IN THE

SUPREME COURT OF THE UNITED STATES.

OCTOBER TERM, 1929.

State of Wisconsin, State of Minnesota, State of Ohio, and State of Pennsylvania, Complainants,

vs.

State of Illinois and Sanitary District of Chicago, Defendants.

State of Missouri, State of Kentucky, State of Tennessee, State of Louisiana, State of Mississippi, and State of Arkansas, Intervening Defendants.

No. 7 Original.

State of Michigan, Complainant,

vs.

State of Illinois and Sanitary District of Chicago, Defendants.

No. 11 Original.

State of New York, Complainant,

vs.

State of Illinois and Sanitary District of Chicago, Defendants.

No. 12 Original.

REPORT OF THE SPECIAL MASTER ON RE-REFERENCE.

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REPORT OF THE SPECIAL MASTER ON RE-REFERENCE.

Pursuant to the order herein, of January 14, 1929, the parties, the complainants and the defendants State of Illinois and Sanitary District of Chicago, having appeared before me at public hearings in the City of Chicago and in the City of Washington, District of Columbia, at various times between March 25, 1929, and October 4, 1929, and having presented their evidence, and the testimony of cer-

tain witnesses called by me having also been received, and the said parties having been heard in argument with respect to the findings of fact, conclusions of law, and recommendations for a decree, which they have requested, respectively, and the matter having been finally submitted on October 18, 1929, I have reported the testimony thus taken, with exhibits, by filing the same in the Office of the Clerk of this Court with my certificate; and I now submit to the Court the following report, setting forth my conclusions and recommendations for a decree.

The Questions Referred to The Special Master.

By its order of January 14, 1929, the cause was referred to me as Special Master "for further examination into the questions indicated by the opinion of this Court this day announced". After referring to the unauthorized increase of the diversion by the Sanitary District of Chicago, pending the suit of the United States, from 4167 cubic feet per second to 8500 cubic feet per second in order to dispose of the sewage in the Sanitary District, and to the exigency which was met by the permit of the Secretary of War of March 3, 1925, which permitted temporarily and upon stated conditions a diversion of 8500 c. f. s.,* the Court said (278 U. S. 367, 418-421):

> "It will be perceived that the interference which was the basis of the Secretary's permit, and which the latter was intended to eliminate, resulted directly from the failure of the Sanitary District to take care of its sewage in some way other than by promoting or continuing the existing diversion. It may be that some flow from the Lake is necessary to keep up navigation in the Chicago River, which really is part of the Port of Chicago, but that amount is negligible as compared with 8,500 second feet now being diverted. Hence,

*For convenience, the abbreviation c. f. s. will be used for cubic feet per second.

beyond that negligible quantity, the validity of the Secretary's permit derives its support entirely from a situation produced by the Sanitary District in violation of the complainants' rights; and but for that support complainants might properly press for an immediate shutting down by injunction of the diversion, save any small part needed to maintain navigation in the river. In these circumstances we think they are entitled to a decree which will be effective in bringing that violation and the unwarranted part of the diversion to an end. But in keeping with the principles on which courts of equity condition their relief, and by way of avoiding any unnecessary hazard to the health of the people of that section, our decree should be so framed as to accord to the Sanitary District a reasonably practicable time within which to provide some other means of disposing of the sewage, reducing the diversion as the artificial disposition of the sewage increases from time to time, until it is entirely disposed of thereby, when there shall be a final, permanent operative and effective injunction.

* * * * * * *

"In increasing the diversion from 4,167 cubic feet a second to 8,500, the Sanitary District defied the authority of the National Government resting in the Secretary of War. And in so far as the prior diversion was not for the purposes of maintaining navigation in the Chicago River it was without any legal basis, because made for an inadmissible purpose. It therefore is the duty of this Court by an appropriate decree to compel the reduction of the diversion to a point where it rests on a legal basis and thus to restore the navigable capacity of Lake Michigan to its proper level. The Sanitary District authorities, relying on the argument with reference to the health of its people, have much too long delayed the needed substitution of suitable sewage plants as a means of avoiding the diversion in the future. Therefore they can not now complain if an immediately heavy burden is placed upon the District because of their attitude and course. The situation re-

quires the District to devise proper methods for providing sufficient money and to construct and put in operation with all reasonable expedition adequate plants for the disposition of the sewage through other means than the Lake diversion.

"Though the restoration of just rights to the complainants will be gradual instead of immediate it must be continuous and as speedy as practicable, and must include everything that is essential to an effective project.

* * * * * * *

"To determine the practical measures needed to effect the object just stated and the period required for their completion there will be need for the examination of experts; and the appropriate provisions of the necessary decree will require careful consideration. For this reason, the case will be again referred to the Master for a further examination into the questions indicated."

The questions thus indicated are deemed to be these:

(1) What are the practical measures necessary for the disposition of the sewage of the Sanitary District of Chicago through other means than the diversion of water from Lake Michigan;

(2) Within what time can these sewage disposal works be completed and put into operation;

(3) What reductions in the diversion will be practicable immediately, and from time to time, pending the completion of the sewage disposal works;

(4) What diversion, if any, of water from Lake Michigan will be necessary for the purpose of maintaining navigation in the Chicago River, as a part of the Port of Chicago, after these sewage disposal works are in full operation?

Findings of Fact.

First. *The practical measures necessary for the disposition of the sewage of the Sanitary District of Chicago through other means than lake diversion.*

The area of the Sanitary District of Chicago (as increased in 1927) comprises approximately 442 square miles, extending from the Illinois State Line on the south and east to the boundary of Cook County on the north, with about 34 miles of frontage on Lake Michigan, thus embracing Chicago and its suburbs. There are 60 municipalities wholly or partly within its limits, with an estimated population of about 3,500,000.

1. *The present situation.*

There are at present within the Sanitary District six works for sewage treatment: the Des Plaines River Works, the North Side Works, and the Calumet Works, and the three small plants known as the Morton Grove, the Glen View and the North-brook.

The North Side Works are completed except that the North Side Pumping Station, which is essential to full operation, is still unfinished. There is also in course of construction the plant known as the West Side Sewage Treatment Works.

The permit issued by the Secretary of War on March 3, 1925, provided as one of its conditions that the Sanitary District should "carry out a program of sewage treatment by artificial processes which will provide the equivalent of the complete (100%) treatment of the sewage of a human population of at least 1,200,000 before the expiration of the permit" on December 31, 1929.

Colonel Schulz, Division Engineer of the Lakes' Division of the Corps of Engineers, United States Army, formerly District Engineer at Chicago, testified (March 25, 1929) as to the existing status of sewage treatment as follows:

"The present status of sewage treatment, including construction work carried out by the Sanitary District, covers the Des Plaines River, 47,000 people, on 100% basis; the Calumet Treatment Plant, 64,500, partly on an 85% basis, partly on a 33⅓% basis; the North Side Treatment Plant, 602,500, 85%. The North Side Treatment Plant is now in operation to the extent of taking care of some 200,000 to 250,000 population; but the 602,500 represents the 100% treatment which from a construction standpoint has been built.

"The West Side Treatment Plant, constructively, 722,200 people; at 33⅓%, 240,500.

"Three small plants, known as the Morton Grove, the Glen View and the Northbrook, 5,000 people, 85% basis, equivalent to 4,000, 100%.

"Total, 958,500 people on 100% basis at the present time.

"The permit runs to December 31, 1929, when the balance of the works are to be put in operation which would give the 1,200,000 population treatment required by this condition.

"In addition to this, the Corn Products Plant has relieved the Canal of an equivalent population of 360,000. This, added to the 958,500, would represent actual and constructive at the present time, of 1,318,500 population.

"When I use the word 'constructive' I mean the actual physical buildings that have been built but can not be placed in use for lack of some further construction to be carried on."

The Sanitary District of Chicago presented the following tabulation of sewage treatment works, and expenditures therefor, as of December 31, 1928:

(Defendants' Exhibit 1385)

DES PLAINES RIVER PROJECT:	*Expenditure to December 31, 1928*
Des Plaines River Sewage Treatment Works	$1,497,329.34

Des Plaines River Intercepting Sewer	713,508.61	
Elmwood Park Outfall Sewer	446,665.65	
Elmwood Park Pumping Station	25,984.33	
Broadview - Bellwood Outfall Sewer	458,727.23	
Oak Park Outfall Sewer	823,104.37	
		$3,965,319.53
CALUMET PROJECT:		
Calumet Sewage Treatment Works	$6,982,805.14	
Calumet Intercepting Sewer	8,545,382.47	
Calumet Pumping Station	1,533,532.65	
Calumet Power Plant	1,172,221.42	
95th St. Pumping Station	923,980.34	
		$19,157,922.02
NORTH SIDE PROJECT:		
North Side Sewage Treatment Works (Practically finished)	$18,949,483.06	
North Side Intercepting Sewer	11,724,146.60	
Evanston Pumping Station	505,917.67	
Evanston Intercepting Sewer	1,453,853.31	
North Shore Intercepting Sewer	796,212.17	
Clifton Ave. Pumping Station	32,651.56	
Niles Center Outfall Sewer	25,258.17	
		$33,487,522.54
WEST SIDE PROJECT:		
52nd Ave. Intercepting Sewer	$282,060.61	
Salt Creek Intercepting Sewer (Contracts 1 and 2)	2,820,000.00	
West Side Intercepting Sewer Contract No. 1)	3,140,000.00	
		$6,242,060.61
MISCELLANEOUS PLANTS AND SEWERS:		
Morton Grove Treatment Works.	$66,384.06	
Glenview Treatment Works	103,516.41	
Northbrook Treatment Works	90,669.64	
Park Ridge Outfall Sewer	242,027.95	
		$502,598.06
		$63,355,422.76

2. *The program of the Sanitary District of Chicago for sewage treatment works.*

This program was presented on this re-reference through the testimony of Langdon Pearse, sanitary engineer of the

Sanitary District of Chicago. The sewage of the area of the Sanitary District of Chicago is to be treated in the four main projects known, respectively, as the North Side, the West Side, the Southwest Side, and the Calumet projects. The program involves modifications and extensions of the plans presented on the original reference, and provides for the addition of a large number of intercepting sewers in order to pick up all the sewage so far as it is practically possible of each of the four divisions of the total area of the Sanitary District and treat it in a single sewage disposal plant.

(a) The North Side project has been changed to include the area in general tributary to the Chicago River watershed on the North Branch. This area will include that part of Chicago north of Fullerton Avenue and in addition the City of Evanston and a number of villages. The sewage treatment works are located in the Village of Niles Center and constitute what is known as a modern activated sludge plant. Mr. Pearse testified that it was designed for a population of 830,000 and that on the completion of the North Branch Pumping Station the plant will be adequate for the entire area and for that population. He stated that at the present time there was a population of about 800,000 tributary to these works. The program of the Sanitary District contemplates certain additions in order to make adequate provision up to the year 1945. The designed basis for that year is 178 gallons per capita per day.

(b) The West Side project relates to the area south and west of the North Side project, including that part of Chicago between Fullerton Avenue and the Chicago River and Main Channel, the Loop district, and certain towns along Salt Creek and the lower Des Plaines River. The plant is under construction and is located in the Village of Stickney. It is designed to treat the sewage of a population of 1,850,000 persons, as of 1940, by sedimentation in Imhoff tanks,

in addition to providing for the digestion of sludge brought from the North Side sewage treatment works. Upon the completion of the Imhoff tank plant and appurtenances, it is proposed to add an activated sludge plant. When the West Side works are finished, the Des Plaines River plant will be abandoned except for experimental purposes. The designed basis for 1945 is 216 gallons per capita per day.

(c) The Southwest Side project covers generally the region between the West Side project and the Calumet project. The plant has not been designed or constructed nor has the site been obtained. The program of the Sanitary District contemplates a plant to be located to the south of the West Side sewage treatment works and south of the Main Channel of the Sanitary District. Mr. Pearse testified that this plant is to be provided to take care of the domestic sewage of the project area and also the stockyards' wastes. The plant is to be of the activated sludge type with the necessary works and appurtenances. The designed basis of this plant for 1945 is 256 gallons per capita per day.

(d) The Calumet area lies to the south from Eighty-seventh Street. The initial installation was designed for a population of 225,000. The plant is to be extended so as to handle the increase of population of the present tributary area, as well as the population of an additional area, and will consist of Imhoff tanks and trickling filters, with the necessary works and appurtenances, so as to treat the sewage of a total population of 455,000 as of the year 1945. The designed basis for that year is 250 gallons per capita per day.

(e) The program of the Sanitary District includes the intercepting sewers, pumping stations, disposal stations and other works pertinent to its construction program, in order to collect and treat all the sewage originating within the boundaries of the Sanitary District of Chicago.

This program of the Sanitary District is summarized, with estimates of cost, in the following statement sub-

mitted in connection with Mr. Pearse's testimony:

(Defendants' Exhibit 1387)

THE SANITARY DISTRICT OF CHICAGO

Tabulation of Estimates on Sewage Treatment Program up to 1945 after Dec. 31, 1928.

	Estimated Cost	
DES PLAINES RIVER PROJECT:		
(In its entirety including the proposed Des Plaines Intercepting Sewer extending to the City of Des Plaines, hooking up the sewage of the Des Plaines River Valley and bringing it to the West Side Works)	$4,025,000.00	
Hillside-Berkeley Outlet Sewer..	230,000.00	
		$4,255,000.00
CALUMET PROJECT:		
(This project will include enlarging the Calumet Sewage Treatment Works for complete treatment and to take care of the additional territory which is to be brought in)		
Calumet Sewage Treatment Works Enlargement	$11,718,000.00	
Calumet Intercepting Sewers (To bring in Colfax and South Park Avenues areas)	2,359,000.00	
Harvey Intercepting Sewer....	1,500,000.00	
Calumet City Intercepting Sewer	1,500,000.00	
California Ave. Outfall Sewer..	940,000.00	
Evergreen Park - Mt. Greenwood Sewer	725,000.00	
Blue Island Extension.....	750,000.00	
California Ave. - Evergreen Park Extension	1,000,000.00	
		$20,492,000.00
NORTH SIDE PROJECT:		
North Side Sewage Treatment ment Works (enlargement)...	$700,000.00	
Howard Street Intercepting Sewer	2,268,000.00	
North Shore Relief Sewer.....	815,000.00	
Additional North Side Int. Sewer	1,000,000.00	
		$4,783,000.00

WEST SIDE PROJECT:		
West Side Sewage Treatment Works (To complete sedimentation plant)	$8,679,000.00	
West Side Sewage Treatment Works	31,890,000.00	
(This will include the additional works required for complete treatment)		
West Side Intercepting Sewer (Remaining contracts)	15,750,000.00	
Additional West Side Intercepting Sewers	2,000,000.00	
Oak Park Intercepting Sewer, District's share	3,500,000.00	
		$61,819,000.00
SOUTHWEST SIDE PROJECT:		
Southwest Side Sewage Treatment Works	$38,870,000.00	
(This will provide complete treatment)		
Southwest Side Intercepting Sewer	7,900,000.00	
South Side Intercepting Sewer	18,640,000.00	
Racine Avenue Pumping Station	4,025,000.00	
Connections	943,000.00	
Miscellaneous	439,000.00	
		$70,817,000.00
MISCELLANEOUS PLANTS AND SEWERS:		
Allowance for unforeseen additions or extensions of intercepting sewers and treatment works to provide complete treatment		$10,000,000.00
		$172,166,000.00
Chicago River Controlling Works		4,000,000.00
Grand Total		$176,166,000.00

This program of the Sanitary District embraces (in addition to sewage treatment works) the installation of controlling works at or near the mouth of the Chicago River, or near the northern or eastern terminus of the Drainage Canal, in order to prevent reversals of the river and the discharge at storm times of the sewage effluent and the

storm water with untreated sewage into Lake Michigan. This part of the program will be considered later in connection with the reduction of the diversion of water from the Lake (*infra,* pp. 105-117).

Sewage Treatment Processes.

The description of the processes, to which the program of the Sanitary District refers, is briefly as follows: The processes are sedimentation, followed by trickling filters, and what is called the activated sludge process.

The sedimentation—trickling filter—process consists of coarse bar screens, skimming tanks, grit chambers, sedimentation tanks, trickling filters, final settling tanks, and sludge drying beds. The coarse bar screens are used to remove large floating material; the skimming tanks intercept oil, grease and floating solids; the grit chambers remove the sand and grit. Imhoff sedimentation tanks have an upper compartment for sedimentation and a lower compartment for the digestion of the settled solids. Part of the organic matter passes off as gas, part is liquefied and part remains as sludge. After digestion the remaining material or sludge is removed and dried on sludge drying beds. Trickling filters which are used after the sedimentation process are underdrained beds. The clarified sewage from the tanks is sprinkled over the surface of the bed through nozzles. The unstable, putrescible organic matter is changed to stable, mineral matter.

The activated sludge process is similar to the sedimentation process in the preliminary steps. The sewage passes through coarse bar screens, grit chambers, fine screens or preliminary settling and skimming tanks, aeration tanks, and final settling tanks. As the sewage enters the aeration tanks it is mixed with activated sludge and a constant stream of air is bubbled up through the mixture serving both for agitation and oxidation. The final settling tanks are the next step. The sludge which settles to the bottom of these tanks is continuously removed, a portion is re-

turned to the sewage as it enters the aeration tanks and the excess is disposed of either by pressing and drying for a fertilizer or by digestion in deep tanks.

Adequacy of the proposed sewage treatment works.

Mr. Pearse has been connected with the Sanitary District of Chicago since 1909, and as sanitary engineer has made a comprehensive and thorough study of its sewage disposal problems. He prepared the plans for, and supervised, the construction of the Calumet, Des Plaines River, North-brook, Glen View, Morton Grove and North Side Treatment Plants, of the Sanitary District and has provided plans for, and supervised, the existing work on the West Side Sewage Treatment Plant. He has also had considerable experience as consulting sanitary engineer in private practice. In connection with the Sanitary District work he has visited sewage plants of the United States, England, France and Germany for the purpose of ascertaining the best and latest methods. Mr. Pearse testified that the population served by these works at the end of fifteen years (1945) would be 6,366,000, including a human population of 4,785,000 and an additional number estimated at 1,581,000 for what is called "the population equivalent allowed for industrial wastes." Mr. Pearse stated that this program "would take care of the sewage of that population so far as present engineering knowledge would permit it to be taken care of." In his opinion, the plan submitted "for sewage treatment up to 1945 is the best plan that can be devised to take care of all the sewage of the population, whether the effluent goes to the Mississippi watershed or whether it goes to the Lake."

The growth of the population, within the District, after the year 1945, has been estimated at from 60,000 to 100,000 a year. Additional works will have to be added to carry the treatment forward and the Sanitary District has estimated an amount of $9,070,000 to make provision for this purpose to the year 1955.

The program does not include the treatment of all the storm water. The plants are designed to take care of about 50% in excess of the dry weather sewage flow.

The opinion expressed by Mr. Pearse as to the adequacy of the program of the Sanitary District was supported by other sanitary experts called by the defendants.

Harrison P. Eddy, of Boston, was graduated at the Worcester Polytechnic Institute in 1891; was employed by the city of Worcester as Superintendent of Sewage Treatment Plant and later, until 1907, as Superintendent of Sewers, having direct charge of the operation of the sewer system and sewage treatment. Since then, he has served seventy-five municipalities as consulting engineer including the cities of Boston, New Orleans, Louisville, Cincinnati, Buffalo, Pittsburgh, Dayton, Akron, Toronto, Milwaukee, Cleveland and Chicago. His first service to the Sanitary District of Chicago was as a member of a commission with George W. Fuller and T. Chalkley Hatton investigating the problem of the disposal of sewage from the North Side, called the North Side Treatment Project. He is now engaged on the sewage disposal work of Hartford, Connecticut, Rochester, New York, and Louisville, Kentucky. Mr. Eddy was one of the twenty-eight engineers known as the Engineering Board of Review employed by the Sanitary District of Chicago in September, 1924, to make a comprehensive examination and report. Since about the middle of February of this year (1929), he has been one of a group of engineers reviewing the whole sewage problem now confronting the Sanitary District. That group is divided into sub-committees and he is a member of the committee which has particular reference to sewage disposal, his associates being Dean Marston, President of the American Society of Civil Engineers, John H. Gregory, Professor of Civil and Sanitary Engineering in Johns Hopkins University, and Asa Phillips, formerly of the District of Columbia Sewer Department. Referring to the program of construction outlined by Mr. Pearse and to the

various items mentioned in Defendants' Exhibit 1387 (*supra*), Mr. Eddy testified:

> "That program is based on the scientific principles upon which the successful treatment and purification of sewage must be founded. The allowances and bases of design which have been adopted are such as to assure satisfactory purification of the sewage, and the type and design of the works are in accordance with best practice and in accord with the latest developments of the art. They conform to researches which have been carried out in various places, and particularly by the District itself and are up-to-date. The art is rapidly changing. Even before these works can be completed, undoubtedly improvements will be suggested which should be investigated and very likely adopted, if they are found to be actual improvements. The program in so far as bases of design are concerned, should be considered in a measure tentative, depending upon investigations which will have to be made as the work is carried out and as the conditions change. But as of today, I consider that the program is in full accord with the best practice and the most modern ideas."*

Mr. Eddy further testified that the storm water designed to be taken care of in excess of the sewage flow is approximately 50% of the sewage flow. Taking the annual average storm discharge, he would expect that from 40 to 50% would be carried to the treatment plants and would be treated in the same manner, although perhaps not to the degree of efficiency, with which the dry weather flow would be treated. The degree of efficiency would be due to the effect of the storm water upon the treatment process.

Professor John H. Gregory, of Baltimore, another sanitary expert witness for the defendants, has been in active practice since his graduation at the Massachusetts Insti-

*The complainants prepared an Abstract of the testimony presented by them on the re-reference, and the defendants prepared an Abstract of the testimony presented by both parties. Quotations in this Report from the testimony are taken, for the most part, from one or the other of these Abstracts.

tute of Technology in 1895. From 1904 to 1909, he was in active charge of the design and construction of both water works and sewerage works of Columbus, Ohio. In 1909 and 1910, he was resident engineer of the Passaic River Valley sewage project and also was engineer with the Metropolitan Sewerage Commission of New York. From 1911 to 1917, he was a member of the firm of Hering & Gregory, consulting engineers in New York who designed the Albany Sewage Disposal Works and those in Trenton, New Jersey. From about 1920, he has been in charge of the Civil Engineering Department of the Engineering School and of the Sanitary Engineering Department of the School of Hygiene and Public Health of the Johns Hopkins University, also continuing in private practice. For the past eight years he has been consulting engineer of the Sewer Department of Baltimore in connection with the design and construction of large sewers and sewage treatment works. For the past three years he has been consulting engineer for Columbus, Ohio, in connection with its present sewage disposal program. He has served from 100 to 125 cities and towns in the United States on problems in relation to sanitary engineering. In 1925, he was one of a committee of three engineers to deal with the sewage situation at Detroit. Mr. Eddy was another one of this committee. Professor Gregory was also a member of the Engineering Board of Review of the Sanitary District in 1924, and from February of this year he has been serving as one of the group of engineers mentioned by Mr. Eddy with respect to the sewage disposal plans of the Sanitary District. He testified as follows in relation to the adequacy of the program which the Sanitary District has presented:

> "From the standpoint of design and construction, I think the program mentioned in said exhibit" (Exhibit 1387, *supra*) "is a reasonable one. I have considered the main bases of design. The designs are in accordance with the best accepted practice at the present time, and in accordance with the present state of the art on sewage treatment.

"Under this program, when the works are in operation, a portion of the storm flow will reach the sewage treatment works. The sewers of Chicago are a combined system, and whatever excess capacity there might be in the sewers over and above the dry weather flow at times of storm will carry the storm water to the treatment works, where that storm water, together with the sewage, will receive treatment. The remainder of the storm water would overflow into the water channels and the rivers.

"When I speak of capacity of the sewers, I am referring to intercepting sewers. The intercepting sewers I undestand are designed for a capacity of 50% in excess of the dry weather flow."

3. *The Complainants' program.*

So far as the sewage treatment works are concerned, the complainants have not proposed any radical changes in the program of the Sanitary District of Chicago. They have not objected to the division of the territory into the projects above described, or to the collection of the sewage in one plant in each project area, or to the types of the plants designed by the Sanitary District or to the general methods of treatment proposed. The complainants state that a practical program for the disposal of the sewage of the Sanitary District by means other than lake diversion will be provided by completion of the North Side, West Side and Calumet sewage disposal plants, by the construction of the Southwest Side sewage disposal plant, and by the construction of a water filtration plant.

Complainants have presented their Exhibit 238 as a concise tabular representation of their program, including a statement of the dates on which they contend the respective portions could be completed. This exhibit (omitting for the present that portion of the exhibit which relates to the proposed limitation of the diversion (see *infra,* p. 88) is as follows:

(Complainants' Exhibit 238)

PROGRAM FOR DISPOSAL OF SEWAGE OF THE SANITARY DISTRICT OF CHICAGO BY MEANS OTHER THAN LAKE DIVERSION

Sewage Disposal Construction	Date of Completion
North Side Plant (Complete)	December 31, 1929
West Side Plant	
Tanks	December 31, 1929
Complete treatment	December 31, 1933
Calumet Plant (Complete)	December 31, 1932
South-west Side Plant	
Tank Treatment	December 31, 1932
Complete Treatment	December 31, 1935
Water Filtration Plants	December 31, 1934

The complainants say that this program for sewage treatment is substantially the same as the program submitted by the Sanitary District. That is, as stated in the complainants' brief, "the complainants' sanitary experts approve generally of the methods of treatment of the sewage proposed and the types of the various plants built or to be constructed by the Sanitary District of Chicago, although they recommend various changes in the method of operation of the plants, and do not approve the estimates of quantities or of costs which have been made on behalf of the Sanitary District."

