runoff of approximately one inch in 24 hours from the area drained, has been suggested for immediate installation, with provision for future increase to the extent of thirty or even fifty per cent, with progressive development in the cultivation of the lands served. The tentative locations of the pumping stations, with memorandum of tributary drainage areas and quantities of water to be handled, appear in Tables on pages 113 and 114.

The estimated costs of these alternative developments have already been submitted in the preliminary report.

The information thus far collected indicates that the steam plant installation seems to offer some slight advantages over the others.

The project for drainage by pumping has the merits of smaller cost of

installation, ready enlargement to meet the growing needs of the future, operating cost in large measure dependent upon the rainfall, and flexibility in operation. It has one great advantage not possessed by the gravity scheme in that it lends itself advantageously to the future development of an irrigation scheme for these lands which shall utilize the pumping plant during the dry season, when it would otherwise be out of commission, without materially increasing the fixed charges upon the plant.

DRAINAGE IN PART BY GRAVITY, IN PART BY PUMPING

Finally there has been considered a project for segregating your lands into two or four parcels, and draining the easterly parcel by gravity by an outlet canal discharging into the Atlantic Ocean, along the same general lines, but of less magnitude, than that involved in the gravity scheme first outlined; and draining the remaining parcels by pumping, in the same general manner outlined in the pumping project described above.

This project, as the others, involves some interchange of land, diking and canalization, and the construction of various pumping stations and the main outlet canal. In its details it is similar to the scheme previously described.

The final decision, as to which of these projects is to be preferred, may perhaps advantageously be suspended until you can determine the feasibility of co-operation with the State authorities in the exchange of lands, the construction of a gravity outlet from your lands, and the possibility of securing by purchase, or otherwise, the necessary rights-of-way upon which to locate this outlet canal. Present indications point to the all pumping project as likely to be the most practicable and advantageous, although the scheme for drainage in part by gravity, in part by pumping, has distinct merit if it is feasible. While the scheme for draining the entire property by gravity alone is desirable from an operating point of view, the first cost seems to us prohibitive under existing conditions.

As to the choice between pumping by steam, electricity or oil, present evidence indicates that the steam driven plant will prove more advantageous under existing circumstances; but this subject is worthy of further study.

STATE CO-OPERATION

In carrying out the plans for the drainage of your property, the co-operation of the State authorities, and more particularly the Trustees of the Internal Improvement Fund of the State of Florida, is desirable:

1. In the passage of a sound drainage act.
2. In the exchange of lands so as to segregate your land holdings into as few and compact parcels as possible.
3. In the enlarging of the New River, the Miami River and Canal, and Snake Creek.
4. In the increase in number and magnitude of outlets from the Everglades to the sea.
5. In the abandonment of the section of the proposed Miami Canal crossing your property diagonally southeasterly from its junction with the South New River Canal.
6. In granting authority to you to build certain locks between the canals proposed by you for construction upon your property and canals heretofore built or projected by the State.
7. In limiting the speed of power boats upon the canals to prevent the unreasonable washing or slipping away of the banks of these canals.
8. In the control of the water hyacinths and similar aquatic growths.

We assume that all necessary co-operation can be secured. Should you determine to drain and reclaim your lands, doing the work independently of the action of the State if necessary, your lands will be the first lands in

the Everglades to be reclaimed on any considerable scale. Such pioneer reclamation will be of the greatest advantage to the State and to all individual land owners within the Everglades, for it will demonstrate beyond question **the fact that the reclamation of the Everglades is practicable both as an engineering and as a financial undertaking.**

The Board of Engineers expresses its obligations for information furnished and courtesies extended to it by the Trustees of the Internal Improvement Fund of the State of Florida, and their former Chief Engineer, Major J. O. Wright; by Captain H. H. Slattery, U. S. A., in charge of the Jacksonville office of the U. S. Engineer Corps; by A. J. Mitchell, Forecaster, U. S. Weather Bureau at Jacksonville; and by the officers of the Everglade Land Sales Company.

Respectfully submitted,

(Signed) DANIEL W. MEAD
(Signed) ALLEN HAAZEN
(Signed) LEONARD METCALF

Board of Consulting Engineers