L. R. Howson is the leading sanitary expert for the complainants. He was graduated from the University of Wisconsin in civil engineering in 1908 and received the degree of civil engineer from the same institution in 1912, for work done subsequent to graduation. Since 1913, he has been a member of the firm of Alvord, Burdick & Howson of Chicago, whose work consists of various phases of hydraulic and sanitary engineering, including sewerage and sewage disposal, water supply and water treatment. It appears that they have investigated sewerage and sewage

disposal problems for a number of cities. In 1925, Mr. Howson's firm was retained by the War Department as competent and disinterested experts to make a thorough study of the disposal of the sewage of the Sanitary District of Chicago and questions relating to the diversion of water from Lake Michigan and in April of that year they made an elaborate report (signed by Mr. Burdick and Mr. Howson) to the district engineer at Chicago. Major General Edgar Jadwin, Chief of Engineers, testified that the War Department has been following the lead of this firm in relation to sanitary questions. Stating his conclusion as to what would be a practical program for the disposal of the sewage of the Sanitary District by means other than lake diversion in a manner that would not be detrimental to the Chicago water supply, Mr. Howson testified:

> "With respect to sewage disposal, such a program involves the completion of the North Side pumping station, and the placing in full operation of the North Side activated sludge plant. At the West Side it involves the completion of the work now in progress on the pumping station, Imhoff tanks, skimming tanks, and the sludge drying beds, for which contracts are let, and the installation of complete secondary treatment by the activated sludge process.
>
> "At the Southwest plant it involves complete treatment of the sewage through the preliminary process of tankage, followed by activated sludge treatment.
>
> "At the Calumet plant, the Imhoff installation now there should be enlarged, followed by secondary treatment of the sprinkling filter type.
>
> "In all these projects, of course, the necessary intercepting sewers to get the sewage to the plant are involved. That is substantially the program, as I understand it, outlined by the engineers for the Chicago Sanitary District, which I believe to be a good program, well adapted to meet the conditions.
>
> "No major modifications of the program of the Sanitary District to achieve the best practical sewage dis-

posal so far as the plants themselves are concerned are necessary. It would be wise to give the preliminary treatment to a larger per cent of the storm water overflow; that is, put it through the preliminary tanks and then by-pass it without putting it through the aeration tanks and secondary treatment. The program as a whole, with that modification, which is not essential, but which will somewhat improve it, is well adapted to the situation. Whether or not the North Side plant will require enlargement before 1945, may be contingent upon whether or not Chicago meters its water supply in the meantime. Aside from those minor things, the program is a good one.

"I am not affirming the correctness of the estimates involved in the construction of these various plants, but am referring to the efficiency of those plants from the sewage disposal viewpoint. With respect to water supply Chicago should install efficient filtration works for the entire supply."

George B. Gascoigne, sanitary expert called for the complainants, is a consulting sanitary engineer residing in a suburb of Cleveland, Ohio. He was graduated in civil engineering from the Ohio State University in 1910. In addition to his relation to a number of small works, he has been in charge of the investigation of processes of sewage treatment for the city of Cleveland and has been consulting engineer in the supervision of the construction of the Cleveland Southerly Sewage Treatment Works recently completed under his direction. This is a plant costing about $3,500,000 and serving about 300,000 persons. On the original reference in 1927, he testified that he had served about twenty-five municipalities upon major sewage projects. Since then he has visited many sewage plants in Europe. In cooperation with the engineering staff of the city of Buffalo, he is now employed to develop a comprehensive plan of sewerage and sewage treatment and to prepare, submit plans and specifications for the South Buffalo Sewage Works which will serve about 300,000 persons.

Comprehensive plans of sewage treatment have been completed under his direction for the westerly portion of Cuyahoga County, Ohio, covering an area of about 87,000 acres and estimated to cost eventually about $7,000,000. After stating what in his judgment would be a practical program for the disposal of the sewage of the Sanitary District, Mr. Gascoigne testified:

"This is not exactly the same program for sewage treatment which was proposed by the Sanitary District. The difference is the possible substitution of aeration treatment at the Calumet site for trickling filters, and the treatment of from two to three times the average sewage flow instead of 50 per cent of the average flow, as proposed by the Sanitary District. The treatment of from two to three times the sewage flow refers to treatment in the preliminary tanks of the excess flow, and by-passing the final treatment. That would not require any enlargement of the present facilities but simply the use of the present facilities to a greater extent with nothing but the possible additional cost of operation.

"The difference between the average dry weather flow and the average sewage flow is that the average sewage flow reaching the treatment works is the average of all the flows that arrive there, while the average dry weather flow is the average of the flows that reach a plant during dry weather flow conditions. The average sewage flow is usually about 10 or 15 per cent larger than the average dry weather flow, and the difference might be greater.

"This program is intended to serve 1945 conditions. It is not necessary to enlarge the North Side Plant to serve 1945 conditions.

"In this program I am not assuming larger or different facilities for sewage treatment than those contemplated for the Sanitary District in the program to which their witnesses have testified. I am assuming the same devices but operated a little differently."

Darwin W. Townsend, another of complainants' sanitary experts, has been engaged in sanitary engineering work for the past nineteen years, fourteen of which has been in connection with the activated sludge process of sewage disposal. From 1910 to 1914, he was employed by T. Chalkley Hatton, consulting engineer at Wilmington, Delaware, upon designs and the preparation of plans for sewage disposal, water filtration plants, and general water works systems. From 1914 to the present time, he has been employed by the sewage authorities of Milwaukee being at first chief draftsman, then engineer of designs and at present is assistant chief engineer. Mr. Hatton was Chief Engineer of the Sewerage Commissions of Milwaukee when Mr. Townsend entered that employment. It also appears that Mr. Townsend assisted Mr. Hatton on his report on the North Side Sewage Treatment Works in Chicago. Mr. Townsend testified that from 1917 to 1923, he was in charge of the preparation of designs for Milwaukee's activated sludge plant being under the direction of Mr. Hatton. He was in direct charge of preparation of plans for intercepting sewers, from 1923 to 1927, and has had general supervision of all construction and design work on behalf of the commissions of Milwaukee. He states that the total expenditures on this work from 1914 to date approximated $25,000,000. Mr. Townsend, after giving his views as to a practical program for sewage treatment in the Sanitary District of Chicago, testified:

> "This program is for 1945 conditions and substantially the plan for sewage disposal which has been proposed by the Sanitary District. It would be advisable to make provision for taking through the preliminary portions of the treatment plants a quantity of storm water equivalent to about three times the average dry water flow and by-passing the effluent between the preliminary tanks and the activated sludge tanks. This does not involve any enlargement of the plans but merely a different utilization of the preliminary

treatment plant. It is not necessary to enlarge the North Side activated sludge plant for 1945 basis."

Joseph W. Ellms, called for the complainants, is a consulting sanitary engineer residing at Cleveland. He was educated at the Massachusetts Institute of Technology and from about the year 1896 has been engaged in the investigation of water purification methods. In 1918, he was retained by the city of Cleveland as its engineer of water purification and started the filtration plant there. Since his testimony in the former reference in this proceeding, he has been in charge of the operation of that plant and also of the sewage disposal plant at Cleveland. He testified that he was familiar with the works that had been constructed by the Sanitary District of Chicago for sewage disposal and with the program which the Sanitary District had submitted. As to these, he said:

"The works constructed or to be constructed, as proposed by the Sanitary District under this program, are, from the standpoint of present knowledge of the art of sanitary engineering, the best possible works to be constructed from any practicable standpoint to completely treat the sewage arising within the District."

The evidence does not, in my judgment, furnish a basis for a finding that enlargements are necessary in the sewage disposal plants as proposed in the program of the Sanitary District. The complainants state that the changes they propose in these plants relate to their operation. Mr. Howson said that his proposed modification would "somewhat improve" the program, but that the modification was "not essential." Mr. Gascoigne assumed that the change he proposed "would require no enlargement of the plants proposed to be built". Mr. Townsend said that no enlargement would be required, "but merely a different utilization of the preliminary treatment plant."

The complainants have not proposed the installation of a separate system of sanitary sewers. When the defendants presented testimony as to their estimates of the extremely heavy, and in their view prohibitive, cost that would be involved in that undertaking (estimated by William R. Matthews, engineer of the Bureau of Sewers of Chicago at over $400,000,000) counsel for complainants stated that complainants' program does not provide for any such sewer system; that the defendants had not advanced any program involving the construction of a separate sewer system for Chicago nor had the complainants. "Nowhere," says the complainants' brief, "have any of complainants' witnesses stated that there was any necessity to construct such a system". No plans have been furnished by the complainants for a different system of interceptors. It appears that Chicago has a combined sewer system and under the complainants' program the sewage reaching the treatment plants over and above the dry weather flow will depend upon the excess capacity of the sewers over and above that flow. The question raised by the complainants thus apparently depends on the method of operation of the preliminary treatment. As the suggested change does not appear to be regarded as an essential feature, its feasibility may be left to be determined in the course of the actual operations.

The complainants, however, state that the program they propose does materially differ from the one presented by the Sanitary District in two respects. The first is that the program of the Sanitary District contemplates a continued diversion of a certain amount of lake water, while the complainants propose that there shall be no diversion whatever or any flow at Lockport after the completion of the program. But this difference between the two programs does not relate to the character of the sewage treatment works, as such, but to the disposition of the effluent, a question which will be examined later. The second difference is that the program presented by the complainants provides

for the installation of water purification works for all the domestic water supply of the City of Chicago. But the complainants recognize that the construction of such works is not a part of the program for the treatment of the sewage of the Sanitary District and in the findings of fact which the complainants have requested it is stated that, since the construction of water filtration plants is not an indispensable element in the practical disposal of the sewage by means other than lake diversion, the construction of such water purification works should be left to the discretion of the defendants. It also appears that the design and construction of water filtration plants for the City of Chicago is under the jurisdiction of that city which has not been made a party to this suit. Thus, what are stated in the complainants' brief to be the two material differences between the two programs do not relate to the sewage treatment works.

The complainants also say that while "they consider any additions to or modifications of their program, summarized in Exhibit 238, to be wholly unnecessary," they have pointed out that "there are several variations which might be incorporated in that program, if Chicago desired to improve the present standard or quality of its water supply, or entertained any honest doubt as to the efficacy of this program from the public health standpoint. These variations are the extension of the present intakes" (for the water supply), "the substitution of a new intake off the North Shore in the vicinity of Wilmette, chlorination of the sewage effluent and/or the installation of control works at the junction of the drainage canal and the Chicago River." The complainants say that they do not urge any of these modifications and in their proposed findings they state that the "construction or installation of any such additional works or structures should be left to the discretion of the defendants."

4. *Efficacy of the proposed sewage treatment.*

What is called "complete treatment" is not absolutely complete; that is, 100% purification does not appear to be practicable. The experts for the respective parties differ as to the degree of purification which will be achieved by the proposed sewage treatment works of the Sanitary District when completed and put in full operation. Mr. Pearse testified for the defendants that the "practical degree of purification is 85%. At times on monthly averages it may be 90 or even 92% for activated sludge process". On his cross-examination, Mr. Pearse acknowledged the correctness of the statement in a publication entitled "Engineering Works, The Sanitary District of Chicago, August, 1928" that the activated sludge progess "accomplishes from 85 to 95 per cent. reduction of the biochemical oxygen demand, 90 to 95 per cent. reduction of suspended solids and from 92 to 98 per cent. reduction in bacteria". He said that he was talking "of ranges on a large program". He felt "that we can do better than 85%. We may be able to average 90%." But he thought that the effect "should be evaluated when, as and if it had happened in actual performance."

Mr. Eddy testified on this point as follows:

> "The degree of purification to be accomplished will necessarily vary according to conditions. Under certain conditions it will be very high, fully 90%, possibly as high as 95% at times. Under other conditions the degree of purification will not be as high, and will drop to 85 or 80 or possibly lower.
>
> "The conditions which affect the degree of purification are the temperature, the storm flows, the industrial wastes which are discharged into the sewers, and other conditions which affect chiefly the biological action upon which the processes employed for the most part depend. Taking all of the plants into consideration, a general average of 85% of purification is a reasonable assumption."

Professor Gregory testified that 100% purification of sewage was not practicable; that the degree of purification depended upon a number of different factors,—"the season of the year, the rate of flow coming to the treatment works, and as to whether it is normal dry weather flow or carrying considerable volumes of storm water." It was his opinion that "by and large an annual average in the neighborhood of 85% can be accomplished."

The complainants attribute a higher degree of efficiency to the sewage treatment process. Mr. Howson testified:

> "A properly operated modern activated sludge plant will remove from 90 to 95% of the suspended solids, approximately 95% of the bacteria and 95% of the biochemical oxygen demand."

Mr. Gascoigne put the removal at "from 90 to 95% of the suspended matter, averaging 92%;" "of biochemical oxygen demand from 90 to 95%, averaging 92%," and "95% of the bacteria."

Mr. Townsend testified that a properly designed and efficiently operated activated sludge plant "should remove 95% of the suspended solids, 95% of the bacteria, and should effect a reduction of 96% of the biochemical oxygen demand."

Complainants also refer to the testimony of George W. Fuller, sanitary expert called for the defendants on the original reference to the effect that trickling filters with final sedimentation would remove 80 to 90% of the suspended solids, 90% or more of the bacteria, or possibly 95% so far as the B coli group of bacteria, which will not multiply, are concerned. Mr. Fuller added that the activated sludge process would be slightly more efficient depending upon operating conditions. He said that modern activated sludge plants have removed 98% of the bacteria.

The complainants contend that on the testimony presented by defendants the average efficiency of the proposed sewage disposal plants would be in excess of

90% and that, on the testimony introduced by the complainants, the average efficiency at ordinary times would be approximately 95%. The complainants also insist that practically 100% of the bacteria would be removed by chlorination of the effluent and that it is only bacteria which affect health.

As no works have yet been built which afford a demonstration on the scale proposed in the program of the Sanitary District, the evidence can be that of expert opinion only and the proof of actual efficiency must await the operation of the plants. The evidence justifies the conclusion that an average of 85% purification is the *minimum* that can reasonably be expected and that there is a strong probability that the average efficiency of the sewage treatment plants will be as high as 90% and it may be still higher.

There has been much controversy as to the character of the effluent from the sewage treatment plants operating with this degree of efficiency. For the defendants, Mr. Pearse testified that on the assumption of 85% purification, the remainder of 15% would represent "what the treatment has been unable to reach of the organic matter. Some of it may be finely divided colloidal matter of various compositions, and would represent also in a general way the raw sewage of a population equal to 15% of the total population from which the effluent is derived." He based this statement upon a test of the reduction of the biochemical oxygen demand. Hence, the defendants argue, on the assumption of a treatment of from 85 to 90% efficiency, that the effluent from the sewage treatment plants would be equivalent to the raw sewage or untreated wastes of 10 to 15% of the population. Mr. Pearse's attention was called to the pamphlet issued by the Sanitary District in August, 1928, which stated that in the activated sludge process, the effluent discharged from the final settling tanks is "a clear, non-putrescible, odorless liquid". Mr. Pearse testified that this is "a reasonably correct state-

ment with the understanding that the term 'non-putrescible' is based on a particular type of test." The liquid is reasonably clear. At times there are degrees of cloudiness produced by the passage of suspended matter. There is a certain amount of very finely divided suspended matter that passes out of the tanks, that varies according to the skill of the operators." Mr. Pearse, in a hearing before the Committee on Rivers and Harbors of the House of Representatives in 1924, stated: "The biological processes, such as sprinkling filters, or activated sludge, when properly operated, produce a high grade effluent, requiring no dilution, in which fish can live. The effluent, further, will create no nuisance, and can be turned into a water course, even though dry, without fear of consequences. Such a process removes about 80 to 90 per cent. of the bacteria. However, where bacterial removal is desired, sterilizing agents must be employed." On the original reference, Mr. Pearse admitted the foregoing statement, but said that he was endeavoring to explain the matter "in a purely general, brief way to non-technical men." He reaffirmed that the statement was correct "in that fish were living in the effluent of the Sanitary District trickling filters right at the filters. Young carp were living in the effluent, some shiners from Lake Michigan, and some others."

Mr. Eddy testified:

> "The sewage effluents will contain some relatively finely divided suspended matter. This is spoken of as floc. It looks like very small particles of sponge as it is seen in the settling tanks after aeration at the activated sludge plants. Such matter, although every provision practicable is made for its removal in the tanks, does escape in substantial quantities in the aggregate. These matters will tend to settle in the waterways by coalescing, forming larger particles, by being carried into quiet water where there is opportunity for sedimentation. They will become attracted to the sides and to structures like piles, piers, and constitute a

> sediment on the sides and on the bottom which will draw upon the supply of dissolved oxygen in the waters themselves."

The complainants call attention to a statement by Mr. Eddy in November, 1919, to the Board of Estimate of Milwaukee:

> "The activated sludge system will produce an effluent which is—speaking now in general terms—as good in appearance as the lake water itself. It won't show material color—it won't contain a noticeable quantity of suspended matter. It will be very low in bacteria, although in that respect there will be more than there are in the normal lake water, of course; it does not completely sterilize the sewage; and in all respects is an effluent which ought to be absolutely satisfactory. I think that there can be no question upon that point."

Dr. F. W. Mohlman, for ten years director of laboratories for the Sanitary District, who had made an investigation of conditions at Milwaukee during the past summer, testified that he had observed the effluent from various activated sludge plants and that it was not "clear, sparkling and odorless" as contended by complainants. As to the term "stability", the witness stated that "the term 'stable', 'stability', as applied to an effluent from a sewage treatment plant, refers to a chemical or biochemical determination which is made in a closed bottle in the presence of a dye, methylene blue. The disappearance of the blue color of this dye coincides with the disappearance of oxygen, both dissolved oxygen and ozygen present in nitrates. This is the extent of the stability test." On cross-examination he said that "turbidity" is one measure of clearness of a liquid," and he estimated that a good activated sludge effluent "might have a turbidity of twenty"; he said that it was not customary in the analysis of sewage effluents to test that; that the maximum turbidity of the drinking water at Chicago in April, 1927, was 115 parts per million,

the average was 50 and the minimum was 8". Referring to the statement made by Mr. Eddy in 1919 (*supra*), Dr. Mohlman agreed that "in general terms" the activated sludge system will produce an effluent which is "as good in appearance as the lake water is at times."

The complainants' sanitary experts testified that the effluent of a modern activated sludge plant is "stable, odorless and clear". Mr. Howson said that the effluent of such a plant "discharged into an open channel, without dilution, will remain stable indefinitely." Combatting the view that the percentage which fell short of complete purification would be equivalent to the raw sewage or untreated wastes of a similar percentage of the population, Mr. Howson testified:

> "The residual organic matter in the effluent of an activated sludge treatment plant is very different from an equal percentage of the raw sewage as a potential source of nuisance. The organic matter in the raw sewage would be in coarse visible shape, would be in an environment which would not be capable of supplying the amount of oxygen necessary to keep it from putrefying, and it would putrefy. The organic matter remaining in the activated sludge effluent would be finely divided, practically invisible to the eye, would be in an environment of an effluent which contains an excess of oxygen in the form of dissolved oxygen or as nitrate oxygen, in excess of the demand of the organic matter, so that the organic matter remaining in the effluent would not subsequently putrefy. The available oxygen in the effluent of a well operated activated sludge plant is equal to or greater than the oxygen demand so as to preserve the stability of the effluent."

Mr. Gascoigne also testified on this point as follows:

> "Assuming 90 per cent treatment of the sewage of a city, the practical result is not equivalent to the

discharge of 10 per cent. of the sewage of the city in a raw state. The objectionable substances of raw sewage may be classified as floating solids, fatty and oily products, settleable solids, non-settleable putrescible matters, and bacteria. The effluents from sewage treatment works providing 90 per cent. treatment, especially if it be of the activated sludge type, will be clear, sparkling and odorless, and have remaining in it of the above five substances, only a very small or minor part of the putrescible matter and bacteria. Therefore, the discharge of the raw sewage of say, 500,000 people or approximately 10 per cent. of the population estimated tributary of the Sanitary District sewage works in 1950 is an entirely different matter, from a nuisance and public health standpoint, from discharging in the Chicago River and its branches the effluent from sewage works serving,—say, 5,000,000 people."

Mr. Townsend said:

"With respect to a comparison of the residual organic matter in the effluent of an activated sludge sewage treatment plant with an equal percentage of the raw sewage as a potential source of nuisance, from the standpoint of bulk, the organic load would be the same. However, from the standpoint of environment of the organic load in the two cases, there is a radical difference. In the case of the organic matter in the effluent, the effluent is rich in oxygen both in the form of dissolved oxygen and nitrates. This oxygen supply, being more than adequate to meet the oxygen demand results in stability. In case of raw sewage, the contained oxygen supply may be or rather is decidedly deficient, the net result being that the oxygen demand could not be supplied and putrefaction would result."

The effect of storm water overflow, in carrying with it untreated sewage and wastes, was recognized. Mr. Ellms, one of the complainants' witnesses, testified as to storm flow:

"Assuming that the controlling works were not operated and that there is no discharge from the canal to the Des Plaines River at any time, matters of sewage origin could not be prevented from reaching the Calumet River and Lake Michigan from the Chicago River. During storm times the quantity of entirely untreated sewage matter that would be discharged into the Chicago River and thence into the Lake, would depend on the amount of storm flow that was permitted to by-pass the sewage disposal plants. The storm overflows directly from the sewers to the river would pass directly into the river. It might be possible that with storm flow some particles of sewage origin would be visible, but the dilution would be very great, as a rule, according to the amount of storm discharge. That would pass into the Lake.

"When the sewers first begin to spill over through these by-passes into the river, that is the time when one gets the large amount of accumulated sewage, etc., and heavy matter in the sewers.

"Intercepting or trunk sewers have overflows directly into the river. In using the word 'by-passing' I had in mind the sewage treatment plants themselves in which a certain amount of the strong storm flow would be treated in settling tanks first and then not carried through the complete process but the rest of the sewage by-passed.

"Assuming that the sewage treatment plants are completed in accordance with this program, and assuming a storm, the sewers, becoming charged with heavy flow, will increase the flow at the sewage treatment plants. As this flow increases it may be more than the different parts of the plant can treat completely; and consequently it may be necessary to remove some of the sewage before it has passed through all of the processes for which the plant is built, and this portion which is by-passed is what the witness had reference to before as being by-passed directly to the main outfalls and into the river. Also there are other outfalls or overflows necessary upon certain of the re-

lief sewers which the witness understands carries water directly into the river, but which never passes through or into the plants. Such overflows are not carried to the plant at all.

"Such other flows consist of sewage and storm water which is not carried through the plant. As to that harmonizing with my view that the program is a complete system of sewage treatment, it is the usual practice, because otherwise there would be so much sewage carried into these trunk sewers and interceptors that no treatment plants would be large enough to carry them. I am referring to storm conditions. The overflow is at such an elevation that the sewers will carry a certain amount over the usual average flows and the plants are designed for the purpose of taking care of more than the dry weather flow. In the absence of storm, that is, under the normal condition without storms, no sewage would go directly into the river after this sewage treatment program was completed. The sewage to which the witness referred as passing into the river in time of storm, in addition to that which would be by-passed at the sewage treatment works, was from the relief overflows along the interceptors.

"The method of treating the dry weather flow and a certain percentage of the storm water flow is the common and usual practice. I do not know of any city in this country with a combined sewer system where the combined storm water flow and the sewage are treated. I think a very large proportion of the storm water is treated in some plants in England by tank method of settlement. That is not complete treatment. The entire flow is not given complete treatment. I had some recollection that there were certain plants in England that did tank all of their storm flow. I cannot mention any of them,—I do not remember one."

Conclusions. With respect to the defendants' program for sewage treatment works, I find:

(1) That the completion of the North Side, West Side, Calumet, and Southwest Side Sewage Treatment works,

above described, with their appurtenances and the necessary intercepting sewers, and the efficient operation of these plants, will afford practical measures from the standpoint of present sanitary engineering knowledge for the complete treatment of the dry weather flow of sewage and wastes of all the area comprised within the Sanitary District of Chicago, and also, in times of storm, of approximately 150% of the ordinary dry weather flow of sewage and wastes; that in the actual operation of these plants it may appear that a greater amount of the storm flow can be treated at least in part.

(2) That what is described as "complete treatment" of the sewage taken to the sewage treatment works (that is, apart from the excess storm flow which remains untreated) does not amount to 100% purification; that with efficient operation the proposed sewage treatment plants should attain not less than an annual average of 85% purification of the sewage treated, and that it is probable that the degree of purification will be 90% or more.

(3) That the remainder of the storm flow, in excess of the volume treated in the sewage treatment plants, will pass into the Chicago River and its branches, and into the canals of the Sanitary District, and any storm flow so passed into the river, its branches and the canals, will contain sewage and wastes which have not been treated by the sewage treatment works.

Second. *The time within which the sewage disposal works can be completed and put into operation.*

General Estimates. While the sanitary experts of the respective parties are in close agreement as to the appropriate methods of sewage treatment and the proper types of treatment plants, there is a wide difference in their esti-

mates as to the time that should be allowed for the completion of the Sanitary District's program.

Defendants' witnesses. The sanitary experts of the defendants estimate that from twelve to fifteen years will be required for the completion of the sewage treatment plants.

Mr. Pearse testified (referring to the program summarized in Defendants' Exhibit 1387):

> "It is my opinion that it will take in general fifteen years to carry out the program; assuming that everything was to go right and the money was readily forthcoming as required by the engineers, we might complete it in twelve years. If, on the other hand things do not go right, if we have delays that are contingent upon public delays of various character such as have occurred here through injunctions, it might be more than fifteen years.
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> * * * * * * *
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> "I think that fifteen years is a fair estimate, and even if the work were private work, to complete it in that time would be subject to commendation. It is difficult to fix exact times for this kind of work because of the unknown factors in figuring ahead from twelve to fifteen years."

On cross-examination he further testified:

> "A private corporation might do it in twelve years, but I doubt whether a municipality here, under the experience that I have had in eighteen years, could do it in less than twelve years, and in figuring the time I assumed that the funds would be forthcoming for the work; that there was no question of limit of funds and I based my opinion as to time also upon a knowledge of the volume of work that can be routed through an organization like the Sanitary District and handling it with the contractors that are available to do that work and the speed which they have exhibited in handling

such work; that I have had to take the yardstick of dollars; that it is very difficult to analyze work the way counsel have tried to drag it out on cross examination by taking each particular part of the works, and the volume of work was estimated in dollars that the Sanitary organization has been able to do in the past four years; that the volume of work that the Sanitary District has been able to put out averaged about $5,000,000 a year; that the total amount of sewage treatment works in the program is very close to $100,000,000 so that it would be necessary to double the amount of work that has been actually routed through the organization in order to design the work and get out all the plans that are needed in ten years. When contract plans are made, you are not through the job. You have hundreds, even thousands of plans that come in from contractors that have to be checked. There are supplementary plans. Frequently it is necessary to re-draw the plans because the contractor comes in with a new foreman on the work and it has to be re-designed. Work has to be re-designed frequently to fit the contractors' plant.

". . . The sewers may be built in the time it would take to build the treatment works. Design work on treatment works must be co-extensive on two or three works at the same time. You cannot take the whole of the plant and design the whole of it at the start. We would want to get working on two plants and carry them along. Measurement of time depends on an estimate of expense."

Mr. Eddy's estimate of the time for completion of the program was from thirteen to fifteen years. He said:

"With reasonable allowance for inevitable delays which cannot be specified in detail, but which are well known to exist on almost all work of this kind, a period of say thirteen years for construction, with perhaps an allowance of two years for delay, is as short a period as is suitable for the design, construction, tuning up

and placing in full complete operation of the treatment works. That time can probably be reduced somewhat. If it is done, however, it will be done at an increase in cost of work, not only actual cost, but in decrease in value of work when it shall have been completed.

"The reasons why I have fixed the time of completion of the entire program at from thirteen to fifteen years are:

"Development of a suitable personnel in the engineering office for design; the thorough investigation and studies of preliminary design, as to the exact process to be adopted; investigation of the industrial wastes for the Southwest Plant. This is an important factor not only with respect to the plant itself, but with respect to the success of the plant; type of plant, the dimensions of the plant, the success of the plant in operation, depends in very large measure upon the character and quantity of the industrial wastes.

"No investigation of that subject has been made for some twelve years. Industrial wastes are estimated to represent about 50% of the load upon the Southwest Plant. An investigation of that subject should be made, in my judgment.

"In addition, there is the ordinary preparation of detail drawings and designs. The actual construction work must be laid out and conducted in such a way that there shall not be conflict of contractors, so that all contractors, are able to work to advantage. Time is required for tuning up and testing the plant, after it shall have been completed. A long period of time, as much as a year, frequently is required before the plant can be efficiently operated, after it has been practically completed, due to the necessity of testing and adjustments, in some cases new parts and making the plant thoroughly effective.

". . . There is not much difficulty in securing the ordinary designers and draftsmen. The delay comes in securing the key men necessary to carry the work forward in an efficient manner.

"Whenever an organization is increased, it is almost always the case that there is a loss of efficiency due to the new men. For the increase in the District's office to carry out the program in accordance with the time I have suggested, there might be a period of a year and a half to two years required before the design department is brought to a high standard of efficiency. That will mean delay. It will also mean expense, the discarding of designs and drawings."

Professor Gregory testified:

"The length of time is dependent upon the time necessary to get the Southwest Side Sewage Treatment Works into operation. The sewers and sewage pumping stations can be built at least within the time needed to build the Southwest Side Works. Barring any unforeseen delays which very frequently, or often, occur on large work, it would require somewhere from twelve to fourteen years. I think twelve would be a minimum, which would require very expeditious designing and construction. They might be built in twelve years. But providing for some factor of safety, twelve to fourteen years is proper.

"In making the estimate of time, I have assumed that the moneys for the construction work would be provided as and when needed.

"My reasons for this estimate of time are based upon the fact that the Southwest Side Works involve the problem of handling and treating a large amount of industrial wastes from the Stock Yards; that the first step in the problem would be the ascertaining of the present conditions with reference to the Stock Yards' wastes, of which there has been no investigation since 1917, and it should be ascertained whether the conditions are now as they were then; that six months to a year may be needed for that investigation; that time is needed for a decision as to the type of works after the character of these wastes is known; that time would be required for the acquisi-

tion of the site; that time will be needed for the study of preliminary layouts—arrangement of the works to best serve the treatment of such sewage and how they can be arranged on the ground available; that after a decision has been made as to arrangement, considerable time for the preparation of the contract plans and specifications for the first heavy contract work would be required; that after that is started, the problems of design and construction would go along together and subsequent contracts would be made to provide for the complete construction of the work; that at the end of the construction period a time is needed for what is often spoken of as tuning up and adjustment; that there is another problem which enters very largely into the time element, and that is the question of designing force; that it is very difficult to get high-grade competent engineers, especially those who may have had some experience along the line of works which have to be built."

The defendants also refer to the testimony of George W. Fuller, an eminent expert of broad experience, who testified on the original reference as follows:

"I think it would be 1945, assuming that the District has funds in hand, before it could complete the program that was reviewed and approved by the Engineering Board of Review and adopted by the Trustees of the Sanitary District two years ago."

Complainants' witnesses. The general estimate of the complainants' sanitary experts of the time required for the completion of the entire program for the sewage treatment works was from five to six years. Mr. Howson testified:

"Assuming the funds to be available, from five to six years would be a reasonable period of time for the design and construction of the work involved in the

program, which I have outlined. I have made an estimate of the time of completion of the various sewage disposal plants involved in this program on the basis of a reasonable allowance of time; but proceeding as rapidly as possible without unduly increasing the expense."

In complainants' Exhibit 238, Mr. Howson put as the latest date for the completion of the entire program, December 31, 1935. As to the basis of his estimate, Mr. Howson said:

"The basis of my conclusions with respect to the period of time required for the design and construction of the various plants involved in the sewage disposal program is that the design of the major units, either Imhoff tanks or aeration tanks, could be completed in approximately six months' time and that approximately two months additional would be required for contractors to figure and the taking of bids, so that the first construction would probably start in some eight or nine months. The other plans could be going along concurrently and the entire design completed in a year and a half. Such a design program would permit the uninterrupted continuation of construction work from the date when construction was begun on the first unit. This program contemplates the designing being done by three organizations, one of which would be the Sanitary District and the other two probably done in consulting engineering offices. The employment of consulting engineers to design two of these plants would not increase the cost. That part of my estimate of time which involves the construction period of these plants is based upon a knowledge of construction progress in large work including progress on some of the more important work of the Chicago Sanitary District. It is also based upon estimates and data complied by experienced contractors and builders, with whom I have consulted.

"This program contemplates the concurrent construction of several plants. That is practical from a construction standpoint."

In the report of Alvord, Burdick & Howson to the War Department in April, 1925, which was in large part Mr. Howson's production, and the statements in which he testified were accurate as to the facts and sound as to opinions, it was stated:

"It would be our opinion that five years' time, under average construction conditions, would be a reasonable minimum estimate of the time required to design and build the intercepters and sewage treatment plants at the costs herein outlined. Even with the most unfavorable construction conditions, the contingency of labor troubles, and similar delays, we can see no reason why the period should exceed eight to ten years.

"All of the above is predicated upon the ability of the Sanitary District to finance the program within the construction period."

Mr. Gascoigne testified:

"Assuming the funds to be available, from five to six years would be a reasonable period of time for the design and construction of the sewage disposal plants involved in this program."

He said that there should be full operation of the Southwest Side plant, which would take the longest time to finish, by December 31, 1935.

The basis of his opinion was given as follows:

"The basis of my judgment as to the period of time required for the design and construction of the various plants is that a major contract for one of these larger plants, such as the aeration tanks and the sludge settling tanks could be put under contract in a period

of nine months, six of which would be necessary for the design, about two months for the receiving bids, and another month for the awarding of contracts, and that the complete design for one of these larger plants could be completed in a year and a half. That process of designing would permit uninterrupted continuation of the construction program on an individual plant.

"This estimate of the time for design and construction of these plants does not contemplate that all of the designing work will be accomplished in the Sanitary District municipal offices; but that the design of the intercepting sewers will be completed by the engineering department of the Sanitary District, which will also design one of the larger sewage treatment works; and that two of the larger sewage treatment works will be designed by outside engineering organizations. The employment of consulting firms of sanitary engineers to design two of these sewage treatment plants would not increase the cost.

"The basis of my judgment in estimating the time required for construction is my experience in constructing similar works, the progress which has been made on the North Side Sewage Works, and consultation with construction engineers and contractors who have gone into this matter in detail."

On further examination, Mr. Gascoigne stated that he had allowed practically six years and a half altogether for the completion of the Southwest Side Plant.

Mr. Townsend testified that the entire program could be carried out, assuming the funds to be available, and assuming such progress as could be made without materially increasing the cost, in a period from five to six years. On cross-examination he stated that he allowed the five year period for construction and he would add a year and eight months for contingencies. So that, referring to the Southwest Side plant, he "would make the time six years and eight months for completion from the present time."

In the above mentioned report of Alvord, Burdick & Howson to the War Department data were assembled re-

lating to construction progress on Sanitary District contracts and on certain other enterprises of large magnitude. Among these the following may be mentioned:

Description	Approximate cost	Start of Work or Date of Contract	Date of Completion	Period of Construction	Ave. Exp. per year in Period
Sanitary District Work:					
Calumet Treatment Works..	$6,125,000	1902	1922	2 yrs.	3,000,000
North Side Treatment Works	5,900,000	1923	1926**	3½ yrs.	1,700,000
Chicago Produce Market	17,000,000	1925	1925	6 mos.	34,000,000
Union Station (Chicago)	60,000,000	1916	1925	9 yrs.	6,660,000
Greater N. Y. Water Supply..	176,000,000	1907	1917	10 yrs.	17,600,000
Milwaukee Sewage Disposal Plant	8,167,000	1918	1925	7 yrs.	1,160,000

**Date of completion in contract.

The defendants point out that the North Side Treatment Works, as shown by defendant's Exhibit 1385, cost about $18,950,000; that preliminary studies for the design of this plant were started in 1921 and that, while the first contract for the aeration tanks was let in August, 1923, the works consisting of the aeration portion of an activated sludge plant, were placed in operation about October, 1928. The pumping station which is essential to the complete operation of the plant is not yet finished (*infra,* pp. 45, 46).

With respect to the Milwaukee Sewage Disposal Plant, Mr. Townsend testified on cross-examination that preliminary plans or study plans were prepared as far back as 1916; that the first contract plans were begun in 1918; that the first contract was let in December, 1918, that work was begun in February, 1919, and that the plant was put in operation in June, 1925; that the plant to its designed capacity began operating constinuously in January, 1928. This delay in full operation, Mr. Townsend explained, was incident to the manufacture of commercial fertilizer at Milwaukee which involved a dewatering process undemonstrated up to that time. He said that this difficulty would not have arisen if the sludge had been disposed of in sludge drying beds.

Reference was also made (on the cross-examination of Mr. Gascoigne) to the time taken for the completion of the activated sludge plant at Cleveland. Mr. Gascoigne stated that demonstration and experimental work as regards activated sludge "oriented around the years 1915 and 1916"; that there were a number of preliminary studies; that the project drawings for the Southerly Sewage Works at Cleveland were submitted in July, 1924; that the plans and specifications were completed in March, 1925; that bids were received in October of that year; that the contract was awarded in March, 1926; that the date for completion was fixed by the successful contractor at November 1, 1927; that the plant went into operation about July 1, 1928 and was believed to be in full operation at the time the witness was testifying (April, 1929). This is apart from sludge beds for which proceedings to award contract are under way. The sludge has been stored in the bottom of the Imhoff tanks.

The evidence as to the time of the completion of each of the sewage treatment works, separately considered.

The controversy becomes more sharply defined as each of the treatment plants of the Sanitary District is considered by itself. The main dispute relates to the treatment works themselves, as there is no reason to doubt that the intercepting sewers and isolated pumping stations can be provided within the time required for the construction of the treatment plants.

North Side Treatment Works (*supra,* p. 8). There is no substantial controversy with respect to these. They are practically complete except for the North Side Pumping Station. At the early hearings on the re-reference (March-April, 1929) it was assumed that this pumping station could be finished so that the works could be put into full operation by December 31, 1929. But on account of lack of funds the work was suspended. Funds have recently

been provided and Mr. Ramey, the assistant chief engineer of the Sanitary District, testified (September, 1929), that the pumping station was now seventy-five per cent. completed and that it would require about six to eight months more to finish it. He expected that the North Side plant would be in full operation by April 1 or May 1, 1930. The defendants' proposed findings give July 1, 1930 as the effective date.

Calumet Treatment Works (enlargement, *supra,* p. 9). Mr. Pearse, for the defendants, testified that it might take between two years and two years and a half to design this plant. He allowed, roughly, "a period for design and construction of something like four to four and a half years." The present plant was built in about two years; the work of construction was commenced during October, 1920, and the works were placed in operation in September, 1922.

Mr. Eddy, for the defendants, stated that the design for the Calumet Complete Treatment Plant should be started at once, following early with construction and should be in operation January 1, 1936. He gave no special reason for this long period, that is, aside from the general considerations to which he testified in giving his estimates for the completion of the entire program as above stated.

Complainants' program (Exhibit 238, *supra,* p. 18) puts December 31, 1932, as the date for the completion of the Calumet plant. This was supported by the testimony of Messrs. Howson, Gascoigne and Townsend. Mr. Howson's testimony was that "the additional Imhoff tanks, the sprinkling filters and the secondary sedimentation tanks, that is, the complete process for Calumet" could be in operation by that date.

On all the testimony, including that of Mr. Pearse, it seems to be a reasonable conclusion that this plant can be completed, provided that the work proceeds promptly, and concurrently with other work, by December 31, 1933.

West Side Treatment Works (*supra,* pp. 8, 9). There is little disagreement with regard to the time for completion of Batteries A and B for sedimentation. Mr. Eddy testified that these should be completed and in operation January 1, 1930. Professor Gregory fixed January 1, 1930, for the first battery and "sometime in 1930" for the second battery. Mr. Ramey stated (September, 1929) that Battery A was complete; that Battery B was seventy per cent. complete and would require from five to six working months to finish; that the sludge drying beds would require a year to complete, but that some of the beds would be ready by June 1, 1930. The complainants' witnesses (testifying last April) put the completion of the two batteries at December 31, 1929.

As to the third battery (C), Mr. Eddy testified, for the defendants, that it should be in operation on July 1, 1932, and that the complete treatment plant should be in operation January 1, 1941. Professor Gregory's estimate was that the remaining sedimentation works for the West Side plant should go into operation "sometime in the year 1933" and the complete treatment works about January 1, 1942. He added that he had contemplated starting the design for these works at the beginning of 1932, and that if the design could be started earlier the date of operation would be somewhat advanced.

For the complainants, the time for the completion of the third battery and also the aeration tanks so as to effect complete treatment at the West Side plant was fixed by Mr. Howson at December 31, 1933; by Mr. Gascoigne at December 31, 1934; by Mr. Townsend at December 31, 1932.

The long time allowed by defendants' witnesses for the completion of the West Side Treatment Plant (1940-1941) does not seem to me to be justified. The estimate apparently depends in considerable measure upon a contemplated order of precedence of work on the defendants' program and does not seem to comply with the demand of the opinion of this Court for reasonable expedition. The site has

been acquired, the contemplated methods of treatment have been the subject of investigation and careful study for a long period; and while the proposed works are on an extensive scale they embody processes with which the staff of the Sanitary District has become expertly familiar.

The evidence shows that, at all events, this plant can be completed, if the work is prosecuted concurrently with the rest of the defendants' program, well within the time which may be allowed for the construction of the Southwest Side Treatment Plant, and my conclusion is that the West Side Treatment Plant should be completed and in operation by December 31, 1935.

Southwest Side Treatment Works. This plant is the critical, or controlling, factor in the program of the Sanitary District as it admittedly will take the longest time to construct. It is to be a vast plant, three times as large as the North Side Treatment Plant, according to estimated quantities. The defendants emphasize the general considerations with respect to organization, personnel, the time required for special investigations, preliminary studies, designs and plans, as already stated, that is, in substance, what has been quoted from the testimony of the sanitary experts Pearse, Eddy and Gregory.

Mr. Eddy testified that the portion of this plant which is planned for sedimentation should be in operation January 1, 1936, and the entire plant, for complete treatment, January 1, 1943.

Professor Gregory said that the complete treatment works should go into operation "sometime in 1942". He said that "to completely design the Southwest plant from A to Z would require from three to four years." But he said further:

> "Aeration tanks might be the part of the work that would take the longest to design. If you made no allowance for any preliminary studies at all and no allowance at the end of the construction for tuning up, the construction time would be three years, the design

time two years, making five years for the construction of the Southwest Side Plant. Leaving out the tuning-up period, the period of construction and design would be five years, but not taken as a whole. I didn't say that I thought the whole design would start on the first day. I have given you my best judgment as to the reasonable period for carrying on the design of some portions of the work after some other portions had been put under contract and were under construction. Some of the structural designs would be carried on simultaneously and some of them would be deferred."

The complainants' program (Exhibit 238) puts the date for the completion of the tank treatment at this plant December 31, 1932, and for complete treatment December 31, 1935. Their sanitary experts, Howson, Gascoigne and Townsend testified to this effect. Mr. Gascoigne stated:

"I allowed four years for completing the plant after the contracts were let. I have allowed practically six and one-half years altogether for the completion of the plant. I did not allow two and one-half years for whatever is necessary up to the time of letting contracts. I have allowed a year and a half to prepare plans and specifications, four years for construction, and a six to twelve months period to take care of the tuning up and getting things into shape and to provide for contingencies that nobody can tell about in advance. I have allowed one and a half years for everything that I think necessary up to the letting of the contracts."

Mr. Gascoigne further testified that he allowed 1,000 working days as the time for construction in the four year period.

Mr. Townsend estimated five years as the time for construction and added a year and eight months as a reasonable safety factor for contingencies, making in all six years and eight months.

Steps preliminary to the physical construction of the Southwest Side plant.

Acquisition of site. The Sanitary District has had in contemplation for this plant about six hundred acres lying to the south of the West Side plant and south of the main channel of the Drainage Canal. This location has been designated generally by the Sanitary District on its map, but the site has not yet been acquired. Mr. Henry A. Berger, recently elected a trustee of the Sanitary District, testified as to its difficulties. He stated that under the statutes of Illinois it is a condition precedent to condemnation proceedings that a *bona fide* offer of purchase should be made to the owners of the land sought to be acquired. The Sanitary District could not make such an offer without the moneys being available, and it was without funds. The legislature of Illinois had required the Sanitary District to submit its bond issues to a *referendum.* It had not made such a submission to the voters of the District but, immediately following the decision of this Court in January last, the Sanitary District sought authority from the legislature to issue bonds, without a *referendum,* unlimited in amount but limited to the specific purpose of carrying out any decree of this Court, or any order of a department of government or any act of Congress. Much opposition developed to the granting of this authority. It was at a time when charges had been made with respect to the padding of the payrolls of the Sanitary District and the payrolls had been reduced from about 5,000 to about 1,300. There was also a grand jury investigation into charges of mal-administration. After discussions, an amendment was introduced limiting the amount for a bond issue, without a *referendum,* to $40,000,000, and specifying the projects to be covered. The bill in that form passed in the State Senate, but there was opposition in the House. After consultation with the Governor, the amount was fixed at $27,000,000. An amendment to attach a *referendum* clause was defeated in the House by a majority of one. In the Senate the bill finally passed with

a margin of one vote and in the House with a majority of seven. The legislation became effective on July 1, 1929. The Sanitary District prepared the necessary bond ordinances, a contract for the printing of the bonds was made on competitive bids, as required by statute, and the bonds were offered for sale in August. The highest bid received (92½) was regarded as too low and the bids were rejected. The bonds were advertised and a bid of 93.89 was accepted. The bonds had a ready sale and a credit resulted to the treasury of the Sanitary District about September 20, 1929.

On taking up the question of acquiring the contemplated site for the Southwest Side Plant, it was found that the proposed tract had been sub-divided for purposes of sale in lots and that there were many separate owners. The Sanitary District has considered another site in the same general location, but from a quarter to half a mile further west, and this project at the last hearing on this re-reference was under consideration by the engineers of the Sanitary District. This question can be determined promptly and there seems to be no reason why proceedings for purchase or condemnation should not go speedily forward. It is stated that under the practice in Illinois condemnation suits are expedited. It appears that under the law of Illinois possession cannot be taken until judgment in condemnation has been entered and the money paid, or secured in case of appeal by the owner.

In the estimates given by the complainants' witnesses, it does not appear that time has been allowed for the acquisition of the site. Mr. Howson's estimate of from five to six years, or according to Complainants' Exhibit 238, to December 31, 1935, was apparently for design and construction. Mr. Gascoigne testified that he did not know whether the site for the Southwest Side plant had been acquired. He allowed a year and a half for what was necessary up to the time of letting contracts. While he did not profess to be familiar with the Illinois law, he seemed to be under the impression that it would be sufficient to start condemnation

proceedings and that construction could proceed on giving a bond to cover the final award. Mr. Townsend testified that he "did not take into consideration the question as to whether the site had been acquired." His estimate of time was based, he said, entirely upon his opinion and knowledge of the time required to construct the Milwaukee plant. He said that the site for that plant was available from the start, as it was city property. Mr. Townsend estimated that the work of construction could be done in five years and he allowed an additional year and eight months for contingencies, whatever they might be, which he thought would cover the acquisition of a site.

It is manifest that the time within which the site for the Southwest Side plant can be acquired cannot be definitely stated and can only be approximated with reference to the usual course of legal proceedings. But these proceedings should be taken into consideration in determining the time which should be allowed for the necessary steps preliminary to the physical construction of this plant.

Preliminary studies in relation to industrial wastes. The Southwest Side plant is intended to deal with industrial wastes, including those of the stockyards and the packing-town area, and these are estimated to constitute about fifty per cent. of the load upon the plant and a volume equivalent to sewage of about 1,000,000 persons. It is urged by the defendants that before the plant can be properly designed, the type of works must be determined upon after the present character of the wastes is known. Mr. Pearse testified that the Sanitary District ran an experimental plant at the stockyards for about three years prior to the entry of the United States into the War and that tests for treating these wastes by various processes were made in 1917; that no determinations have been made since that time and that the packers have refused entry into their plants. Mr. Pearse did not know whether the wastes from such works at this time were the same as they had been and it was his opinion that the matter should now be investigated; that there may

have been some changes in the processes of manufacture or additions to capacities and other matters of which he had no knowledge. Mr. Pearse said that it "might take a year to explore the conditions" obtaining in the packers' plant and "after that, there would be preliminary study and plans which would take a couple of years. It might be a little less, but probably would not be more." Mr. Eddy testified that the type of plant, its dimensions and success in operation depended in very large measure upon the character and quantity of the industrial wastes. Professor Gregory gave a similar opinion; he said that six months to a year might be required for the investigation.

The complainants point to a statement in the description by the Sanitary District in its pamphlet issued under date of August, 1928, as follows:

> "The Sanitary District began the study of sewage disposal by methods other than dilution on March 1, 1909. A laboratory was established at Thirty-ninth Street for this study. This was closed in February, 1924, a new laboratory being established at 1014 South Michigan Avenue. In May, 1928, the Main Laboratory was moved to the 5th and 6th floors of 845 South Wabash Avenue. New equipment, incubators and chemical apparatus were installed in these quarters suitable for chemical and bacteriological research on sewage and industrial wastes. Experimental sewage testing stations were built and operated at Thirty-ninth Street, on domestic sewage from 1908 to 1911; at the Stockyards, on packing house wastes from 1912 to 1918; along the North Branch, on tannery wastes from 1919 to 1922; at Argo on the special wastes of the Corn Products Refinery Company, from 1920 to 1926; and at the plant of the Sherwin-Williams Paint Company from 1926 to 1928. In 1925, the industrial wastes were estimated as equivalent to a population of over 1,600,000. In 1928, the Corn Products wastes would have been equivalent to 400,000 population if no recoveries had been made, but by means of the 'bottling up' process installed in

> September, 1926, this equivalent has been reduced to 50,000 in 1928, giving a reduction of 350,000 from the total load of industrial wastes. This waste is therefore the first to be eliminated from the treatment program.
>
> "The Packingtown situation is still in the State and Federal courts in an effort to determine where the responsibility for treatment rests. Processes of treatment have been worked out. Regardless of division of cost, the most practicable solution now seems to be to carry the wastes west to the proposed Southwest Treatment Works for treatment mixed with domestic sewage from the tributary area."

The complainants insist that the defendants' contention ignores the fact that packing wastes are being treated in the activated sludge plant at Milwaukee; that these wastes come from plants operated by the same management as that which operates the packing plants at Chicago and where any innovation in that industry would necessarily be in force and effect. It is urged that the manufacture of fertilizer by the packing plants has grown greatly, showing that both the quantity of waste in proportion to the "kill" has lessened and that the quantity of objectionable matter in the waste has likewise decreased. It is also insisted by the complainants that the amount of the "kill" at the Chicago packing houses is available "to every one by the year and by the day." The defendants in reply refer to the testimony of the complainants' sanitary expert, Townsend, the assistant chief engineer at the Milwaukee plant. He testified: "Assuming that the Sanitary District started special tests and experiment stations to determine the best methods of treating packinghouse wastes in 1912 or 1913, and continued to make those tests for three years, it is my opinion that that should afford reasonably adequate information as to the nature of the treatment required. I do not think it likely that the waste from the slaughter of hogs at the present time would be substantially different than the waste that obtained from 1912 to 1915." But on cross-examina-

tion he testified that he did not say that he "thought the character of the waste and the volume of the waste at Packingtown are the same as they were in 1917 when the investigation was made." He thought that he testified as to the character of the waste. He did not know whether any changes had been made in the process of manufacture at Packingtown. He said: "There may possibly have been changes made. The volume of the wastes might be different." He assumed that the Sanitary District, in deciding to build the plant, had settled the question. He added: "If they have no reliable information upon which to base the designing of the plant, the plant should not be designed until that information is obtained."

It seems that a reasonable time should be allowed for examination of the present condition of the stockyards' wastes. But in view of the experimentation heretofore had by the Sanitary District, and the information already acquired, it does not appear that the exigency is so grave, or the absence of knowledge so serious, as to justify postponing the plan and construction of the Southwest Side plant for an indefinite time. It seems to me that the Sanitary District should be able to obtain within a few months, at the most, whatever information is essential to enable it to proceed with the designing of this plant.

Time for designing the Southwest Side plant. For the defendants, Mr. Pearse testified that he "would allow from three to four years for the design of the pumping station, skimming tanks, Imhoff tanks, grit chambers and settling tanks; and when that is done, it is still necessary to put in certain collateral work to get them up." Mr. Eddy gave the general testimony already quoted as to the time required to complete the entire plant and one of his reasons was the time needed to develop a suitable presonnel in the engineering office of the Sanitary District for design. He thought "there might be a period of a year and a half to two years required before the design department is brought to a high standard of efficiency." Professor Gregory, who

said that completely to design the Southwest plant would require from three to four years, had not made "any tentative layout" in estimating the time, but considered "the broad general proposition" of what, in his judgment, would be needed. It was his opinion that "to design the pumping station alone a year and a half, perhaps more, would be required before the contract could be let;" that it would take six months as a minimum to design the skimming tanks; it "might take a year or more to design the Imhoffs"; six to nine months to design grit chambers and screens," and then he "would not necessarily be ready to let the contract for them;" "it might take a couple of years to design the aeration tanks", and "a year and a half to design the blower house;" it "probably would take a year to design the sludge beds."

For the complainants, Mr. Howson estimated (*supra,* p. 41) that "the design of the major units, either Imhoff tanks or aeration tanks" could be completed "in approximately six months time;" that "the other plans could be going along concurrently and the entire design could be completed in a year and a half. This design program", he said, "would permit the uninterrupted continuation of construction work from the date when construction was begun on the first unit." He did not contemplate that all the designing work would be done at the Sanitary District's office, but that it would be done under three organizations, one, that of the Sanitary District, and the other two, those of consulting engineering offices. Mr. Gascoigne testified (*supra,* p. 43) that complete design for one of the larger plants could be made in a year and a half. He figured that in the case of a major contract, such as that of the aeration tanks and sludge settling tanks, six months would be necessary for the design. His estimate was on the assumption that two of the larger works would be designed by outside engineering organizations. In his estimate of six years and a half for completion of the plant, he allowed one year and a half for what was necessary up to the time of letting contracts. Mr. Townsend testified that "the two major con-

struction items, the Southwest Side plant and the aeration plant for the West Side plant could be designed in six months." He said that "the entire work of designing the Southwest plant, together with the remaining designing work of all the other plants could be completed in one and a half years."

It is apparent that the time required for the designing of the Southwest Side plant will depend to a considerable extent on the assistance of outside consulting engineering offices. This does not appear to be an impracticable or unusual course as the services of sanitary engineers employed as experts in this case have similarly been utilized by municipalities. The evidence shows that the city of New York has recently contracted with Fuller & McClintock for the complete design of a system of sewage treatment works of the activated sludge type to be located on Ward's Island, and it appears that the firm of Pearse, Greeley & Hansen, of which Mr. Pearse, the sanitary engineer of the Sanitary District, is the head, has undertaken to prepare for Fuller & McClintock the plans for the aeration tanks at the Ward's Island plant. Mr. Howson and Mr. Gascoigne testified that the employment of consulting engineers to design two plants would not increase the cost. The time necessary for designing in advance of physical construction might also depend to some extent on the policy adopted, that is, whether there should be complete plans and specifications for the entire plant and a letting of a contract to one contractor for the whole, or whether there should be designs of certain major units at the start so that the work of physical construction should progress while designs for other portions were being made. The testimony of the building experts (*infra,* p. 58) as to the time of physical construction proceeded on the assumption of one contract for the whole plant. This might expedite the actual construction by avoiding possible interferences of different contractors with one another, although it might lengthen the time for preparing the plans and specifications.

Taking bids and awarding contracts. It is undisputed that after designs are completed, and plans and specifications prepared, time must be allowed for advertising for bids and for the requisite action before contracts are awarded. Defendants' expert Mr. Howson said that approximately two months would be needed for this purpose and Mr. Gascoigne allowed about two months for the receiving of bids and another month for the awarding of contracts.

Conclusion as to time for preliminary steps, preparation of plans and specifications and public letting.

Taking the entire evidence into consideration in relation to the construction of the Southwest Side Treatment Plant, and with proper regard to requirements as to the public letting of municipal contracts, I conclude that two years and six months would be a reasonable time to allow for the necessary preliminary steps, for preparing plans and specifications and for advertising and passing upon bids.

Time required for the physical construction of the Southwest Side plant.

Two building experts were called for the Complainants and one for the defendants.

Complainants' building experts. Herbert P. Linnell, engineer, employed by Foundation Company of America, was graduated in 1894 from the Worcester Polytechnic Institute and was employed in general engineering work until 1906, when he became office engineer of the Atlantic, Gulf & Pacific Company of New York. From 1908 to 1918, he was chief engineer and vice-president of that Company at Manila, Philippine Islands, and constructed over seventy-five per cent. of the large engineering works of the Islands. He maintained and operated structural steel shops, machine shops and foundries, for the construction of buildings, bridges, etc. Some of the principal work was in the construction of the harbor works at Manila, piers, sea walls,

water works and sewers, including about two hundred bridges and piers, etc. with the United States Army Engineers and United States Navy. The witness estimated that he executed about $40,000,000 worth of that work. In 1918, he became District Plant Engineer for the United States Shipping Board Emergency Fleet Corporation in charge of the fifth district. From 1919 to 1926, he was practically in retirement, but acted in a consulting capacity for private corporations. Since 1926, he has been with the Foundation Company of America, investigating and reporting on new projects, principally in Central and South America, and at times acting as consulting engineer for the Company's clients.

The Foundation Company is engaged in extensive operations in Europe and South America as well as in the United States. During the last two years a great deal of the work of the witness has been in Central and South America, including one case for an English syndicate desiring port works on the Pacific Coast in Guatemala, for which the witness made all the engineering investigations. Prior to that the witness had been in Venezuela twice and with other engineers under his direction he had made complete surveys and designed a sewer system for Caracas. He has recently returned from Yucatan where for five months he was investigating conditions and designing the port works at Progresso. Between trips to Central and South America, he had investigated contracts for a new water works tunnel at Detroit and made estimates for large buildings in that city. The witness has never constructed anything in Chicago and has not had any personal supervision of any construction work in that city. Except for the examination of the work in connection with the West Side Sewage Treatment plant, he has never made any examination of work in Chicago with reference to making estimates. In connection with the present work, he investigated reports obtained from the Chicago office of the Foundation Company with respect to labor conditions in Chicago. The witness also stated that he had

never had anything actively to do with the construction of sewage treatment plants.

The Foundation Company was retained by complainants to examine into the program of the Sanitary District. The witness had examined the North Side plant, the site of the West Side plant and had also seen the proposed site of the Southwest Side plant. Estimates of quantities for the North Side, Calumet, West Side and Southwest Side plants were furnished him by the defendants' sanitary expert Mr. Howson who had received them from Mr. Pearse. He also had received from the Sanitary District a proposed lay-out of the Southwest Side plant. He had devoted twelve to fourteen hours a day for seven or eight days to the study of the Sanitary District project.

Mr. Linnell testified that assuming that the quantities were correct and that plans were available, he was of the opinion that it would take four years from the award of the contract to complete the Southwest Side plant. He had prepared a graphic exhibit, showing the time for the completion of the works, which was received in evidence. This plan gave the different items going into the Southwest Side plant and the number of months, with horizontal lines indicating the start and finish of each operation in the construction program. He also had prepared a graph showing the principal items of the equipment necessary for the construction and also the length of time that the particular parts of the equipment would be in operation.

It was the opinion of Mr. Linnell that assuming that different contractors had the contracts for the different plants —the Southwest Side, extensions to the North Side, the Calumet and the West Side—the several contracts could be carried on concurrently, that is, the physical construction; any interference that might occur in obtaining equipment might delay the work two or three months. With respect to detailed plans and specifications, the witness said that there were "no absolute details that have been worked out to the exact arrangement of such things as reinforcing bars and

the exact type of trim of buildings, and such details as that". The witness "could not bid a cost on the plans and specifications as furnished him." He would not dare to venture a firm proposal, which would involve the magnitude of this controlling factor, because he did not have sufficient detail to determine his costs.

In arriving at his opinion, which he called his "firm opinion", that the plant could be built in four years, he stated that he took into consideration availability of material and labor, and the time necessary for procuring plant and equipment. For shutdowns in winter and storm conditions, he provided practically twenty per cent. of twelve months or roughly two and a half months. He believed that the actual time in which the work could be done would be three or three and a quarter years. He stated that the four year limit included layoffs due to seasons, inclement weather; he gave no consideration to the five and a half day week that prevails in Chicago. All contingencies, "due to inclement weather, winter weather, the five and a half day week and contingencies of a construction job" would be included in the twenty per cent. which he had allowed. He had not heard of a proposed rule providing for a five day week in Chicago, and he would not take that into consideration in arriving at the time of construction; that in his opinion would not make a difference in the computation of time but might affect the cost.

The difficulty in obtaining the proper type of first class mechanics due to inaccessibility of plant location had no weight at all in his view. He simply determined that the labor was available. He gave no thought to local transportation facilities for men; that did not enter into the question; he said the question of labor getting to the site was not usually considered; he did not consider whether labor resided near the place of construction unless the work was located in an outlying district; it was never considered in a city; all employees managed to get to the point where they earned their wages. He had not considered the question of housing labor in Chicago. He allowed no time for

delays that might occur in obtaining contractors' plant and equipment; he had obtained direct quotations of time on principal elements of work and took these quotations as being from responsible firms and that they would deliver as agreed. He knew of no delays due to non-reception of material or equipment that would be serious to a contractor of experience. The seriousness of delay would depend entirely on what was delayed; he considered that deliveries would come as required. He did not take into consideration the possibility of the delay of construction due to revision of designs made necessary by unforeseen soil conditions; he assumed that the estimate of quantities furnished him was correct; he took into consideration the possibility of sub-soil conditions necessitating piling foundations but that would not necessarily mean delay in time; it might mean another operation. He did not consider any allowance for possible delay caused by rejections of material or equipment after delivery; there was very little delay caused in this manner; he did not consider at all the likelihood of delay in receipt of material and equipment due to tie-up of railroads by strikes or flood conditions; if that occurred and delayed the work, it would extend the time. His time study was based on one contractor having the entire job. He would sublet his equipment; might sublet pile driving and excavation, but nothing of any large size. He did not take into consideration the possibility of delay due to failure or inability of sub-contractors to perform; he did not consider sub-contractors at all. The fact that the law requires the Sanitary District to advertise and let to lowest responsible bidder did not enter into his computation. His estimate of the time started with the award of the contract.

Mr. Linnell also stated that no one could foresee the matter of strikes, whether in Chicago or elsewhere; that that was never taken into consideration in preparing a bid; that there was usually a clause in the specifications, and contract, allowing for an increase of time for delays beyond the contractor's control. There were many contingencies which

might cause delays, other than strikes; a protection clause of that kind was almost necessary and was probably insisted upon by every contractor. He believed that if he had absolute specifications the maximum time for completion would be three and a half years. Actual detailed plans and specifications might make a difference of six months in his computation, but he did not think they would require a longer time than four years. He assumed that the Southwest Side plant would be substantially the same as the North and West Side plants. His time estimate included the turning of the completed plant over to the owner for acceptance and operation. The ordinary time for testing would not extend over a month. If the Sanitary District's specifications required more difficult or longer tests that would have to be considered. He gave no consideration to final test other than ordinary test.

The other building expert called by the complainants was W. J. Hunkin, a contractor of Cleveland, Ohio. He has been in the contracting business about forty-five years. He has built breakwaters, piers, railroads, power houses, locks, blast furnaces, steel mills, office buildings, etc. He is now building the Arlington Memorial Bridge at Washington under a contract for about two million dollars; also the War Memorial at Indianapolis at about the same cost; also the Masonic Cathedral at Indianapolis. He constructed the Corrigan-McKinney Steel Plant at Cleveland.

Mr. Hunkin visited the West Side Sewage Treatment plant at Chicago, inspected the work there, and saw the site for the Southwest Side plant without examining it. He had the Sanitary District's estimate of quantities and also the plan for the proposed layout of the Southwest Side works which the Sanitary District had prepared. He had familiarized himself with labor conditions in Chicago, and determined the feasibility of obtaining the necessary materials. He had received the estimate of quantities about

two weeks before he testified and had been "up day and night at it since he had it".

Mr. Hunkin testified that it was his opinion that the Southwest Side sewage treatment plant could be completed within fifteen hundred calendar days. The construction of that plant could go on concurrently with the construction of the other plants and the building of the intercepting sewers. He thought that he was liberal in fixing the time. He took into consideration a job which he had just completed costing about $11,000,000,—the Electric Illuminating Company's Power Plant at Avon, Ohio. With respect to labor and climatic conditions he observed that "the work at Avon was right on the Lake." He gave consideration to the fact that Chicago was a union labor city. He observed that "if it has got anything on Cleveland, he would like to see it. Cleveland is terrible." He had also considered seasonal conditions at Chicago.

In estimating fifteen hundred calendar days, he allowed two hundred and fifty days for Sundays and holidays in the four years, two hundred days for lost time during the winter months and one hundred days for lost time during bad weather. In his fifteen hundred calendar days he had thus included five hundred and fifty days in which no work would be done. He believed that all the projects, including sewers, could be completed within nine hundred and fifty working days. The sewers were not included in his estimate of fifteen hundred calendar days which he had figured for the building of the Southwest Side plant. He did include in his estimate the time necessary to complete the West Side project now under construction. He estimated that this period of fifteen hundred calendar days would begin on the day that the contract was awarded. It made no difference in his calculation when the work was started.

Defendants' building expert. The witness called by the defendants was John C. Ruettinger, general manager of

the John Griffiths & Sons Company of Chicago which built the North Side Sewage Treatment plant for the Sanitary District. He was 57 years of age, and prior to his employment with the John Griffiths & Sons Company had been building superintendent for ten years, and general manager for another ten years, of the William Grace Company. In that capacity he made the estimates, prepared the bids, and superintended the construction of a large number of important buildings in Chicago. He then became building superintendent with the John Griffiths & Sons Company, and after five years with that Company he was made general manager and had held the latter position for the last fourteen years. In the latter employment he had figured the plans and specifications, arranged the bids, and supervised the building, among others, of the Hotel Sherman, Mandel Brothers store building, the Federal Reserve Bank Building ($10,000,000), the Temple Building, the Morrison Hotel, all in Chicago; also he had in his similar charge the caisson foundations, the general excavation, the general superstructure, and most of the steel therefor, all the stone work, all the interior work, and all the train sheds, amounting to practically the entire work on the Union Station at Chicago (the work of his company amounting to $10,000,000), and many other buildings. He is now working (representing his company in the same way) on the new Merchandise Mart for Marshall Field & Company and the Chicago Civic Opera Building occupying an entire block, and his company is about to erect a forty-seven story building on the site of the old Tacoma Building in Chicago. He also put in caisson foundations and did the excavation work on the Daily News Building, the foundations reaching to rock, a little more than a hundred feet deep.

Mr. Ruettinger testified that his company had built everything in connection with the North Side Sewage Treatment plant, except the operating galleries and certain relatively small contracts which had been let to competitors on lower

bids. His company had the building of the aeration and settlement tanks, the general excavation and concrete work, and had constructed the pump and blower house, the administration building, etc., the contracts amounting to about $14,000,000. His company had bid on the first section of the West Side Treatment plant but unsuccessfully. Mr. Ruettinger had examined the estimates of quantities and the proposed layout of the Southwest Side plant, which had been furnished by the Sanitary District (the same estimates as those which formed the basis of the testimony of the complainants' building experts, Linnell and Hunkin). He had also examined Mr. Linnell's progress charts.

Mr. Ruettinger subjected these charts and Mr. Linnell's estimates of time and proposed methods of work to a detailed criticism. The witness also gave his own opinion as to the progress that would be possible in constructing the plant and the time to be allowed for completion. He figured on one hundred and seventy-one working days in a year as being available for excavating in open areas and pouring concrete for the tank construction. He said that this computation was arrived at

> "by deducting four winter months" (December to March inclusive), "the Sundays in the remaining months, two days for rain in each working month, the half holidays on Saturdays and the regular holidays, making a total deduction of 194 days, which allows for no unusual conditions such as extraordinary rain, breakdown in transportation, strikes or jurisdictional disputes."

Mr. Ruettinger testified that if it were assumed that he would receive the contract to build the entire plant on January 1, 1930, it could be completed about October 1, 1937, a period of seven calendar years and nine months. In this estimate, Mr. Ruettinger said that he made no allowance for such contingencies "as strikes, tie-up in materials,

breakdowns in transportation, breakdowns in any of the operating machinery, delays in operation of cableways because of accident or breakdown, any loss of time due to inaccessibility of the site, possible shortage of labor during the World's Fair in Chicago, or jurisdictional disputes between trade unions, but have assumed one hundred per cent efficiency, working continuously and without cessation"; and he stated that the contingencies mentioned would probably require at least six months allowance to cover them. He also assumed in estimating that the plant could be completed and ready for operation about October 1, 1937, if he received the contract on January 1, 1930, that complete plans, specifications and details were provided at the beginning of the work, and said that any delays arising from changes in plans, or from bad foundations, or from the necessity of creating pile foundations, would have to be added to the time estimated.

Conclusion as to the time for physical construction of the Southwest Side plant. While neither of the building experts called by the complainants had experience in the construction of sewage treatment works, it does not appear that, from the standpoint of physical construction, such works involve building operations which would lie outside the range of the expert knowledge of contractors of wide experience in the erection of large structures, manufacturing plants and public works. The extensive experience which the complainants' witnesses had in such enterprises would undoubtedly qualify them to undertake the building of the proposed sewage treatment works and to form an expert judgment as to the time necessary for their construction. Nor is there ground for concluding that there are such differences between the conditions as to labor and other requirements in Chicago, and conditions obtaining in large American cities, as seriously to affect the weight of the opinions of the complainants' witnesses. As to climatic conditions, it does not appear that those at Chicago and

Cleveland, for example, would be greatly dissimilar. It may also be observed that all the building experts were manifestly looking at the question from the standpoint of contractors and were not considering strikes, or what are called "jurisdictional disputes" of labor, or such unforeseen contingencies beyond a contractor's control as would normally be covered by a protection clause in his contract.

One matter stands out prominently and accounts in considerable measure for the disparity in the estimates of time. That is the calculation of the number of working days in a calendar year. For the complainants, Mr. Linnell, in his estimate of four years for construction, allowed twenty per cent, or roughly two and a half months, for shutdowns in winter and storm conditions. Mr. Hunkin, in his estimate of fifteen hundred calendar days, assumed that there would be nine hundred and fifty working days in that period; that is, that there would be only five hundred and fifty days without work. Mr. Ruettinger, on the other hand, in his period of seven calendar years and nine months, figured on only one hundred and seventy-one working days in a year as permitting the prosecution of a very large part of the work which would consist of excavation and pouring concrete. On an assumption of available working days similar to the assumptions made by the other building experts, Mr. Ruettinger's estimate of seven calendar years and nine months would be considerably reduced. Mr. Hunkin's estimate of working days was largely based on his experience in places situated on Lake Erie,—Cleveland and Avon. It seems to me that Mr. Ruettinger is too liberal in his deductions for lost time. He is not only opposed by the testimony of the other contractors, but the complainants have also introduced in evidence monthly estimate sheets relating to the construction of the North Side plant and indicating the progress of excavation and other outdoor work during the winter months (Complainants' Exhibits 278, 280, 281).

The other differences in the estimates of time, on the part of the building experts, relate to many technical details of construction which it would be impracticable to attempt to review in this report. They concern the time required to obtain and erect cableways so as to begin work, the rate of pour of the concrete for the tanks with cableways, and the question of the concurrent construction of different parts of the plant such as tanks and buildings. It is manifest that such matters easily permit of variations in calculations relating to a vast plant, the construction of which from any point of view must extend over several years. While Mr. Ruettinger is severely critical of Mr. Linnell's estimates of time for the different building operations, the complainants subject Mr. Ruettinger's testimony to a close analysis and vigorous attack. In reaching a conclusion, the criterion to be applied is of controlling importance. Common experience shows that works of magnitude, especially public works, admit of many delays which are not demonstrably due to neglect and that much depends on the vigor with which the work is pressed. Much time can be saved or lost in large building operations according to the attitude which is taken as to the importance of early completion. In the present case, the Court has already laid down the requirement that the work shall proceed "with all reasonable expedition". With this established criterion in mind, and after a careful examination of the testimony and exhibits, I have reached the conclusion that the estimate of seven calendar years and nine months for the physical construction of the Southwest Side Treatment Works is against the weight of the evidence. I think, however, that the period of four years, or four years and thirty-nine days (1,500 calendar days) for such construction is too short to be laid down as a definite requirement. It is not supported even by all of complainants' witnesses. Mr. Gascoigne allowed four years for construction, but thought it well to add six to twelve months for "tuning up, getting things into shape and for contingencies that nobody can tell about in advance", thus

making an allowance, from the time of the letting of the contract, of four years and six months to five years. Mr. Townsend allowed five years for construction.

The requirement to be laid down, while demanding expedition, should be reasonable in all respects. It should not fix what could be considered to be the shortest conceivable time under highly favorable conditions of work, but should have regard to what may fairly be expected under average conditions without unjustified delay. The evidence shows that in works of this description allowance must be made for the tests and final adjustments which are necessary to full operation. It makes clear that bare physical construction even to the point of starting the operation of the plant does not necessarily mean a completed plant in the sense that its readiness to serve at its estimated full capacity can safely be counted upon. My conclusion on all the evidence is that a reasonable allowance of time for the physical construction of the Southwest Side Treatment Plant, including tuning up, so that it would be ready for complete operation, would be a period of five and a half calendar years.

Conclusion as to the time required for completion of the Southwest Side plant.

Taking the time required for the preliminary steps that is, acquisition of site and preliminary studies, for preparation of plans and specifications for the securing of and passing upon bids, and for physical construction and tuning up, I conclude that the Southwest Side Sewage Treatment Plant, separately considered and assuming available funds, could be completed within eight calendar years.

Considerations affecting the time for the completion of the entire program for the sewage treatment works.

In addition to the question of the time required for the completion of the sewage treatment works, separately con-

sidered, is that of the feasibility of concurrent operations in constructing the different plants.

The difficulties of securing a satisfactory degree of efficiency in municipal administration, and of making haste in the prosecution of public works, cannot be overlooked in any municipal program. But these difficulties count for less in connection with technical bureaus, or expert staffs, than on the political side of administration. In the present instance, the actual construction will presumably be had under contracts made with competent private organizations which are available to carry through enterprises of this magnitude in the same manner as though they were initiated by private enterprise. There should be no loss of time incidental to the supervision of the execution of such contracts, and it is in the preliminary steps, in studies and designs, in the preparation of plans and specifications, that time might be lost through deficiencies in bureau organization and equipment. But this work would belong to an expert engineering staff and it is not regarded as unreasonable to require that the Sanitary District should, if it has not already done so, equip itself with the technical assistance suitable and adequate to meet the exigency.

As already pointed out, the complainants' witnesses in their estimate of time for completing the entire program of the Sanitary District have assumed that the designing of the various works would be done by three organizations, one of which would be the Sanitary District and the others would be provided by consulting engineering offices, a procedure which it is said would not increase the cost while it would expedite the work. Although I have concluded that a longer period should be allowed than that estimated by these witnesses for the complainants, I am satisfied that to complete the designs, and prepare the plans and specifications even within the period so allowed, it will probably be necessary for the Sanitary District to obtain the assistance of the staffs of consulting engineering offices. But I see no reason why this should not be done, or why a longer time should be allowed merely for the pur-

pose of dispensing with such available aid. I regard it as practicable, and as required by the demand of this Court for reasonable expedition, that the work on the various projects of the Sanitary District program should proceed concurrently.

Financial considerations. The complainants' witnesses have proceeded on the assumption that no delay whatever would be caused by lack of funds or the effort to procure them. In opposing the estimates of these witnesses, the defendants have stressed with special emphasis the heavy burden of expense that will be placed upon the Sanitary District and the legal limitations upon its borrowing power. Mr. Pearse testified that he "had to take the yardstick of dollars," that is, in considering the program in its broad aspects, in order to measure the time of accomplishment. In the statement of its sewage treatment program up to 1945 (Defendants' Exhibit 1387) the Sanitary District estimated the entire cost of completion (including $4,000,000 for control works (*supra,* p. 11), at $176,166,000. This was for contemplated outlays after December 31, 1928. On account of lack of funds, little work was done from that date to the end of September, 1929, so that these estimates are substantially those of future expenditures. Mr. Pearse testified that these estimates were based upon the contract prices prevailing in Chicago territory during the last five or six years. Referring to comparisons with earlier estimates, he said:

> "Defendants' Exhibit 1122, being a report of the Engineering Board of Review, shows the estimated cost of the sewage treatment plants at $130,000,000 (1924). At the former hearings I showed the total cost according to estimates made then, after December 31, 1924, for sewage disposal program to be $157,000,000, and that estimate was for complete treatment and was comparable with the $130,000,000 estimate of the Board of Review in 1924. The estimates of $157,000,-

000 in 1926 or 1927 were based upon complete metering.

". . . Since the Board of Review made this estimate, we have expended $51,000,000 on the sewage treatment program.

"Defendants' Exhibit 1387, offered at this hearing, estimates a further cost for complete program to be $176,000,000. Adding to that the $51,000,000, makes a total of $227,000,000. The total figures there are estimates, but the program is not co-extensive with the Board of Review program. The $176,000,000 program includes the $4,000,000 for a gate" (controlling works) "which was not in the Board of Review estimate. The Board of Review included $3,000,000 for Corn Products Refining Company" (wastes) "so these two outlays just about offset one another. The Board of Review estimate for a 17 foot sewer is $155.00 per linear foot. Our present estimate for 17 foot sewer is $255.00 a foot. The $155.00 represented the Board of Review's best judgment, I suppose. The Board of Review estimated the 15 foot sewer at $130.00, and the estimate under Defendants' Exhibit 1387 is $200.00 per linear foot, . . . The Board of Review estimated the 9 foot sewer at $75.00 a foot on the West Side and I used the figure in my estimate of $150.00 per foot. However, we have attempted in making the estimates to set the price according to the character of the work as we can best estimate it. So you will find different prices for same size of sewer. . . .

"The Board of Review estimated a 17 foot sewer for the Southwest Side at $160.00 per foot, and I have estimated a sewer of the same size and the same place at $242.00 a foot. An 18 foot sewer for the West Side Plant was estimated by the Board of Review at $170.00 a foot, while I have estimated a sewer 17 feet 6 inches in the same place at $255.00 a foot. It is my opinion that the Board of Review underestimated the sewers. There has been some increase in labor rates since 1924.

"I believe from the reported prices that I have heard in the City Hall that we have estimated more than is claimed to be the construction cost for constructing the

tunnels in clay, than it cost the City of Chicago for tunnels 165 feet underground in rock. The Sanitary District is building its tunnels by contract in clay with the use of timbering, which is a different matter in construction from building like tunnels in solid rock. I want to convey the impression that insofar as we are able to compare the costs, that is, on the data that is available, and it is not official from the city, but it is what I hear and not what I know, that it is cheaper to build those rock tunnels on the figures given out than to build the sewers in the clay by contract as we have to do. I regarded the rock tunnel work done by the city as a different kind of work. I estimated what the work would cost under the conditions with which we have to do it, by contract.

* * * * * * *

"As to the cost of sewer construction under the program shown in Exhibit 1387, so far as the Southwest Side interceptor proper is concerned, we are using practically the same cost for the same lengths and sizes as we did when I testified in 1927. As to the West Side interceptors, as such, there has been an increase because of the fact that we found that on letting contract number 1 and contract number 2 of the West Side sewer, that the bids received (and there were nine bids in one case and seven in another), indicated that the prices that we were receiving for that kind of work were higher than our former estimates. In so far as we have tried to estimate this work on the prices that we have reason to expect in this territory, we felt that we were justified in increasing those base prices, and that is the reason for any increases on such sewer construction costs. The prices actually used in the estimate for the works mentioned in Defendants' Exhibit 1387, are based upon actual experience in the letting of contracts for similar work by the Sanitary District."

Mr. Eddy testified that he had made a study as to the reasonableness of the estimates of cost of the various items

set forth in Defendants' Exhibit 1387, and it was his opinion that they were reasonable and that "the estimates are applicable to the conditions under which the work has to be done here."

The defendants' building expert who testified as to the time for the completion of the Southwest Side Treatment Plant (*supra,* p. 64) did not testify as to estimates of cost.

The complainants state that they do not consider costs a material issue, but that they do consider the defendants' estimates to be "grossly excessive". On this re-reference, the complainants did not introduce independent testimony as to the cost of the program for sewage treatment, but they refer to the estimates of their witnesses on the original reference in this suit. Mr. Howson then testified that, assuming universal metering of the water supply of Chicago, he had estimated that "the reasonable cost for the necessary works for providing complete treatment of all the sewage of the Sanitary District of Chicago through either activated plants or sprinkling filter plants for 1945 conditions would be approximately $76,000,000"; that "the practical elimination of the Corn Products waste", and other proposed changes, would reduce this total to approximately $73,000,000; and that he estimated the cost of complete sewage disposal to serve 1955 conditions at $82,000,000; all these figures being in addition to contracts let prior to January 1, 1925. Mr. Gascoigne on the original reference estimated that the necessary expenditures (exclusive of those made prior to January 1, 1925) to provide complete treatment of the sewage of the Sanitary District to serve 1955 conditions would be $82,250,000.

The complainants especially emphasize the disparity between the present estimates of the defendants, which counting the amount already expended for construction ($51,000,000) reach a total of $227,000,000, and the amount estimated by the Engineering Board of Review in 1924 ($130,000,000), and the estimates presented by the defendants on the original reference, 1926-1927, which amounted to

$157,000,000 (*supra,* p. 72). While the assumptions in these various estimates as to particular works are not identical, there is a marked increase in the estimated cost of corresponding items and the evidence indicates that the present estimates of the Sanitary District may be regarded as generous.

The defendants urge that the total contemplated outlays have a highly important bearing upon the time to be allowed for completing their program because of the limitation on the amount which under the law can be expended annually. With respect to past experience, it appears by the testimony of Mr. Pearse that in the four years, 1925 to 1928, inclusive, the Sanitary District expended $51,000,000 for construction. According to the testimony of Mr. Ramey on the original reference there was construction work by the Sanitary District to the amount of $14,000,000 in 1925 and about $11,500,000 in 1926, including dredging, bridges, etc. Mr. Pearse said that in 1927, the Sanitary District expended $15,000,000 in construction work.

It is pointed out by the defendants that the Sanitary District is a municipal corporation, distinct from the other municipal entities functioning within Cook County, and is limited by the Constitution of the State (Sec. 12, Art. 9) which provides that no municipal corporation "shall be allowed to become indebted in any manner or for any purpose, to an amount, including existing indebtedness, in the aggregate exceeding five per cent. on the value of the taxable property therein, to be ascertained by the last assessment for State and County taxes previous to the incurring of such indebtedness."

From the testimony on the re-reference (March, 1929) it appears that the total assesed valuation (said to be on a basis of 100%) of the property within the Sanitary District for the year 1927, was $4,735,115,222, or at what is stated to be the "equalized value of property 1927," $4,-597,395,603, which gave a debt incurring capacity at five per cent. of $229,869,780, as of March 25, 1929. The out-

standing bonds at that time were $108,501,000 and contract liabilities (including judgments) which it is said must be counted against the debt limit under the Illinois law (*Schnell* v. *City of Rock Island,* 232 Ill. 89) amounted to $46,128,224.44, leaving an unexercised debt incurring capacity on March 25, 1929 of $75,241,555.56. On this basis, the Sanitary District through Mr. Ramey, its assistant chief engineer, submitted a calculation as to the number of bonds which might be issued by the Sanitary District, say for twelve or fifteen years, for construction work. His computations show that the District could issue continuously about $15,000,000 of bonds per year. Mr. Ramey testified:

> "I have taken the total bonding capacity of the Sanitary District as 5% of the latest assessed valuation, making a total of approximately $230,000,000. The outstanding bonds at the present time are $108,500,000, leaving a surplus of $121,500,000. Deducting the amount due each year on the present bonds outstanding, I assume that we issue $15,000,000 of bonds each year, redeem those at the rate of 5% in each of the future years, get a total of bonds that are to be redeemed each year by adding the redemptions on present outstanding bonds to the redemptions on future bond issues which are to be issued each year at the rate of $15,000,000 a year; then subtracting the total redemptions in any one year from the total issue in any one year, which is $15,000,000 in this computation, I get a figure which I can add to the present outstanding bonds. As long as my resulting figure remains below my bonding capacity, I can issue bonds at the rate assumed, I increase the bonding capacity $2,500,000 each year, assuming that the assessed valuation will increase at the rate of $50,000,000 per year. This calculation is made in strict accordance with the exhibit which we offered in 1927, but is made on a different basis because at that time we did not have the bonding capacity of 5% of the assessed valuation, and the assessed valuation was lower. The bonding ca-

> pacity was 4% of the then assessed valuation, which was half of the real valuation. Today the assessed valuation is 100% of the actual valuation, and our bonding capacity is 5% of that."

Mr. Ramey testified that he made allowances for the amount of the outstanding contract obligations of the Sanitary District as well as its bonded indebtedness.

It was also urged by the defendants that a citizen and property-owner in Cook County, in addition to paying taxes for the work of the Sanitary District, is also paying his portion of the assessments levied by the State, by the City of Chicago, by the County itself, and by a large number of taxing agencies existing within this area, and is thus subject to a heavy tax burden. Evidence was also given as to the assessed valuation of property in the City of Chicago and the amount of the city's debt limit and its unexercised debt incurring power. Counsel offered to prove estimates in relation to the improvements contemplated by the Chicago Planning Commission, a branch of the city government, consisting of persons prominent in the affairs of Chicago. The Commission was created in 1909 and many improvements have already been undertaken in accordance with its recommendations. Counsel offered to prove the estimates of contemplated improvements relating to the South Park District, the Lincoln Park District, adequate landing fields for aircraft, including the estimated cost of the lake front landing, and various proposed street improvements and the construction of superhighways to relieve traffic congestion. It was estimated, according to the offer of proof, that the cost of projects recommended by the Chicago Planning Commission which it was hoped might be undertaken within the next ten or fifteen years would require the issue by governmental agencies, other than the city itself, of approximately $141,000,000 of bonds. It was evident that the consideration of these various projects would involve an examination of details with respect to each, estimates of cost, relative

importance and time required, necessitating a large number of collateral inquiries into which I did not feel at liberty to enter under the order of re-reference. It is apparent that in a great and growing city there is a constant demand for important improvements, but the issue before me is a more limited one. The application of the City of Chicago to be made a party to these suits had been denied by this Court, and as I read its opinion directing this re-reference the Court did not intend that contemplated improvements within the City of Chicago should be permited to stand in the way of the obligation with respect to sewage disposal to which the Court found the Sanitary District to be subject. Accordingly, the testimony with respect to the projects of the Chicago Planning Commission, as disclosed in the offer of proof, was excluded.

It is observed in the brief of the counsel for the Sanitary District that the abandonment or curtailment of other public improvements by Cook County, the City of Chicago, Park Boards and other agencies, would not add a single dollar to either the tax levying or bond issuing powers of the Sanitary District; that is, that while the general tax burden is manifestly affected by these various public enterprises, the debt incurring capacity of the Sanitary District under the constitution and statutes of Illinois stands upon its own footing. On Mr. Ramey's estimate of the availability of $15,000,000 a year for additional indebtedness of the Sanitary District, it would be nearly twelve years before the total amount of expenditures as estimated ($176,166,000) on the sewage disposal program of the Sanitary District could be covered. Counsel pointed to the extreme difficulty of amending the constitution of Illinois and also of obtaining necessary legislation to facilitate the issue of bonds by the Sanitary District. It is not to be assumed, however, that the people of the State of Illinois would not take whatever proceedings might be necessary to equip the Sanitary District with adequate authority to discharge its obligations under the decree of this Court.

If a period of nine years were allowed for the completion of the program of the Sanitary District, less than $20,000,000 a year would be required to cover the entire present estimate of $176,166,000 (including controlling works). Even at the rate of Mr. Ramey's estimate of $15,000,000 a year, there could be made available in that period a total of $135,000,000 which, taking into consideration the amount already expended for construction work, as testified, ($51,000,000) would make a total outlay of $186,000,000, which is $29,000,000 more than the estimated cost of the sewage disposal program for complete treatment ($157,000,000) as outlined by the defendants on the original reference on the basis of contemplated expenditures after December 31, 1924 (*supra,* p. 72).

In its opinion this Court was explicit in its statement that the Sanitary District authorities had "much too long delayed the needed substitution of suitable sewage plants as a means of avoiding the diversion in the future", and that therefore they could "not now complain if an immediately heavy burden is placed upon the District because of their attitude and course." In view of this deliberate judgment of this Court, it does not seem to me that, assuming that with available funds the sewage disposal program could be carried to completion within eight years, there should be a further delay of four years merely because of the difference in the annual outlay that might be required in comparison with the annual expenditures of recent years (*supra,* p. 76). I am of the opinion that if an additional period of one year were allowed for the completion of the Southwest Side plant, making the entire period nine years, it would be as liberal a concession to the difficulties of the situation as the opinion of this Court can be deemed to justify.

General Conclusion.

I conclude, therefore, taking the time required for the completion of each of the sewage treatment works, sepa-

rately considered, and the circumstances which affect the completion of the Sanitary District's program as a whole, that a reasonable time to be allowed to the Sanitary District for completing the Southwest Side Sewage Treatment Plant, and thus for carrying out the entire program for sewage treatment, would be nine calendar years from January 1, 1930, that is, until December 31, 1938.

Ancillary structures.

Controlling works. The foregoing does not embrace a statement of the evidence with respect to the importance and time required for the construction of controlling works in order to prevent a reversal of the Chicago River at times of storm (*infra,* pp. 105-117). In order to install such works in the navigable waterway, as proposed by defendants, it would be necessary to obtain the permission of the Secretary of War, upon the recommendation of the Chief of Engineers, as provided in Section 10 of the Act of March 3, 1899, 30 Stat. 1151, U. S. C. Tit. 33, Sec. 403. There seems to be no serious dispute as to the time that would be required to build such works. Mr. Eddy, for the defendants, testified that he thought "it would take at least two and possibly three years". Mr. Howson figured on their installation by December 31, 1932. In their proposed findings, the defendants have provided that the Sanitary District shall immediately submit plans to the Chief of Engineers or his representative for such works to be constructed at or near the mouth of the Chicago River, or at or near the northern or eastern terminus of the Main Drainage Canal, and that they shall be completed and in operation within a period of two years subsequent to the date of the Secretary of War's authorization under the statute.

Water purification or filtration plants. Whether or not water purification works should be constructed will depend upon the disposition of the effluent from the sewage treatment works. The construction of such works is not in-

cluded in the Sanitary District's program, but is embraced in the program presented by the complainants (Complainants' Exhibit 238). The complainants, however, propose that this matter be left to the discretion of the defendants.

It was Mr. Howson's opinion that Chicago should install efficient filtration works for the entire water supply. He thought that such works could be designed in about one year's time and constructed in an additional four years. But it should be noted that Mr. Howson also testified on the original reference that filtration must be predicated upon metering if it is to be economically designed and done; that through sectionalization of the city for metering and the progressive design and construction of filtration plants for full metering in the various sections, the entire city can be placed under meter control; and that water supply and filtration plants could be constructed within about ten years from the date of the government permit. The witness was referring to the permit of 1925 in giving this testimony in 1926-1927. Colonel Schulz testified on the re-reference that to comply with the condition of the 1925 permit as to metering, the City of Chicago should have installed about 41,500 meters per year up to 1935, the end of the ten year period. But that there had been only a total of 29,945 meters installed up to the end of 1928.

Mr. Joseph W. Ellms, an expert in water purification matters, testified that "assuming the funds to be available four or five years would be a reasonable period of time for the design and construction of the water filtration plants." The evidence warrants the conclusion that, aside from the question of metering, water filtration works, if the defendants decided to build them, could be completed within a period of five calendar years.

As to the cost of such plants, Mr. Howson gave an estimate on the original reference, based upon an assumption of complete metering, of $30,000,000. Mr. Ellms at the same hearing testified that the reasonable cost would be "anywhere from $35,000,000 to $40,000,000." The defendants' witnesses on the original hearing testified that

the cost of water purification plants would be from $50,000,000 to $60,000,000.

This estimate for water purification plants was apart from the estimated cost of a super-tunnel which it was said might be built in the vicinity of Wilmette, four and a half miles off shore and approximately twenty miles from the mouth of the Chicago River, for the purpose of replacing the present water intakes of Chicago; this Mr. Howson estimated would cost about $40,000,000 and would take from five to eight years to construct. The defendants' witnesses estimated the cost of such a tunnel to be about $70,000,000.

Third. *The reductions in the diversion of water from Lake Michigan which are practicable pending the completion of the sewage disposal works.*

The defendants' position. (a) The defendants urge that it is not the function of the Court to determine what reductions may be made in the diversion during the period of construction or what the amount of the diversion shall be when the sewage treatment plants are in full operation. It is said that as navigable waters, and navigation, will be affected by the amount and quantity of the diversion, the determination of these questions lies with the political department of the Government and, under the Act of Congress of March 3, 1899, is subject to the action to be taken by the Secretary of War on the recommendation of the Chief of Engineers. It is the defendants' position that the opinion of the Court in this case does not indicate that the Court expects the Master to make any determination of these questions, but that he is merely to determine what practical measures may be adopted to dispose of the sewage and the time necessary for carrying such measures into effect.

This Court, in its opinion in these cases, recognized the authority of the Secretary of War in relation to the diver-

sion at Chicago. It was said that the construction of Section 10 of the Act of March 3, 1899, "was settled by this Court in the decision of the first Chicago Drainage Canal case in 266 U. S. 405, 429" (278 U. S. p. 414). By its decree in that case, the Court enforced the limitation of the former permit of the Secretary of War fixing the amount of the diversion. The Court in its opinion in the present suits also recognized the authority of the Secretary of War to issue the temporary and conditional permit of March 3, 1925, in view of the exigency then existing and in the interest of navigation and its protection. That permit runs until December 31, 1929. This Court, however, stated that "the normal power" of the Secretary of War is "to maintain the navigable capacity of Lake Michigan and not to restrict it or destroy it by diversions", and that beyond the quantity, said to be negligible, that would be necessary to keep up navigation in the Chicago River as a part of the Port of Chicago, "the validity of the Secretary's permit derives its support entirely from the situation produced by the Sanitary District in violation of the complainants' rights; and but for that support complainants might properly press for an immediate shutting down by injunction of the diversion, save any small part needed to maintain navigation in the river." The Court expressed the opinion that the complainants are entitled to a decree "which will be effective in bringing that violation and the unwarranted part of the diversion to an end." In keeping, however, with the principles upon which courts of equity condition their relief, and by way of avoiding any unnecessary hazard to the health of the people of that section, the Court said that its decree "should be so framed as to accord to the Sanitary District a reasonably practicable time within which to provide some other means of disposing of the sewage, reducing the diversion as the artificial disposition of the sewage increases from time to time, until it is entirely disposed of thereby, when there shall be a final, permanent operative and effective injunction." (278 U. S. 418, 419.)

In view of these expressions, and as the Master was directed to make a report of his conclusions and recommendations for a decree, it would seem to be clear that the consideration of practicable reductions in the diversion pending the completion of the sewage disposal works is necessarily embraced within the terms of the re-reference.

(b) The defendants, further, point out that since the hearings on the original reference (1926-1927) the levels of Lake Michigan, and of the other Great Lakes, have risen, and the defendants urge that the necessity for immediate reduction in the diversion no longer exists.

The change in lake levels cannot be taken to modify the decision of this Court with respect to the legal rights of the complainants in relation to the diversion, or as to the nature of the ultimate relief to be awarded. The evidence, however, was received in order that the Court may have the facts before it in considering the provisions of its decree.

In the former report, I made findings as to the mean annual levels of Lake Michigan above mean tidewater at New York from the year 1860 to 1925.* It was found that since

*"It will be observed that the mean level above tidewater was as high as 582.68 feet in the year 1860; that, after a fall to as low as 580.59 in 1872, it returned to 582.61 in 1876; and after another fall, rose in 1886 to 582.96. It then fell so that, for the year 1899, the year before the opening of the drainage canal, the mean level was 580.32, or 2.36 feet, a little over 28 inches, lower than the mean level of 1860, and 2.64 feet, or over 31½ inches lower than the mean level for the year 1886.

"In the years 1900 to 1905, the mean level was between 580 and 581, the lowest being 580.21 feet in 1902, and the highest being 580.98 feet in 1905. Thus in 1905, the mean level of Lake Michigan was nearly 8 inches higher than for the year 1899.

"After 1905, the mean level slightly rose, and then fell in 1909 to 580.50 feet, which was still about two inches higher than the level of 1899. There followed a lowering of the mean level to 580.15 in 1910, and to 579.60 in 1911, but this was restored to 580.68 in 1913, and after another fall, the level came back to 580.35 in 1916, approximately the same mean level as that of 1899. It then rose as high as 581.40 feet in 1918, falling to 580.56 in 1920, which was still higher than the mean level of 1899. Since then, there has been a decided drop; so that in 1924, the mean level was 579.09 feet and for 1925 it was 578.24, showing a fall in the mean level from 1920, to the end of 1925 of over 27 inches." (*Report of Special Master,* November 23, 1927.)

1920 there had been a decided drop; that in 1924, the mean level was 579.09 feet, and in 1925, it was 578.24 feet. The evidence on the re-reference shows that the lowering continued in 1926. The mean level for that year was 578.14 feet. In 1927, there was a rise so that the mean level was 578.96 feet. The range in 1928 was from 578.72 feet in January to 580.63 feet in December, the mean level for the year being 579.92 feet, or approximately twenty-one inches higher than that of 1926. In 1929, there was a decided rise until the highest point shown (that is the last record appearing on the United States Lake Survey Chart, in evidence) was 582.4 feet in July, 1929, or approximately three feet and nine inches higher than at the corresponding time in 1926.

The levels of Lake Huron and Lake Michigan are the same. Lake Erie and Lake Ontario, during the period above described, exhibited a corresponding relative rise in levels.

It was testified (March 28, 1929) that the control gates at the outlet of Lake Superior were opened in the fall of 1928 in order artificially to reduce the level of that lake and that these controlling works "have been operated wide open since October, 1928". The United States Lake Survey chart shows a rise in the level of Lake Superior to 603.4 feet in October, 1928, the highest point reached since 1916; thereafter there was a fall to 602.4 feet in February, 1929, after which the level of Lake Superior rose until it reached 602.85 feet in July, 1929.

(c) The defendants also insist that while, "with the construction of controlling works, certain amounts of reduction" (of the diversion)) "may be accomplished when certain units of the program are placed in operation," the extent of that reduction cannot now be definitely determined. That determination, they say, should be made at the times the different important units of the works go into operation. And it is said, further, that, if the Court

undertakes to fix the amount of the diversion, it should provide the means for a careful study and investigation of the conditions that will exist as works are installed during the construction period as well as at the end of that period.

Mr. Eddy's testimony supported this view. But, subject to that qualification, he gave his best judgment as to the extent of practicable reductions. He testified that "there should be no reduction in the diversion until there is an absolute barrier against the discharge of storm water into Lake Michigan, which would mean the date of completion of controlling works in the Chicago River or at the head of the Drainage Canal." If controlling works were in operation, he thought that, exclusive of pumpage, there could be a reduction for January 1, 1930, from 8,500 c. f. s. to 6,500 c. f. s. "upon the assumption that the Calumet plant is in operation, and it now is, providing sedimentation and a small trickling filter; that the West Side plant for sedimentation to serve about 1,000,000 is in operation; that the North Side plant is in complete operation." Assuming that it would take two years to install the controlling works, his estimate of a diversion of 6,500 c. f. s., on the basis above stated, "would be applicable to January 1, 1932." The next date he set for reduction of the diversion was January 1, 1936, upon his estimate of the time required for the progress of the construction of the treatment plants (*supra,* p. 37). On that date he thought the flow could be further reduced from 6,500 c. f. s. to 4,500 c. f. s. The next stage, he said, would naturally be when complete treatment was provided (*infra,* p. 130).

The complainants' position with respect to the reduction of the diversion.

The complainants in their program submit the following schedule for the reduction of the diversion following the statement already quoted (*supra,* p. 18) as to the

sewage treatment works and time for completion (Complainants' Exhibit 238):

"A. Diversion (Excl. water consumption) with Control Works built by December 31, 1932, can be as follows:

		c. f. s.	*Date*
(1)	Present Diversion	8500	now
(2)	Diversion reduced to	6500	12/31/1929
(3)	" " "	5000	12/31/1932
(4)	" " "	3000	12/31/1933
(5)	" " "	0*	12/31/1935

*i. e., no flow at Lockport.

B. Without control works diversion can be reduced to 6500 c. f. s. plus sewage on December 31, 1929, and to zero flow at Lockport on December 31, 1935."

Mr. Howson, in presenting this program, testified:

"There could be a reduction in the diversion as of December 31, 1929, to 6500 c. f. s. plus the domestic pumpage, which would be a reduction of the present 8500 c. f. s. direct diversion to 6500 c. f. s. I believe there could be no further reduction in the flow until complete treatment is in effect on December 31, 1935, unless control works are installed as a part of the program, or unless hydraulic testimony should establish that a lower flow than 6500 c. f. s. would prevent reversals of the Chicago River which is the critical thing prior to the completion of the program. The diversion can be reduced in proportion to the organic load removed, up to the point to where reversals can be controlled by the facilities available, at Lockport or through new works.

"Assuming that the reversals are controlled either at Lockport, or by new controlling works subsequently to December 31, 1929, the diversion could be reduced to 5000 c. f. s. plus pumpage on December 31, 1932, and to 3000 c. f. s. plus pumpage on December 31, 1933. All of the preceding figures are in addition to pumpage. On December 31, 1935, when the program I have out-

lined will be completed, the entire flow at Lockport can be cut off."

Mr. Gascoigne testified:

> "By December 31, 1929, the diversion can be reduced to 6500 c. f. s. in addition to the pumpage or used water supply. By December 31, 1935, no flow at Lockport is necessary if this program is carried out and completed. The foregoing reductions are not dependent upon the construction of controlling works. If controlling works were constructed and placed in operation so as to prevent any reversals, it would be practical to reduce the diversion subsequent to December 31, 1929, and prior to the cessation of all flow on December 31, 1935, in accordance with the organic load removed from the River by the additional treatment of sewage at the various treatment plant sites. I have not computed the practical reductions on that basis between December 31, 1929, and the termination of all flow on December 31, 1935."

Mr. Townsend testified that he had not made any estimate of reduction of the diversion in cubic feet per second at any time prior to the completion of the program. But he said:

> "It would be practical from time to time, during the course of the construction of the program outlined by me" (*supra*, p. 22) "to reduce the amount of lake water diversion. On and after December 31, 1929, the present rate of lake water diversion may be decreased. The extent of that decrease either would be proportionate to the reduction of the organic load removed by sewage treatment plants at that time, or would be limited by the extent to which the reduction could be made without causing reversals of the Chicago River. Either factor may be the controlling factor, depending upon the hydraulics of the river."

Testimony of Major General Jadwin, Chief of Engineers. In anticipation of the hearing under the order of re-reference, I informed the Chief of Engineers of my appointment and of the date of the hearing, and made the following request:

> "At the time above stated, I should like to have testimony from you, or from the District Engineer at Chicago, or other officer of the War Department competent to testify, with respect to the proceedings that have been taken by the Sanitary District of Chicago under the permit of March 3, 1925, with respect to the installation of sewage disposal plants and other measures for which the permit provides; also as to the extent of the diversion by the Sanitary District of the waters from Lake Michigan at the present time.
>
> "I should also like to have your testimony, or that of a competent officer of the War Department, with regard to the extent of the flow from Lake Michigan, if any, that would be necessary to maintain navigation in the Chicago river, in the event that all diversion for the purpose of taking care of the sewage of the Sanitary District were discontinued."

In response, General Jadwin presented Colonel Schulz, who testified with respect to compliance with the conditions of the permit of March 3, 1925 (*supra,* p. 5). General Jadwin then made a formal statement upon the question of diversion. Preliminarily, he said that but for these hearings the War Department would have got in touch with the representatives of both sides and have given them full opportunity to bring forward their respective points, and then the Department would have prepared its opinion; but the Department was very familiar with the general fundamentals of the case, and he had had the advantage of the opinion of a number of his officers who were present at the hearing, and he had prepared a tentative answer to the question; that he had in mind nothing which might arise

to cause a change in it, but that he would like to be free to advise the Master of a change in the Department's position, if any reason were found therefor. No such change has been suggested. General Jadwin's statement was as follows:

"1. With the accomplishment of sewage purification expected before December 31, 1929, a diversion of 7250 c. f. s. is believed necessary to maintain tolerable conditions of navigation in the Chicago River. With the progressive increase in sewage purification this amount may be decreased to an ultimate minimum of 5000 c. f. s., including water supply, or to such other flow as may be determined by the Secretary of War, on the recommendation of the Chief of Engineers to meet the requirements of through navigation on the Chicago River and on projects authorized by Congress from time to time.

"2. In explaining this answer it seems advisable to define certain terms in order to avoid misunderstandings as to the sense in which they are used. The term 'Chicago River' is taken to embrace the main stem of the stream and its navigable branches and also the Calumet River and its navigable branches, since the latter stand in the same relation to the Sanitary District and the interests of navigation as does the Chicago River. The term 'Flow from Lake Michigan' or 'Diversion' in its most general aspect, includes three elements; first, the water flowing or pumped from the lake directed into the Chicago River and its branches, and passing through the Sanitary District's canal to the Illinois watershed; second, the run-off of the watersheds of the Chicago and Calumet Rivers, which is diverted from its natural course toward Lake Michigan and enters the Sanitary canal largely through the city sewers; and third, the water pumped from the lake for domestic use and passing into the Sanitary canal as sewage or as effluent from sewage treatment plants. As used by the War Department, the term 'Diversion'

is the flow diverted by the Sanitary District exclusive of the water drawn by the City of Chicago for water supply purposes and entering the Chicago River as sewage. It is determined by deducting from the total flow out of the Drainage Canal at Lockport the amount pumped by the City into its water mains. As so computed, the Diversion includes the run-off of the Chicago and Calumet drainage area.

"3. The introduction of deposits of sewage into the Chicago River would, without dilution, render it so foul and putrid as to materially impair its navigable condition and capacity through its deterrent effect on the navigators and on those engaged in loading and unloading the vessels. This statement is based on the effect on navigation and with the intention of keeping this effect separate from the effect on the important question of sanitation of Chicago. The sanitary conditions essential for working conditions for those engaged in navigation should be substantially the same as for the residents on shore.

"With the accomplishment of sewage treatment expected to be effected by the Sanitary District before December 31, 1929, a total diversion, in excess of sewage, amounting to 7250 c. f. s., will be requisite to dilute the sewage and carry it away to an extent sufficient to render the Chicago and Calumet Rivers suitable for navigation. Even with the attainment of the maximum practical treatment of all sewage, some circulation of water will be necessary to keep the condition of the waters tolerable for navigation. The effluent from sewage treatment plants is not pure water, and the added refuse from ships and streets, together with unavoidable accumulations of oil, requires more water for flushing than is available from the natural run-off, which the urban development has in large part intercepted and turned into sewers. When the ultimate practicable treatment of sewage is accomplished, it is believed that the needs of navigation in the Chicago and Calumet Rivers proper may be found not to exceed a flow of clear water from the lake averaging

1500 c. f. s., augmented by the natural run-off of the Chicago and Calumet River watersheds and the effluents from the treatment plants. This would give an average annual flow of about 3200 c. f. s. at Lockport. This diversion would create a current on the principal river channels of from ¼ to ⅓ foot per second, and would be sufficient to renew the average water content of the main portions of the Chicago River in about two days. Unless the total diversion be considerably greater than 3200 c. f. s., the progressive putrefaction of the polluted water would become offensive, to a degree detrimental to navigation, because of the longer time required for its passage through the drainage canal to the navigable waters of the Des Plaines River, and the upper reaches of the Illinois River.

"4. Although the term 'Navigation on the Chicago River' may be applied in a very restricted sense, it is not believed that a complete answer in the matter of diversion at Chicago can be given without regard to the physical relation which exists between the Port of Chicago and the great Inland Waterway System made up of the Mississippi, Ohio, Missouri and Illinois Rivers and their navigable tributaries and the traditional policy of Congress in developing and improving waterways to meet the increasing needs of commerce. It has, therefore, become a more pressing matter to provide for the actual connection of the inland waterway system with the Great Lakes. The Engineer Department, in reporting on the Illinois River project made reference to the work being done upstream by the State of Illinois and also that by the Sanitary District. This work partook of the nature of local co-operation. The Federal project for the Chicago River connects the South Branch and the Sanitary Canal with Lake Michigan.

"The river and harbor act of 1927 which directed the existing project for the Illinois River specified that it did not authorize a diversion of water. The project directed by Congress provided specifically for a channel with a depth of 9 feet without specifying the manner

in which this depth should be obtained. The report before Congress when the project was adopted provided for alternative plans, varying in cost with the amount of diversion, the cost generally increasing as the diversion decreased. The plans were designed to provide a channel of the requisite cross-section with diversions of varying amounts between 1,000 and 10,000 c. f. s. With the lesser flows the depth would be secured by dams and locks, with the greater flows by open channel dredging. A review of the project has since been directed by Congress.

"Questions have arisen as to possible changes that may be necessary in the project to handle navigation in the future.

"There has not been as yet an official determination by the Engineer Department, of its recommendation as to the best type of improvement of the Illinois River.

"That is in response to the call from Congress.

"It is therefore seen that it is not practicable to state at this time what the amount of diversion is that may be needed in the Chicago River to meet the requirements of navigation in the broad sense. It may be that the proper proviso would be flexible and enable the United States to secure the fullest benefits of the navigation possibilities of the inland river system of waterways in connection with the Great Lakes water system, when, and if such increases are indicated. Besides providing water necessary for adequate depths and widths of channels another requisite for navigation of the Illinois River is that the water should not be unreasonably offensive. This matter has been studied by sanitary engineers employed by this Department. They made an elaborate study and advised that 4167 c. f. s. total flow measured at Lockport was the minimum total diversion necessary with the activated sludge method of sewage purification and with a 90% metering to prevent the occurrence of a nuisance in the Illinois and Des Plaines rivers and to permit fish life therein. There may be some room for argument

as to this standard, but it seems certain that with too little water, the water will be so foul as to be a menace to the health of the workers upon vessels and at terminals. Certainly it is not possible to specify at this time the precise amount of water required to keep the waterway in a reasonably acceptable condition for navigation many years hence, with the growth of the city, changes in the sanitary art, and other developments not yet foreseen. The diversion eventually required can only be stated in round figures. To allow for contingencies, I have placed the eventual amount at 5,000 c. f. s. measured at Lockport.

"It therefore appears that the diversion required for navigation in the Chicago River proper may not be the controlling factor in fixing the ultimate diversion, but that the need of an Inland Waterway System when determined and defined by Congress, or, under its authority, by the Chief of Engineers and the Secretary of War, may prove to be greater than those for navigation in the Chicago River itself.

"In other words, although local navigation on the Chicago River may be safeguarded by a total diversion of about 3200 c. f. s. measured at Lockport, the through navigation between Chicago and the Mississippi system will require about 5000 c. f. s. to keep the water in the channels south of Chicago in acceptable condition with an as yet undetermined but possibly greater flow required for the maintenance of adequate channel depths and widths.

"Storm Water Run-off.

"The amounts of the diversion stated in this answer are average annual diversions. The temporary diversions of a much greater flow to prevent sewage contaminated water from a storm water run-off of the Chicago and Calumet watersheds from reaching Lake Michigan will not affect in any sensible degree the levels of the Great Lakes and should be contemplated in the decree. The control works necessary to prevent the reversal of flow with the small annual diversion

recommended are under study by the Department and will be presented at a later date.

"No consideration of the ultimate diversion to be permitted is complete without mentioning the proposed compensation works in the Great Lakes.

"This department originally instituted the proceedings looking to the curtailment of the diversion of water by the Sanitary District to the end that navigation on the Great Lakes and on the St. Lawrence might be protected. It remains fully alive to the importance of safeguarding this navigation. The diversion regarded as necessary for purposes of navigation will reduce by one-half the lowering of the levels of the lakes, and this remaining effect on them can be cured by the construction of suitable compensating works. A moderate diversion will best meet the needs of navigation of the country as a whole."

Questions to be determined. There are thus three questions involved in determining the reductions in diversion that may be practicable pending the completion of the sewage treatment works: (1) What reduction may immediately, or shortly, be had; (2) whether any further reductions can properly be required without the installation of new controlling works; and, (3) if such works are found to be necessary, what reductions may be had after they have been provided.

1. The complainants' witnesses testified that there may be a reduction as of December 31, 1929, to 6,500 c. f. s., in addition to pumpage. This was based on their assumption as to the completion of the pumping station, and the consequent full operation, of the North Side treatment plant, and the completion of the two batteries of Imhoff tanks together with the skimming tanks, grit chamber and pumping station, of the West Side treatment plant. Mr. Eddy, for the defendants, made a similar assumption as to the operation of the treatment works, in his testimony as to a reduction to 6,500 c. f. s. General Jadwin in his state-

ment as to a reduction to 7,250 c. f. s. also contemplated "the accomplishment of sewage purification expected before December 31, 1929."

The work which was expected to be finished by December 31, 1929, has been delayed, and in their proposed findings the complainants have fixed April 1, 1930, as the date for the reduction to 6,500 c. f. s. The most recent testimony is that the North Side treatment plant will be in full operation by April 1 or May 1, 1930, and the defendants' proposed findings put July 1, 1930, for the full operation of this plant and for the completion of the second battery of tanks at the West Side plant. It thus appears that the discussion as to the proposed reduction to 6,500 c. f. s. or to 7,250 c. f. s., may be taken to refer to a date not later than July 1, 1930.

Both the 6,500 c. f. s. proposed by the complainants, and the 7,250 c. f. s. suggested by General Jadwin, are comparable to the 8,500 c. f. s. mean annual diversion prescribed by the permit of March 3, 1925. In making the recommendation which underlay that permit the Chief of Engineers then in office contemplated a reduction of the diversion to 7,250 c. f. s. by December 31, 1929. That recommendation stated:

> "5. It is estimated that the construction of sewage treatment plants for a population of 1,200,000 will permit a reduction in the necessary diversion from Lake Michigan of about 1,250 cubic feet per second. In other words, such construction would permit a reduction in the authorized diversion, by December 31, 1929, to about 7,250 cubic feet per second. As stated above (paragraph 4), it is probable that a still more rapid rate of reduction of diversion may be practicable thereafter."

General Jadwin's present estimate is precisely in accord with the foregoing, and appears to be a general estimate on the basis of what would naturally be expected rather

than on any new or independent, scientific determination of the extent of the sewage purification. In explanation of his estimate, General Jadwin testified:

> "The diversion is going on now, has been going on under the permit that was issued in 1925 and provided for 8,500 c. f. s. as being the proper amount needed for that purpose, 8,500 plus the water supply. It provided for a progressive reduction at the rate of 250 c. f. s., that would bring it to 7,250 c. f. s. at the end of this year. I understand from the Division Engineer that the program is being carried out substantially as prescribed, and I start with that amount. That is, as near as—from any evidence that I have, that is the amount that is now needed.
>
> "When we were preparing the project for the improvement of the Illinois River, this question came up. Congress asked us to report on the diversion necessary for that. We first had the study made by the District Engineer. At that time General Taylor was Chief of Engineers, and Major Putnam was the District Engineer. Major Putnam studied it very carefully. And General Taylor authorized him to employ a firm of expert sanitary engineers to assist him in the matter. The Department approved the appointment of Alvord, Burdick & Howson, who were expert people, competent and disinterested. They made a very careful study which has been before us and has been taken into consideration by my assistants in their progressive study of the diversion.
>
> "In determining that amount of diversion, I considered the amount of water needed for the navigation of the river below, and for the preservation of sanitary conditions there as well as the Port of Chicago, not from the standpoint of taking care of the health of Chicago, but from the standpoint of navigation. People on board boats need substantially the same protection, that is, their protection is the same as the people in the city. There is quite a running parallel in there for a long distance, then they are separated.

"In answer to the question whether the conclusion as to a diversion of 7,250 c. f. s., in addition to pumpage, was based in part upon what I thought necessary for the maintenance of navigation and the health of the navigator in the lower streams as well as in the Chicago Port, my thought is that we determine it in the way that I told you, practically, but I think an analysis will show that it does contemplate taking care of the navigation in the upper Illinois, in view of the fact that through navigation on the Chicago River must pass through that place, and if the navigators are not protected there it would hamper the navigation on the Chicago River. The protection of fish life in the lower river came in in the Alvord, Burdick & Howson report. But my statement did not contemplate that for the purpose of protecting fish. They used that as a measure of suitability of water for navigation. The extent of the diversion which I say is necessary is not for the sake of the fish, but is for the sake of the navigators.

"In determining this amount of 7,250 c. f. s., I have in mind that it was contemplated by the program under which they were working, and of which the District Engineer kept us advised, and that part of the sewage was purified and part was not. I did not analyze what proportion of the sewage was purified. I had those figures and they were mentioned. I didn't check or analyze it. I took the 7,250 as being about the status that the works would naturally be expected to be going at at the end of the year."

It is evident that General Jadwin was considering the nuisance factor in relation to navigation and not simply the question of depths, or current, or other matters relating to navigation irrespective of conditions produced by the inflow of sewage. General Jadwin said that he did not profess to be a sanitary engineer; he based his estimate largely on the studies of other officers, and they had the advice of the firm of sanitary engineers to whom he referred in his testimony. He said that "We got our

view from Messrs. Alvord, Burdick & Howson. We paid them to give us an independent sanitary study and opinion and we have not seen anything to cause us to make a further study;" he was willing to make a further study, if it was desired, but he added—"We are following the lead of Messrs. Alvord, Burdick & Howson on those sanitary matters."

This firm was employed in January, 1925, and made their report to the War Department in April of that year. Their report shows that their study was directed to answers to certain questions, which included the determination of a pollution standard for the Drainage Canal for stated annual diversions from Lake Michigan, this standard being described as "the lowest that will prevent the occurrence of nuisance in the Des Plaines and the Illinois River, and will permit a thriving fish life therein." Mr. Howson, of that firm, who signed the report and had an important part in its preparation, testified to its correctness and that the standard to which it referred had been given to him by the War Department. He said that "a standard for water which requires conditions which will permit the maintenance of a thriving fish life, and one which requires the absence of nuisance are not at all the same. Fish life is a much higher standard. A standard which requires the maintenance of a thriving fish life is not one ordinarily adopted or accepted to satisfy health requirements or to prevent interference with navigation." Mr. Howson testified, as already stated, that on the assumption of the work expected to be completed by December 31, 1929 the direct diversion from Lake Michigan could be reduced to 6,500 c. f. s. plus pumpage.

This estimate finds support in the evidence as to the experience of former years. It was found on the original reference that the average direct diversion in 1925, was 6,940 c. f. s. and, in 1926, 6,888 c. f. s., the conditions then making impracticable a larger diversion. Mr. Ramey testified that the average direct diversion in 1927 was 6,985

c. f. s. It thus appears that an average annual direct diversion of 7,250 c. f. s. would be greater than that which actually obtained in the years 1925 to 1927, inclusive, while a reduction to 6,500 c. f. s. would make the average direct diversion only about 500 c. f. s. less than that of those years. Colonel Schulz testified that he considered the conditions "quite offensive to navigation at the present time" and that, in 1925 and 1926, navigation was going on but the condition was offensive; the river was covered with scum. Mr. Ramey (assistant chief engineer of the Sanitary District) testified on the original reference, referring to the average flow in 1926, with a direct diversion of 6,888 c. f. s., that that flow was perfectly satisfactory so far as the water supply was concerned. He said:

> "Of the 6,888 second-feet of the abstraction for 1926, what witness has termed direct abstraction from Lake Michigan, probably about 5,000 second-feet came in through the Chicago River. Witness thinks about 72% of the water diverted from Lake Michigan comes through the main river. The Sanitary District had no difficulty with the water supply during 1926 while it was maintaining this 5,000 second-feet through the Chicago River. Witness does not know that there was any particular difficulty in 1926. That flow was perfectly satisfactory so far as protecting the water supply coupled with the flow we took from the Lake through the Calumet River. That made conditions satisfactory for the year 1926."

The estimate of Mr. Eddy, the defendant's sanitary expert, was (*supra,* p. 87) that on the conditions expected on January 1, 1930, there could be a reduction of the diversion from 8,500 c. f. s. to 6,500 c. f. s., provided only that controlling works had been established in the Chicago River, or at the head of the Drainage Canal, to prevent the discharge of storm water into the Lake. Assuming that it would take two years to install these works, he said that

his estimate of a diversion of 6,500 c. f. s. would be applicable to January 1, 1932. The clear inference is that with respect to conditions in the river itself and in the Drainage Canal, that is, assuming the prevention of reversals of the river, the reduction of the direct diversion to 6,500 c. f. s. would be feasible on the completion of the sewage treatment work as estimated for January 1, 1930. And it would seem from the evidence that the completion of the North Side treatment plant and of the two batteries of the West Side treatment plant should permit a reduction of 500 c. f. s. in the mean annual direct diversion, so far as the conditions in the river and Drainage Canal are concerned.

Evidence has been introduced to show the quantity of run-off in the Chicago River watershed, that is, the frequencies of different amounts of run-off. On the original reference Mr. Ramey gave the amounts of storm run-off, and their frequency, according to his estimate of 1923 based on 1922 conditions. According to that estimate, the run-off from the drainage area of the Chicago River

> "exceeds 4167 c. f. s. from 7 to 8 times per year
> exceeds 5000 c. f. s. from 5 to 6 times per year
> exceeds 7500 c. f. s. from 3 to 4 times per year
> exceeds 9500 c. f. s. about one time per year."

It was then stated by Mr. Ramey that, as the built up sections of the District increased, the sewered area and the run-off rate would increase. On this re-reference, Mr. Ramey has presented a new calculation of run-off based on conditions of 1929 as follows:

> "2,000 second feet will run off from 55 to 60 times a year; 3,000 second feet will run off from 30 to 35 times a year; 4,167 second feet will run off from 18 to 22 times per year; 5,000 second feet will run off from 12 to 15 times per year; 6,000 second feet from 8 to 10 times per year; 7,000 second feet from 6 to 7 times a year; 7,500 second feet from 5 to 6 times per year;

8,000 second feet from 4 to 5 times per year; 9,000 second feet from 3 to 4 times per year; 10,000 second feet from 2 to 3 times per year; 13,000 second feet, about once per year."

As to new controlling works to prevent reversals of the river, General Jadwin at first stated that if there was a large diversion it was doubtful whether such works would be needed; that with a very small diversion the necessity becomes more pressing; that he did not know whether they were necessary with a diversion of 7,250 c. f. s. and that of 5,000 later; that the matter was under discussion. Subsequently, after full consideration in the War Department, General Jadwin made a formal statement on the subject of controlling works.* He then said that with average annual diversions greater than about 6,000 c. f. s. controlling works placed near the head of the Drainage Canal, that is, at or near its northern or eastern terminus, would add but little to the effectiveness already obtained by the control at Lockport, the western terminus of the main channel of the Drainage Canal, where the present control is maintained by sluice gates and dams. He said, further, that controlling works located at the mouth of the Chicago River would involve a serious interference with navigation; that a control gate there located would not be necessary until the diversion was "so low as to require its frequent operation", and, under such conditions, the closure of the river by the gate would be an unwarranted obstruction, and that if an effective control at the mouth of the river consisted of a lock with sluices, it would cause such delay and inconvenience that it would merit approval only as a last resort. General Jadwin's conclusion was that the question of the control of both the Chicago River and the Calumet River were capable of practical solution, probably without any further control works, with a total annual average diversion of 5,000 c. f. s.

*This is given in full (*infra*, pp. 108-116).

The contemplated direct diversion is exclusive of "pumpage", that is, "of the water drawn by the City of Chicago for water supply purposes and entering the Chicago River as sewage." The average pumpage for 1925 was 1,338 c. f. s.; for 1926, 1,395 c. f. s.; for 1927, 1,421 c. f. s.; for 1928, 1,565 c. f. s. The total flow at Lockport including pumpage would be about 8,000 c. f. s. on the basis of a direct diversion of 6,500 c. f. s. It was found on the original reference that the average annual total flow at Lockport did not exceed 8,000 c. f. s. until 1916; that for the years 1915 to 1919 the average was 8,417 c. f. s. and for the years 1920 to 1924, 8,674 c. f. s. The average total flow at Lockport in 1925 was 8,278 c. f. s., in 1926, 8,283 c. f. s. and in 1927, 8,450 c. f. s. It rose to 10,010 c. f. s. in 1928. But an average annual total flow at Lockport on a basis of 6,500 c. f. s. for direct diversion and 1,500 c. f. s. for domestic pumpage, or a total of 8,000 c. f. s., would be within 450 c. f. s. of the highest mean total flow for any year of the three years 1925 to 1927.

It should be noted that the reduction to 6,500 c. f. s., as compared with the present 8,500 c. f. s. direct diversion, refers to the mean annual direct diversion. As General Jadwin testified: "The temporary diversions of a much greater flow to prevent sewage contaminated water from a storm water run-off of the Chicago and Calumet watersheds from reaching Lake Michigan will not affect in any sensible degree the levels of the Great Lakes and should be contemplated in the decree". Such a temporary diversion was authorized in the permit of March 3, 1925, which provided for an "instantaneous maximum" diversion of not to exceed 11,000 c. f. s. while fixing 8,500 c. f. s. as the "annual average."

The evidence before me sustains the conclusion that a reduction (on the completion of the North Side treatment plant and of the two batteries of the West Side plant) of the mean annual direct diversion to 6,500 c. f. s., which would not preclude greater temporary diversions to apply in emergencies including storm conditions, would afford

sufficient protection both for navigation and the water supply of the City.

2. The next question is whether there should be further reductions of the diversion pending the completion of the sewage treatment program and without the installation of controlling works.

There was a reference to such works in the permit of the Secretary of War of March 3, 1925, which provided as one of its conditions:

> "6. That the Sanitary District shall submit for the approval of the Chief of Engineers and the Secretary of War plans for controlling works to prevent the discharge of the Chicago River into Lake Michigan in times of heavy storms. These works shall be constructed in accordance with the approved plans and shall be completed and ready for operation by July 1, 1929."

In 1927, the Sanitary District submitted plans for controlling works, but these have not been acted upon by the War Department. Colonel Schulz testified (March 25, 1929) on this point:

> "Condition 6. The Sanitary District has submitted plans for controlling works at the mouth of the Chicago River to prevent the discharge of the Chicago River into the Lake at times of heavy storm. The matter has been studied in the Office of the Chief of Engineers. The matter is now before the Department. These controlling works cannot be completed and ready for operation by July 1, 1929. The works can be completed in about two years after the plans are approved."

Colonel Schulz said that he did not know why these plans for the controlling works had not been approved but that

they were for works at the mouth of the river; that they were "not waiting for any move on the part of the Sanitary District. The plans are in Washington."

On the original reference, the complainants introduced the testimony of Brig. Gen. William L. Sibert, in order to show that control gates could be constructed at Western Avenue or at the mouth of the Chicago River so as to provide a quicker control of the flow and prevent reversals of the river, and it was contended that such control would obviate objections to the reduction of the diversion. On this re-reference, the defendants proposed, as an integral part of their program, the construction of controlling works (Defendants' Exhibit 1387, *supra,* p. 11).

The complainants' sanitary experts have not testified that these controlling works would not be needed. On the contrary, Mr. Howson, who prepared complainants' program, predicated the estimate therein for the further reductions of the diversion, after the initial reduction to 6,500 c. f. s., plus pumpage, on "control works built by December 31, 1932". And the tabular representation of that program (Complainants' Exhibit 238, *supra,* p. 88) did not provide for any reduction, after the initial one, in the absence of control works, until the entire program had been completed. Mr. Howson in his testimony stated (*supra,* p. 88) that he believed that "there could be no further reduction in the flow until complete treatment is in effect on December 31, 1935" (that being the date he fixed for completion of the entire sewage treatment works) "unless control works are installed as a part of the program, or unless hydraulic testimony should establish that a lower flow than 6,500 c. f. s. would prevent reversals of the Chicago River which is the critical thing prior to the completion of the program".

The complainants in their brief have summarized the state of the record on this point by saying:

"It is agreed that the practicability of these further reductions" (after the initial reduction to 6,500 c. f. s., plus pumpage) "during the construction of the program depends upon whether controlling works are installed to prevent the reversal of the Chicago River in time of storm or whether the hydraulics of the Chicago River and Drainage Canal will permit the prevention of reversal of the River with controlling works at Lockport. The witnesses for both sides agree that subsequent to December 31, 1929, no progressive reductions may be had in the diversion beyond the point where substantial reversals of the Chicago River are prevented."

Mr. Howson himself did not testify as to the adequacy of the Lockport control for this purpose. Nor did the other sanitary experts called by the complainants give such testimony. As to the hydraulics of the river and canal, the complainants introduced the testimony of Horace W. King, professor of hydraulic engineering at the University of Michigan. There was also testimony for the defendants by Mr. Ramey and by Sherman M. Woodward, professor of mechanics and hydraulics at the University of Iowa. The evidence on this subject is highly technical; it was presented with much detail on examination and cross-examination, and it is impracticable to attempt to review it in this report. My conclusion is that there is no adequate basis, so far as the testimony on the hydraulics of the river and canal is concerned, for a finding that pending the completion of the sewage treatment program it would be proper to require a further reduction of the annual average direct diversion below 6,500 c. f. s. without the installation of new controlling works.

General Jadwin's statement on controlling works. General Jadwin's formal statement on this subject, which he said had been prepared in cooperation with his associates, and which included an answer to the question put by com-

plainants' counsel as to the works which would be required under hypothetical diversions ranging from storm water flow only to a diversion of from 1,000 c. f. s. to 7,000 c. f. s., is as follows:

> "The conclusion as to the general question is that the need for further control works is not yet established.
>
> "Control works are not necessary in the interests of navigation. However and wherever constructed they would impose some delay and inconvenience upon navigation. Their purpose is to prevent the discharge of polluted water from the river into the lake where it would menace the city water supply and beaches. From the navigation standpoint, if conditions of diversion and sewage purification are so adjusted as to maintain tolerable conditions in the river, there is no reason to fear that the occasional storm discharge of untreated sewage into the lake will render conditions there intolerable for navigation.
>
> "The requirement in the present permit that control works be designed and installed appears to have been based on the contention advanced by the Sanitary District that low diversions, without control works, would result in great damage to the city water supply and beaches because of storm reversals, and on the premise that control works could be designed which would effectively prevent such reversals without serious detriment to navigation.
>
> "From the standpoint of the protection of the water supply, it may be noted that the complete prevention of any reversal of flow into the lake is not now accomplished and is not essential. As the sewage purification progresses, the temporary amount of outflow which can be tolerated will increase. As the diversion is decreased, the difficulty of preventing considerable outflows will also increase. It is not now considered possible to fix the exact limit of diversion at which the present control at Lockport will become unsatisfactory. Recent experience with a reduced diversion to prevent

flood damage in the Illinois River indicates, however, that after the sewage purification has reached the practicable standard of efficiency, the present Lockport control may be found satisfactory with a total diversion as low as 5,000 c. f. s., annual average, and might possibly be satisfactory with a lower diversion.

"It is the present attitude of the Chief of Engineers, therefore, that the United States should not require the construction of controlling works, but that the Department will consider any application for the approval of plans of controlling works, to be constructed by the Sanitary District or other agency, and may be expected to approve these plans if the works are shown to be necessary, to be effective, and to be the minimum detriment to navigation.

"The question of control works is therefore a sanitary matter for solution by the Chicago Sanitary District or the City of Chicago. For the information of the Master, an explanation of the causes of reversal of flow in the river and of the effect of control works that have been considered, is presented in order to afford data as to works appropriate to various hypothetical diversions.

"The discussion does not modify in any respect the statement heretofore made that an average diversion of 5,000 c. f. s. will be necessary to maintain navigation in the Illinois River, as contemplated by existing authority of Congress and under the plan of improvement now under way.

"The hypothetical case that he has been requested to consider are as follows:

"That there is no diversion except the storm water.

"That there is a diversion of 1, 2, 3, 4, 5, 6, or 7 thousand cubic feet per second.

"The term used in the question—'To prevent the discharge of storm water' is interpreted by counsel for the complainants as meaning that there shall be no more or greater flow of storm water into the Lake than would necessarily be occasioned by the limiting capacity of the channel without control works during

rains or while the storm water run-off continues after the rain ceases.

"Answer.

"The answer to hypothetical questions is summarized as follows: As stated above, no control works are needed in the interest of navigation. If it be deemed necessary to exclude storm flow from the river to the Lake as a means of protecting the water supply, controllable sluices and a lock might be installed near the head of the Sanitary Canal or near the mouth of the river with results as follows:

"*Location Near Head of Canal.*

"(a) With average diversions greater than about 6,000 c. f. s., this control would add but little to the effectiveness already obtained by the control at Lockport.

"(b) With diversions between 6,000 c. f. s. and 1,000 c. f. s., the works would facilitate the diversion of storm flow, but the control of the effluent and other river contaminations would decrease as the diversion was decreased.

"(c) With gates normally closed (zero diversion), the intermittent discharge necessary to control flood water alone would probably amount to an average of 1,000 c. f. s.

"(d) Due to the limited capacity of the drainage canal, there would be some reversal regardless of the diversion.

"(e) The works would impede through navigation.

"*Location Near the Mouth of the River.*

"(a) An essential part of the plan is to keep flood heights down and thus keep the normal river level below that of the lake. This will, impose a serious handicap upon both through and local navigation.

"(b) The control would require an average diversion at least as great as the inflow into the river, estimated at 1,500 c. f. s. to 2,500 c. f. s., which is less than required to prevent nuisance to navigation.

"(c) The system would positively prevent reversals with all diversions exceeding the above minimum.

"(d) The lowered water level in the river would require additional dredging in the interest of navigation.

"*Effect on Navigation.*

"With either of these systems, navigation of the Illinois River as contemplated in the existing project will be impracticable unless the basic diversion is fixed at or above 5,000 c. f. s.

"*Causes and Frequency of Reversals.*

"Reversals of flow which carry water into the lake may be caused by storm water run-off in the Chicago River or by short period fluctuations of lake level. Storms are of relatively infrequent occurrence, but when they occur, their effect is superimposed upon those of the lake fluctuations. The latter are almost continuous but have no regularity or fixed period of recurrence.

"With the normal flow in the river created by any particular diversion, it is conceivable that a storm might cause a serious reversal if it occurred in conjunction with a falling lake. Whereas the same storm might cause no reversal if combined with a rising lake. Such conditions render it impracticable to calculate with precision the number and duration of reversals which might be expected under a given condition as long as the entrance to the river remains open.

"Under a diversion substantially equal to the capacity of the canal, the number of reversals observed at the mouth of the river has been as follows:

"*Total Average Diversion at Lockport.* (Includes water pumped for domestic use.)

1923	8,348	1 reversal
1924	9,465	8 reversals
1925	8,277	No record
1926	8,286	6 reversals
1927	8,450	13 reversals
1928	10,010	10 reversals

"The average number of reversals was 7.6 per year and the average duration 45 minutes.

"The efficacy of the Lockport control for a diversion of about 5,000 c. f. s. is indicated by observations made from March 17th to 31st, 1929, when the flow was reduced on account of floods in the Illinois.

"During this interval there were reversals almost daily, and upon one day there were 12 reversals. A 3.12 inch rain on March 31st was met by increasing the average diversion at Lockport, to 8,600 c. f. s. for the day, and the duration of the reversal was held down to 70 minutes. Upon the other days the numerous reversals were caused primarily by lake fluctuations. Such reversals cannot be controlled by synchronous variation of flow at Lockport or at any other location in the drainage canal, but these reversals carry no considerable quantity of polluted water into the lake.

"*Types and Location of Works.*

"Two types of control works merit consideration. One is a lock and sluices near the head of the Sanitary Canal about 7½ miles from the mouth of the river. The purpose of the sluices is to afford a better control over the flow in the main stem of the river than is afforded by the present control works at Lockport, 34 and 36 miles from the mouth. The second type includes works in the main stem of the river to positively bar reversals.

"*Control Works at Sanitary Canal.*

"Control works at the head of the Sanitary Canal would not be effective until the diversion had been so reduced that it could be carried through the Sanitary Canal at a substantially lower level than at present, permitting the creation of a substantial and effective head at these sluices. Without attempting to check the various computations that have been made as to the time required for an increased discharge at the control works to become effective in influencing the flow

at the mouth of the river, it is sufficient to note that these computations range from 15 minutes to an hour, as compared with an observed period of 6 to 8 hours with control at Lockport. With the shorter time interval, the control of flood discharges would, for a given diversion, be better than with the gates at Lockport, but it would be impossible to prevent reversals due to short period lake fluctuations, and the difficulty of controlling flood discharges would increase with the decrease of diversion. It would not be possible to divert flood water only, because with each operation of the control a large volume of water stored in the river and in the canal above Lockport would have to be released down the Illinois. As the diversion is decreased, the frequency of operation of the works would be increased to take care of the many small storms which would pass off without reversal or control under high diversions, but which would require control under the low diversion. If any effort were made to control the reversals due to lake fluctuations, the number of operations with the consequent waste of water would be correspondingly increased. With such works, the low limit of diversion which might be attained would depend upon the number and character of reversals which could be tolerated. The total annual diversion certainly could not be held as low as the storm water flow of the river without causing a continuous flow from the river into the lake in normal times, with frequent discharge of storm water into the lake.

"With average diversions of less than 3,000 or 4,000 c. f. s. and the continued discharge of effluent into the river, there would be a practically continuous alternation of inflow and outflow between the river and the lake. This condition would result in sewage laden storm water being carried into the lake after practically every storm large enough to flood the sewers, unless the control gates were kept open after each storm long enough to discharge the polluted contents of the river into the drainage canal. The amount of water necessary to discharge the storm water pollu-

tion cannot be calculated, but is roughly estimated at not less than 1,000 c. f. s. annual average under the assumption of a zero normal flow at the gates, which are here assumed to be closed except in time of storm. Such minimum flow in the Sanitary Canal would create nuisance conditions intolerable to navigation.

"With this minimum expenditure of water, the system would leave the discharge of effluent from the river into the lake completely uncontrolled. With this expenditure increased by normal diversions of 1, 2, 3, 4, or 5 thousand cubic feet per second, control of the effluent would be possible in degree varying with the diversion. With diversions greater than 5 or 6 thousand c. f. s. these works would be practically without effect in increasing the control now possible by manipulating the works at Lockport.

"*Works at Mouth of River.*

"The second type of control works includes those at the mouth of the Chicago River to positively prevent reversal of flow. The early plans contemplated a gate which could be swung across the river to prevent reversals. Aside from the problem of the design of a gate structure of the magnitude required, it is apparent that such a gate is not necessary until the diversion is so low as to require its frequent operation, and that under such conditions the closure of the river to navigation by the gate would be an unwarranted obstruction to navigation. Moreover, the rise in the river from the run-off of a severe storm, with the gate closed, might be excessive.

"An effective control at the mouth of the river would consist of a lock with sluices, the sluices being operated to admit such direct diversion of clear water from the lake as may be found necessary for navigation. While the construction of these works without obstructing navigation during the construction period would offer difficulties, it could be accomplished by the acquisition of sufficient upland, at high cost, to afford the necessary space. The normal level of the river

would be held by means of the Lockport gates at so low an elevation that a storm inflow would not raise the river elevation to an objectionable height. Available evidence indicates that if the river were normally held at or slightly below the low water level of 1925, its maximum levels due to storm water run-off would not exceed those due to high lake levels with an open entrance.

"These works would force every vessel entering the river from the lake to pass through the lock. With the opening of the inland waterway for efficient barge transportation from Chicago to the Mississippi River System, the number of vessels will be greatly increased. While there would be some compensating advantage, in that the low level of the river would increase the head room under the various bridges, the delay and inconvenience to navigation imposed by the passage through the lock would be such that these works would merit approval only as a last resort, after it had been shown that no other means would serve the required purpose.

"These works at the mouth of the river would necessarily entail the diversion of all water entering the river, i. e., sewage, sewage effluent and run-off from the drainage area. Depending upon the growth of the city, prevention of water waste, etc., the minimum diversion physically possible by these works is estimated at from 1,500 to 2,500 c. f. s. Such a deficiency of flow in the Sanitary Canal would result in a nuisance seriously interfering with through navigation.

"*Summary.*

"None of the control works that have been considered can be operated to prevent the discharge of storm water into the lake without also diverting considerable amounts of water other than storm water.

"The efficacy of works at the head of the Sanitary Canal depends, like the present control at Lockport, on human foresight and skill. With these works, the minimum amount of water which it would be necessary

to send down the canal in intermittent surges to prevent most of the storm water from entering the lake would average, for the year, probably about 1,000 c. f. s.; but with so small a diversion, the water supply would be polluted by sewage effluent. The minimum diversion at which this pollution would be tolerable is not certain.

"Effective control works at the mouth of the river require the diversion from the lake of all sewage and sewage effluent amounting to a minimum of from 1,500 to 2,500 c. f. s. They would be effective at any larger diversion, to control reversals, but a serious nuisance factor would still exist in the lower ranges.

"*Calumet River.*

"This discussion has been directed to the specific question of control works for the Chicago River. It does not include the related question of satisfactory control of the Calumet River. Both questions are capable, however, of practical solution, probably without any further control works, with a total annual average diversion of 5,000 c. f. s.

"*Practical Solution.*

"In view of these circumstances, the practical solution, in witness' opinion is to systematically reduce the contaminations and the total diversion, observing the results obtained by the best operation of the present control at Lockport, and accumulating data on the behavior of the flow with this progressively decreasing diversion. This procedure will demonstrate in ample time whether any control works are necessary, and will furnish a correct basis for their design."

General Jadwin's conclusion as to the practicability of a total annual average diversion of 5,000 c. f. s., without any further control works, is not understood to be a definite, much less a final, determination, but rather a tentative conclusion awaiting confirmation as the result of experimentation. Nor is his statement deemed to import a decision

that the location of controlling works at or near the head of the Drainage Canal would constitute such an obstruction to navigation as to be held unreasonable in the circumstances. This location is approximately seven miles from the mouth of the Chicago River and Major Putnam testified on the rereference that such works could be so operated as not to hamper the interests of navigation materially. Through navigation to the Illinois River would have to pass through a lock or locks at Lockport and the additional controlling works at the head of the canal would not seem to involve any burden that could not readily be borne in such navigation. It in no way detracts from the full credit to be given to General Jadwin's important statement to say that its tentative nature, and the postponement of the determination of the question as to the necessity of controlling works, may be deemed to have relation to the possibility of the eventual, permanent allowance of a total diversion of as much as 5,000 c. f. s., and the demonstration in actual experience on that basis that new controlling works would not be needed. On all the evidence, it does not seem to me that an absolute requirement would be justified at this time for a reduction in the diversion below 6,500 c. f. s. pending the completion of the sewage treatment works and without new controlling works.

It is evident that if such a further reduction were required, without provision for controlling works, there would be a serious, and not demonstrably unjustified, apprehension as to the pollution of the water supply of the City of Chicago by reversals in times of storm. As the Sanitary District itself has proposed to avoid this danger by the construction of controlling works, and as the sanitary experts, even those of the complainants, have not been ready to testify to the feasibility of further reductions of the diversion without the installation of such works, that is, pending the completion of the sewage treatment program, I am of the opinion that such further reduction should not be required unless permission is given to install controlling

works and they are constructed in accordance with plans approved by the Secretary of War under the statute.

3. The complainants in their program (Exhibit 238, *supra,* p. 88) provide for a reduction of the diversion "with Control Works built by December 31, 1932, to 5,000 c. f. s. on December 31, 1932, and to 3,000 c. f. s. on December 31, 1933, both amounts being in addition to pumpage." The complainants' program provides for no further reduction until the sewage treatment works are completed and in operation. The complainants ask for findings accordingly.

The defendants concede that with the installation of controlling works there may be certain reductions in the diversion as units of the program are placed in operation, but that the amount of such reductions cannot now be determined definitely. It seems to me, however, to be quite clear from the evidence that if controlling works were installed at or near the head of the Drainage Canal it would then be practicable to reduce the diversion to 5,000 c. f. s. in addition to pumpage.

The question of a further reduction, pending the completion of the sewage treatment program, to 3,000 c. f. s. in addition to pumpage, presents greater difficulty, at least with respect to the time at which such a reduction could be effected. This estimated reduction is based on Mr. Howson's testimony, as neither Mr. Gascoigne nor Mr. Townsend, sanitary experts for the complainants, attempted to make any definite calculation of the amount of the reductions in c. f. s. that might be possible as the organic load was removed from the river by additional sewage treatment, between the initial reduction which they fixed for December 31, 1929, and the completion of the entire program for sewage treatment. Mr. Howson estimated that on December 31, 1933, not only would the extension of the Calumet treatment works have been finished and also the sedimentation tanks of the Southwest Side plant, but that the West Side plant would be in full operation. Mr. Gas-

coigne fixes December 31, 1934 for the completion of the West Side plant.

In my findings as to the enlargement of the Calumet plant (*supra,* p. 46), I concluded that it could be completed by December 31, 1933, and I see no reason why the West Side treatment plant should not be in operation for complete treatment by December 31, 1935. It may then be practicable to reduce the diversion to 3,000 c. f. s. in addition to pumpage. But, after the reduction of the diversion to 5,000 c. f. s., made possible by the progress of the sewage treatment and the installation of controlling works to prevent reversals in the Chicago River, there is slender basis for any estimate approaching exactness of any further reduction of the diversion which can be had prior to the completion of the entire sewage treatment program. Mr. Howson alone, of all the sanitary experts, presents a calculation of a reduction of the diversion to 3,000 c. f. s., and I do not think that this estimate, although it may prove to be accurate, affords a sufficient basis for a present absolute requirement for a reduction to that particular amount.

As already stated, the complainants do not ask for a reduction below 3,000 c. f. s. (in addition to pumpage) until the entire sewage treatment program has been completed.

In my judgment, the reductions in the diversion below 5,000 c. f. s., in addition to pumpage, which may be possible before the completion of the sewage treatment program can properly be determined only by appropriate investigation from time to time as the work of sewage treatment progresses. In this way not only may the propriety of a reduction to 3,000 c. f. s. as proposed by complainants be satisfactorily checked, but it may appear that even further reductions in the diversion may be effected before the sewage treatment works are entirely completed.

Fourth. *The extent of the diversion, if any, that will be necessary for the purpose of maintaining navigation in the Chicago River as a part of the Port of Chicago, after the proposed sewage disposal works are in full operation.*

Pumpage. The complainants ask that all flow at Lockport be enjoined from the date fixed for the completion of the sewage treatment works. This would mean not only the entire cessation of the diversion by the Sanitary District, in the sense in which that term is used by the War Department, but also the termination of the discharge at Lockport of the pumpage, that is, of the water taken by the City of Chicago from Lake Michigan and entering the Chicago River and the Drainage Canal as sewage.

So far as this pumpage is concerned, the question is merely incidental to that relating to the diversion by the Sanitary District. These bills were brought to restrain the abstraction of water from Lake Michigan by the Sanitary District, not to challenge the right of the City of Chicago to take water from the Lake for its water supply. Nor can the bills be regarded as presenting a cause of action based on the charge that the City of Chicago was taking more water from the Lake for appropriate domestic uses than it was entitled to take. The City of Chicago was not made a party to these suits, its entry as a party has been successfully resisted by the complainants, and whatever may be the effect of the procedings against the State of Illinois, as the responsible creator and governor of the municipal corporation, that State has not been called upon to answer on the theory that the mere taking of water by the city for the ordinary uses of its inhabitants constituted an actionable wrong. In its opinion, this Court described these bills as brought "for an injunction against the State of Illinois and the Sanitary District of Chicago from continuing to withdraw 8,500 cubic feet of water a second from Lake Michigan at Chicago" (278 U. S. 367, 399). This amount of 8,500 c. f. s. is the diversion by the

Sanitary District allowed by the permit of March 3, 1925, exclusive of pumpage.

Furthermore, it is not regarded as open to serious question that the City of Chicago, under authority of the State, has the riparian right to take water from Lake Michigan for the ordinary uses of its inhabitants. That would not be, *per se,* an unreasonable use. And if it were sought to prevent an abuse of that right through the taking of an unreasonable amount, it would be necessary to present that issue in an appropriate manner. (*City of Canton* v. *Shock,* 66 Ohio State, 19; *Minneapolis Mill Co.* v. *Board etc. of St. Paul,* 56 Minn. 485; *City of Philadelphia* v. *Collins,* 68 Pa. 106; *City of Auburn* v. *Union Water Power Co.,* 90 Maine, 576; *Barre Water Co.* v. *Carnes,* 65 Vt. 626; *Fisk* v. *Hartford,* 70 Conn. 720.)

If the City of Chicago is entitled to take its water supply from Lake Michigan for the ordinary and reasonable uses of its inhabitants, it cannot be said that the State or the City is subject to any established rule of law which requires it to turn into the Lake what is no longer water but sewage or the effluent of sewage treatment plants. If there were a way of destroying the sewage or sewage effluent altogether, or evaporating it, it does not appear that the State or the City would violate any right of the complainants in doing so (*Fisk* v. *Hartford,* 69 Conn. 375). The question in these suits concerns the diversion by the Sanitary District and not the pumpage independently considered.

But, as there is no means known at present of otherwise disposing of the effluent from the sewage treatment plants, when the sewage disposal program has been fully carried out, it is asumed that the effluent must be turned into the Drainage Canal and Chicago River, thence to be discharged at Lockport, the western terminus of the Canal, or be carried into Lake Michigan. The question of the disposition of the effluent from the sewage treatment plants thus de-

mands consideration in connection with the award of relief as to the diversion by the Sanitary District.

Under the opinion of this Court in the present suits, the question of the allowance of a diversion of water from Lake Michigan in the interest of a waterway to the Mississippi is not deemed to be open to consideration. The Court found that Congress had not acted directly so as to authorize the diversion in question, and the Court referred to the declaration of Congress in the Rivers and Harbors Act of January 21, 1927 (44 Stat. 1013), providing for the improvement of the channel of the Illinois River, that nothing in the Act should be construed as authorizing any diversion of water from Lake Michigan. Accordingly, in dealing with the claims of the States intervening herein on the side of Illinois, the Court said that "They really seek affirmatively to preserve the diversion from Lake Michigan in the interest of such navigation" (of the Mississippi) "and interstate commerce though they have made no express prayer therefor. In our view of the permit of March 3, 1925, and in the absence of direct authority from Congress for a waterway from Lake Michigan to the Mississippi, they show no rightful interest in the maintenance of the diversion" (278 U. S. 367, 420).

Since the Act of 1927, it does not appear that there has been any authorization of the diversion by Congress. It is pointed out by the defendants, however, that the Drainage Canal is actually connected with what is called the Illinois Waterway (which is under improvement by the State of Illinois under the authority of a permit of the Secretary of War) and that there is now through navigation. This navigation appears to be at present of slight volume and importance, consisting of pleasure craft, but such as it is it would be cut off by a complete stoppage of flow at Lockport. As to the present situation, General Jadwin said in his testimony:

"There is very light draft present navigation from the Chicago River to the Illinois waterway coming in in two ways. It comes in through the Hennepin Canal and the Illinois River and one through the Sanitary District Canal. There is a very light draft. Congress has authorized to deepen our part of that to nine feet to meet with this deeper channel which the State of Illinois is now putting in. They are spending a large sum of money in building five large locks. We are already at work on that. I have recently entered into a contract, or Col. Weeks has, with my approval, in accordance with the Act of Congress, for dredging 1,316,960 cubic yards in the lower 20 miles of the Illinois River; for dredging 822,000 yards in the section from there up to LaGrange; dredging 1,383,000 cubic yards in the section up to Peoria, and the specifications are about ready for issue for dredging 1,680,872 cubic yards of dirt and 119,000 cubic yards of rock from Peoria up to Utica. The State of Illinois is in the midst of its expenditures for the improvement, which largely runs along where the Des Plaines River is. That has already been authorized and is a thing which we can finish our part of in about two years. We are simply trailing the State on it. I have a general authority from the Secretary of War to make allotments out of the large appropriation. The work is actually going on. Supposing that it is a depth of nine feet, and all flow from the Lake was ended, the physical consequences with respect to the portion which is now being improved under authority of Congress would be to decrease the navigational dimensions very much. You would not have a nine-foot channel after all this work was done. To get that nine foot channel without any of that water, you would have to add three locks. Colonel Pillsbury reminds me that even then we would not have enough water for lockage. We would have to have about 1,000 cubic feet for lockage if the three extra locks were built. That would, however, not take care of the nuisance factor, and we would have to build the extra locks. It would require

1,000 feet in addition to the water in the Illinois-Des Plaines watershed to take care of the lockage on a slack water system. 1,000 feet of diversion from an outside source would be required to take care of the waterway. Congress said when they authorized this project, that they did not authorize diversion, but Congress had a scale of prices before it for getting nine feet with various flows, running from one to ten thousand, and it authorized the sum of money, three million and something, the maximum limit we could go to, and that maximum limit would call for a diversion of about 4,500 average c. f. s. Congress did not run the sum up to the larger sum that would have taken care of it with the 1,000, although Congress had that larger sum before them. Congress had the report and adopted it with certain figures. Congress has since called for a revision of that report and we are now working on the revision.

"Generally, in the spring there is sufficient water in the Illinois River for lockage. It is during the time of the greatest rain, of course. The lowest flow is in the summer. There is little navigation in the winter. The river freezes down as far as Peoria."

The complainants put in evidence the Report of the Board of Engineers of Rivers and Harbors, under date of April 7, 1928, transmitted by the Chief of Engineers to the Committee on Rivers and Harbors of the House of Representatives on May 11, 1928, containing the following statements as to the Drainage Canal and the Illinois waterway:

"The flow of the canal is maintained by the intake of water from Lake Michigan, mainly via the Chicago River, but partly via the Sag Canal. The flow is controlled at the outlet at Lockport. The flow is authorized by a revocable permit from the Secretary of War, dated March 3, 1925. However, since this is a lake-level canal, no discharge is actually necessary for its use for navigation as distinct from sanitary uses, except for the lockages at Lockport.

"No comment by the board upon this portion of the waterways is required and no Federal expenditures are in prospect.

"7. The Illinois State Waterway is connected with the Drainage Canal by locks at Lockport. Below Lockport the improvement is by the canalization of the Des Plaines River from Lockport to its junction with the Kankakee River (17 miles) and thence of the Illinois River to Starved Rock, Utica (43 miles). The waterway is being built by the State of Illinois, by authority of a permit of the Secretary of War dated March 4, 1920.

"The ruling bottom widths except at the locks, is 200 feet and the ruling depth will be 9 feet when in earth and 10 feet when in rock. The canal will contain five locks each 600 feet long, 110 feet wide and 14 feet deep over the miter sill" (description follows).

* * * * * * *

"The lock at Starved Rock is one mile above Utica. The State expects to arrange for the alteration or removal of all bridges along the State portion of the waterway. The State now expects to complete construction in 1931. . . .

"According to estimates of State engineers the canal system will require a flow from the Drainage Canal of 1,500 cubic foot-seconds for maximum lockages. In House Document No. 1374 (par. 19) an estimate of 1,000 cubic foot-seconds was made for the least flow necessary for lockages from Lake Michigan to the Illinois River. This board believes that figure is correct if based on a canal designed to save water. The State of Illinois estimates its present necessities at 50 lockages of 30 cubic foot-seconds each. This board does not believe in the possibility of such a large number of lockages at Lockport, but after considering questions of seepage and evaporation and the needs of the Illinois-Michigan Canal, has concluded that the figure of 1,500 cubic foot-seconds is on the whole reasonable."

It is to be noted that this Report of the Board of Engineers indicates that from 1,000 c. f. s. to 1,500 c. f. s. would be adequate for lockages from Lake Michigan to the Illinois River. It does not appear that this Report has been acted upon by Congress, or that the situation has changed so far as the legal aspect of the present questions is concerned, since this Court gave its opinion in these suits.

Conditions in the Chicago River.

In considering the needs of navigation, this Court limited its statement to the requirements of navigation in the Chicago River as a part of the Port of Chicago. The Court said:

> "It may be that some flow from the Lake is necessary to keep up navigation in the Chicago River, which really is part of the Port of Chicago, but that amount is negligible as compared with 8,500 second feet now being diverted" (278 U. S. 367, 418).

And again the Court said:

> "In increasing the diversion from 4,167 cubic feet a second to 8,500, the Sanitary District defied the authority of the National Government resting in the Secretary of War. And in so far as the prior diversion was not for the purposes of maintaining navigation in the Chicago River it was without any legal basis, because made for an inadmissible purpose" (*id.* p. 420).

So far as depths are concerned, it appears that no diversion of the water from Lake Michigan is required for purposes of navigation in the Chicago River, and there is testimony that without a flow at Lockport there would be an improvement with respect to the current in the river.

There is still the question as to the conditions which will exist in relation to navigation in the Chicago River as a

part of the Port of Chicago, because of the introduction of the effluent from the sewage treatment works and the untreated sewage carried into the river at times of storm, after the proposed program as substantially approved by the complainants, so far as sewage treatment is concerned, has been completed. That pollution caused by the introduction of sewage has relation to the interests of navigation was recognized by this Court in the case of *New York* v. *New Jersey,* 256 U. S. 296, 397, 398, cited by the Court in referring to the exigency which confronted the Secretary of War when he gave the permit of March 3, 1925 (278 U. S. p. 418). The fact that at that time the Sanitary District had been derelict, and that the present question relates to the conditions which will exist after the sewage has been treated so far as practicable from the standpoint of sanitary engineering knowledge, can not be deemed to change the conception of the interests of navigation or the need of their appropriate protection.

The characteristics and effect of the effluent that will issue from the sewage treatment plants when in full operation have been estimated variously by the witnesses. I have not thought it necessary or advisable to call other sanitary experts of my own selection, as in view of the large number of eminent sanitary experts in one way or another already related to the controversy, it would seem to be futile to seek other experts of the requisite independence and qualifications, and it has seemed that the introduction of the testimony of additional experts would probably have merely the effect of making them, their qualifications and opinions, the subject of attack without affording any more satisfactory basis of judgment than the expert testimony which the parties themselves have submitted.

For the complainants, Mr. Howson testified that assuming the completion of the program outlined by him and summarized in Complainants' Exhibit 238 (*supra,* p. 18), and with no flow at Lockport, a situation would result which would be satisfactory from the viewpoints both of

public health and navigation in the Chicago River as part of the Great Lakes-St. Lawrence system; that "there would not be any visible suspended particles recognizable as of sewage origin in the Chicago River, coming from the sewage treatment plants;" that conditions in the river would then be greatly superior in that respect to those now obtaining; that "there would not be any odors arising from the waters of the river due to the putrefaction of the organic matter contained in the sewage effluent"; that "there would not be any grease, oil or sewage material on the surface of the river due to the flow from the sewage treatment plants," which would also be a material improvement over present conditions; that the water of the river would not be offensive or injurious to the health of passengers or persons employed on vessels or docks.

Mr. Howson also stated that assuming a mean annual flow of 1,000 c. f. s. at Lockport for navigation purposes, the completion of the program he had summarized in Exhibit 238 (*supra*) "would provide a practical method for the disposal of the sewage of the Sanitary District without detriment to the Chicago water supply and without creating any nuisance to navigation in the Chicago and Illinois Rivers."

The testimony of Mr. Gascoigne and Mr. Townsend on these questions was substantially to the same effect as that of Mr. Howson.

H. C. Inches, Great Lakes' captain, who has navigated the Chicago River for many years, testified for the complainants that prior to 1900 he did not experience any difficulty in navigating the river because of the presence of sewage; that since the opening of the Drainage Canal there has been a great deal of trouble and additional expense in handling ships because of current; that the current continued to create difficulty up to 1928; that the sewage in the river did not interfere with navigation. He thought the current in the Chicago River was from two to two and a half miles an hour, more or less. Colonel Curtis McD.

Townsend (Corps of Engineers, U. S. A., retired) who had had considerable experience in relation to rivers and harbors, also testified for the complainants that no water would be needed to maintain a channel for navigation in the Chicago River in case all diversion for the purpose of taking care of the sewage of the Sanitary District were discontinued; that if the flow at Lockport were cut off the conditions of navigation on the river would be improved. He said that he had never seen any injurious effect on navigators by reason of sewage in water; that when in charge of the District of Columbia sewer department, he had found that his men who were working on sewers were as healthy as anyone else; that he himself had been through miles of sewers, breathing a sewer atmosphere, and did not know of its having had any effect on him personally. The complainants also called General Charles E. Keller (retired) who had for about four and a half years as District Engineer officer been in charge of all harbors on the east side of Lake Michigan. He gave his opinion "that the presence or absence of pollution has nothing whatever to do with commerce or the extent of commerce;" that no flow whatever at Lockport would be necessary to maintain navigation in the Chicago River in the event of the termination of the diversion to take care of sewage; that the termination of all flow at Lockport would increase the navigable depths in the Drainage Canal and the Chicago River and that the diminution of the current would be favorable to navigation.

For the defendants, Mr. Eddy testified that "the discharge of the effluent of the completed sewage treatment plants into the Lake would be detrimental to navigation. The effluent would be devoid of oxygen, black and offensive much of the time. It would tend to discolor light-colored paint on boats. It would be offensive to people riding on boats and having to work on the vessels and along the wharves. This condition would gradually decrease in inten-

sity as the distance from the mouth of the river increased, due to the dilution and oxidation which would take place in the waters of the Lake"; and he said that for this conclusion he was assuming that the storm water would be discharged to the Des Plaines River, and that the effluent from purification works in dry weather would flow into the Lake.

Mr. Eddy testified further, that if the effluents from the sewage treatment plants were discharged through the Drainage Canal and the Des Plaines River, there would still be required some water from the Lake in order to maintain the standard which he deemed to be necessary for navigation in the waters of the Port of Chicago. He said on this point:

> "This volume of water will, or should be varied in accordance with seasonal conditions. In the winter time putrefaction is not likely to take place. Storm discharges will take place occasionally and it will be advisable to draw some water to flush them along. But I estimate that that will be a relatively small volume.
>
> "The other extreme will come during warm weather, when I estimate that from 3,000 to perhaps 4,500 second feet will be necessary, dependent upon the temperature and upon the storm discharges. I think an annual average diversion of lake water in addition to the volume discharged from the sewers and the treatment plants of 2,000 c. f. s. will be sufficient to maintain the waters suitable for navigation. This is predicated, however, upon the assumption that controlling works be provided which will prevent a back flow into the lake during storm.
>
> ". . . That is, that 2,000 second feet would represent the annual average diversion of lake water to maintain clean water for navigation purposes, which is exclusive of the Chicago pumpage. It is also exclusive of the rain-water run-off, and such water as is drawn from the ground or other sources for industrial

purposes, which is probably a large amonut. That contemplates that at no time should there be any discharge of any storm water or sewage effluent or any other thing from the Chicago River into Lake Michigan. It also contemplates that there will be a certain amount of water flowing from the Calumet River watershed through the Calumet Sag Channel, and a certain amount of water flowing in the Calumet River will be discharged to the Sag Channel and thence to Lockport.

"It contemplates drawing water from the Little Calumet River, from the Lake at the Little Calumet River, or the Calumet River water itself; from the Lake at the mouth of the Chicago River, the easterly end; and from the Lake at Wilmette, so that there will be a flow continuously through the North Shore channel and the North Branch through the Chicago River and the main Drainage Canal and through the Calumet-Sag channel, all three discharges coming together and passing out at Lockport.

"I am not certain that I stated that it contemplates also that the flow will be increased for short periods, at or immediately after storms in order to keep a substantial flow to wash out and clean out the channels as best may be.

"The annual average diversion, then, would be inclusive of all these amounts; that is, of these three amounts that I have spoken of, 2,000 cubic feet per second, in addition to the sewage and overflow runoff.

"The 2,000 second feet is to be taken directly from the Lake, which is comparable to the 8,500 second feet, exclusive of Chicago pumpage, mentioned in the permit of March 3, 1925."

Mr. Eddy also said that in his estimate of 2,000 c. f. s. he took into consideration the conditions of navigation in the Port of Chicago only and not the requirements of navigation in the Des Plaines or Illinois Rivers. He stated that the estimate was "based upon the population as of 1945"; the diversion was "equivalent to one-third of a cubic foot

per second, per thousand persons, based upon the human population, and the industrial wastes equivalent population." He thought that one-third of a cubic foot per second was a "better figure to use in considering a long period in the future than 2,000 c. f. s., which is based upon specific conditions assumed for 1945."

Dr. Mohlman, for the defendants, (*supra,* p. 30) testified:

> "I have made many studies of what the oxygen demand of these effluents would be, and I have also given consideration to other factors besides the question of the requirements of the effluents themselves. The complicated factor that makes it impossible for me to judge what the conditions will be in the future, with complete treatment, is that we do not know what the effect of storm water discharge, carrying sewage, will have on these streams. My opinion of the effect of such storm water deposits is that they will form septic deposits in the river; that the oxygen will disappear except for a short distance below the activated sludge effluents, and that the condition of the channels will be objectionable. There will be deposits of septic sludge and conditions of pollution that will be highly offensive. That is in the absence of any diluting water from the Lake.
>
> "There would be a small amount of dissolved oxygen immediately below the discharge of the treatment plant effluents, but in the absence of diluting water, the water would be devoid of oxygen, and there would be objectionable conditions, without any flushing or diluting water."

With respect to the storm water overflow, carrying with it untreated sewage, Mr. Townsend, one of the complainants' experts, being asked on cross-examination as to conditions in Milwaukee with which he was familiar (*supra,* p. 22) testified as to these, and also as to the conditions which may be expected at Chicago when the program for

sewage treatment is completed. He said (referring to Milwaukee):

> "I have no figures with me upon which I can state the proportion of the sewage in storm flow passing into the river or the Lake through the old outfalls at rain and thaw periods. There are overflows at the foot of a majority of the streets which pass directly into the three rivers, carrying raw sewage. However, the worst of the polluting material from the streets and deposits in the sewers is taken into the intercepting sewer. Afterwards the sewage diluted with storm flow passes directly into the river.
>
> "I made no tests to determine the correctness of the statement as to the worst of the sewage going into the plant, except that we have found through operation that on the crest of a great many storms the material received is unusually foul. Lots of that goes directly into the Lake or river through these outfalls."

Referring to the Chicago situation, he said:

> ". . . Assuming the program proposed in Complainants' Exhibit 238 be fully carried out, from the time of its completion the raw water from which the water supply is derived will become progressively worse in quality because of the increased volume of treated sewage and of storm overflow to be discharged into Lake Michigan with the increase in the growth of the City of Chicago. As the city increases in population, there will be more effluent and more sewage flowing untreated into the Lake at storm time."

In order to take the effluent from the sewage treatment plants away from the Drainage Canal and the Chicago River, the complainants have suggested that outfall sewers or tunnels might be constructed which would lead from the sewage treatment plants directly into Lake Michigan. It is to be noted, however, that there has been no criticism of the sites selected for the sewage treatment works; in-

deed, the only criticism has been that the proposed site for the Southwest Side plant has not already been acquired. The North Side plant adjoins the North Branch of the Chicago River about ten miles north of its confluence with the South Branch. The large West Side and Southwest Side plants adjoin the main channel of the Drainage Canal several miles west of the head of the Canal at Robey street, a point on the West Fork of the South Branch of the Chicago River about six miles from Lake Michigan. The construction of outfall sewers or tunnels to take the effluents from the sewage treatment plants directly into Lake Michigan would mean the construction of sewers or tunnels from the West Side plant and the Southwest Side plant several miles across the City of Chicago to points on the Lake. This is said by complainants' witnesses to be practicable. But Mr. Howson, the complainants' leading sanitary expert, also said that he meant that he could physically do it if he set out to do it. He did not mean that it was practicable in the sense that he would recommend doing it as an available means for the city in disposing of its sewage at this time. And Mr. Townsend, another of complainants' sanitary experts, stated that this would still leave the storm water problem. He said: "The construction and operation of tunnels directly from the sewage disposal plants at Chicago to the Lake for the purpose of carrying the effluent would still leave the storm water problem; and sewage would go into the river and lake with storm water. The effluent would be discharged directly into the Lake."

Another suggestion which has been made by the complainants is that, assuming that the effluent from the sewage treatment plants flowed into the Drainage Canal and the Chicago River, it would be practicable by means of existing pumping stations to pump water to flush the navigable channels of the Drainage Canal and the Chicago and Calumet Rivers "so that such flushing water would mingle with the effluents of the sewage disposal plants and proceed out into the Lake with no flow at Lockport." It

was thus suggested that circulating water might be pumped into these channels of the Sanitary District at the rate of 1,000 c. f. s. at Wilmette, 2,000 c. f. s. at 39th Street, and 2,000 c. f. s. through the Calumet Sag. Mr. Howson said that if this program were completed the resulting conditions would support fish life. This, however, raises the question as to the conditions which would exist at or near the mouth of the Chicago River. Mr. Townsend said: "If the Chicago River and its branches were flushed by means of pumps at Wilmette, Calumet and 39th Street, any filth in these rivers would be carried to the Lake more quickly because that would increase the velocity."

Dr. Mohlman for the defendants testified on this point that while the introduction into the Drainage Canal and the Chicago River of circulating water as proposed "would provide conditions in the canal system, including the channels of the Chicago River and its branches, which would not be highly objectionable", the "constant flushing of this volume of water, plus the content of the channels into the Lake, would ruin the bathing beaches and make them completely unsafe," and that "it would contaminate the water supply and be in marked contrast to the present condition". He referred to all bathing beaches within a radius of five miles of the mouth of the Chicago River.

General Jadwin expressed the opinion that when the sewage treatment program had been completed, a diversion of a certain amount of lake water would still be necessary for purposes of navigation in the Chicago River. He said that "the effluent from sewage treatment plants is not pure water, and added refuse from ships and streets, together with unavoidable accumulations of oil, requires more water for flushing than is available from the natural run-off, which the urban development has in large part intercepted and turned into sewers." His conclusion (aside from considerations of the Des Plaines and Illinois Rivers and the possibilities of future demands dependent upon

action by Congress) was: "When the ultimate practicable treatment of sewage is accomplished, it is believed that the needs of navigation in the Chicago and Calumet Rivers proper may be found not to exceed a flow of clear water from the Lake averaging 1,500 c. f. s., augmented by the natural run-off of the Chicago and Calumet River watersheds and the effluents from the treatment plants" (*supra,* pp. 92, 93).

The difficulties of prediction inhere in the attempt to estimate results on such a vast and wholly unprecedented scale of sewage treatment as that involved in the disposal of the sewage of a population now estimated at over 3,500,000, with an additional population equivalent of industrial wastes of 1,500,000, and an estimated total of human population and population equivalent of industrial wastes of 6,800,000 in 1945. The experience of very much smaller communities affords little aid in determining the effect of this enormous volume of effluent from the sewage treatment works, and the storm water run-off containing untreated sewage, flowing into the channels of the Drainage Canal and the Chicago River. If the flow at Lockport were entirely stopped, the result would be, as Colonel Townsend, testifying for the complainants, said, "that the only water from the Lake would be that which comes in as the Lake rises and falls." In that case, with the water held at Lockport, there would be "absolutely no slope in the river and its connections." The large sewage treatment works—the West Side and the Southwest Side plants —adjoining the Drainage Canal will pour their effluents into the canal, and if there is no flow at Lockport, these effluents will pass directly into the Chicago River. It is found that one hundred per cent. purification of the sewage taken to the treatment works is not practicable with present knowledge. The expected degree of purification is found to be a minimum of eighty-five per cent. and it is probable that it will be ninety per cent. or more (*supra,* p.

28). This means that an amount not exactly determinable, which may be less than ten per cent. or possibly as high as fifteen per cent., of the sewage will not have been purified and will be represented in the effluent. While the residual organic matter in the effluent may be very different from an equal percentage of the raw sewage as a potential source of nuisance, it is far from demonstrated, in my judgment, that with all flow stopped at Lockport, the concentration of such a vast volume of effluent as will flow from the proposed sewage plants, together with the untreated sewage and wastes carried with the storm flow into the limited channels of the Drainage Canal and Chicago River will not create conditions in these channels seriously detrimental to navigation.

The complainants ask that the decree provide that on and after the date fixed for the completion of the sewage treatment program, that the State of Illinois, the Sanitary District, and all persons acting under the authority of either, be ordered to refrain from so polluting the Chicago River, and the auxiliary navigable channels of the Sanitary District, by the discharge of sewage or otherwise as to create an obstruction to or interference with navigation or navigable capacity. It seems to me that the best way, and the reasonably sure way, of accomplishing this result is to permit an outflow from the Drainage Canal at Lockport. The suggestion that outfall sewers or tunnels might be built to take the effluents directly to Lake Michigan has been made in a general way, but the evidence is by no means convincing that it would be a reasonable requirement to compel the Sanitary District or the city to build such sewers or tunnels to take the effluents from the sewage treatment plants across the city to the Lake (*supra,* p. 134). The problem of the storm flow would still remain and would be especially serious in view of the volume which may be expected in the run-off of this large area with its great and growing population. The pumping of circulating water into the Drainage Canal and the Chicago and

Calumet Rivers would, as pointed out in the testimony (*supra*, p. 135) carry whatever filth there would be in these rivers to the Lake more rapidly. It is not clear that this course would be compatible with the interests of navigation in the Chicago harbor, and that there would be a serious danger of contaminating the water supply and of creating offensive conditions at the bathing beaches of the city is quite evident. As to the water supply, it is urged that water filtration plants should be constructed. The fact remains that the effluents from the sewage treatment plants and the storm water must go somewhere, and if they are taken away from the Lake and discharged through the canal at Lockport, both the danger to the water supply will be removed and conditions suitable to navigation can be maintained.

But if the effluent from the sewage treatment plants and the storm water are to be discharged through the Drainage Canal at Lockport, it is well established that some flow from the Lake will be required. This it appears should not be less than a mean annual diversion of 1,000 c. f. s., in addition to pumpage; and it does not at present appear that it is necessary that the diversion should exceed a mean annual amount of 1,500 c. f. s., in addition to pumpage.

My conclusion is that, so far as the question can be determined at this time, the interests of navigation in the Chicago River as a part of the Port of Chicago, when the above described sewage treatment program has been carried out, will require that the flow of the Drainage Canal be discharged at Lockport, and that for this purpose there will be necessary a diversion of water from Lake Michigan of an annual average of not less than 1,000 c. f. s. and that it would be safer to allow a mean annual diversion of 1,500 c. f. s., in addition to pumpage. Provision should be made for further examination, after the sewage treatment plants have been completed, and the effect of the effluent therefrom with the storm water flow on the navigable channels has

been observed, to the end that the question of any further or other relief may have appropriate consideration in the light of actual conditions.

This disposition is believed to be in accord with the equitable principles which appropriately govern the exercise of the jurisdiction to determine controversies between States, a jurisdiction which is unfettered by technicalities and in the last analysis is for the purpose of establishing substantial justice. In the present instance, equitable considerations are those applicable with appropriate regard to the substantial rights of the complainants, as determined by this Court, after the Sanitary District has carried out the above described comprehensive program for sewage treatment. The injury sustained by the complainants is through the lowering of the levels of the Great Lakes in consequence of the diversion, and it is the substance of that injury which demands consideration in formulating the provisions of the decree.

In my former report it was found that it was possible to determine with approximate accuracy the full extent of a particular diversion of water from the Great Lakes; that a diversion did not operate to cause a continuous and never-ending lowering of levels, but that within practical limits, under present conditions, an approximate equilibrium would be reached within a period of time which could be calculated, after which the effect of the diversion would cease to increase. Accordingly, it was determined that the full effect of a mean annual diversion of 8,500 c. f. s. of water from Lake Michigan at Chicago, through the Drainage Canal of the Sanitary District, was to lower the levels of Lakes Michigan and Huron approximately six inches at mean lake levels; the levels of Lakes Erie and Ontario approximately five inches at mean lake levels; and the levels of the connecting rivers, bays and harbors, so far as they have the same mean levels as the above mentioned lakes, to the same extent respectively. It was also found that if

the diversion at Chicago were ended, assuming that other diversions from the Great Lakes remained the same, the mean levels of the lakes and rivers affected by the Chicago diversion would be raised in the course of several years (about five years in the case of Lakes Michigan and Huron and about one year in the case of Lakes Erie and Ontario) to the same extent as they had been lowered, respectively, by that diversion.

On a similar calculation, the entire effect of a mean annual diversion of 1,000 c. f. s. by the Sanitary District would be a lowering of Lakes Michigan and Huron approximately seven-tenths of an inch, and of a mean annual diversion of 1,500 c. f. s., approximately one inch, at mean lake levels.

Assuming that a mean annual diversion of 8,500 c. f. s. would effect a lowering of six inches, a cessation of the diversion of water by the Sanitary District beyond the annual average of 1,500 c. f. s., that is, a cessation of 7,000 c. f. s. of the diversion of the 8,500 c. f. s. at present allowed, would have the effect of raising the levels of Lakes Michigan and Huron to the same extent as they were lowered by that diversion except by the amount of about one inch.

It can hardly be maintained that a diversion not exceeding an annual average of 1,500 c. f. s. would produce such a substantial injury to the complainants, when the fluctuations of lake levels due to other causes than diversions are considered, as to preclude attention to the serious consequences which may result from a failure to maintain suitable conditions in the interest of navigation in case all flow at Lockport should be terminated. In my opinion such an extreme requirement, after the Sanitary District has provided for sewage treatment so far as practicable, should await more exact knowledge as to its effect.

Summary.

My conclusions are:

(1) That the completion of the North Side, West Side, Calumet, and Southwest Side Sewage Treatment Works, above described, with their appurtenances and the necessary intercepting sewers, and the efficient operation of these plants, will afford practical measures from the standpoint of present sanitary engineering knowledge for the complete treatment of the dry weather flow of sewage and wastes of all the area comprised within the Sanitary District of Chicago, and also, in times of storm, of approximately 150% of the ordinary dry weather flow of sewage and wastes; that in the actual operation of these plants it may appear that a greater amount of the storm flow can be treated at least in part.

(2) That what is described as "complete treatment" of the sewage taken to the sewage treatment works (that is, apart from the excess storm flow which remains untreated) does not amount to 100% purification; that with efficient operation the proposed sewage treatment plants should attain not less than an annual average of 85% purification of the sewage treated, and that it is probable that the degree of purification will be 90% or more.

(3) That the remainder of the storm flow, in excess of the volume treated in the sewage treatment plants will pass into the Chicago River and its branches, and into the canals of the Sanitary District, and any storm flow so passed into the river, its branches and the canals, at storm times will contain sewage and wastes which have not been treated by the sewage treatment works.

(4) That the time that should be allowed for the completion of the sewage treatment works above described is as follows:

(a) That the North Side Sewage Treatment Works, with appurtenances, should be completed on or before July 1, 1930;

(b) That the Calumet Sewage Treatment Works, with appurtenances, should be completed on or before December 31, 1933;

(c) That Batteries A and B of the Imhoff tanks of the West Side Sewage Treatment Works should be completed on or before July 1, 1930.

(d) That the West Side Sewage Treatment Works, with appurtenances, should be completed on or before December 31, 1935;

(e) That the Southwest Side Sewage Treatment Works, with appurtenances, should be completed on or before December 31, 1938;

(f) That the necessary intercepting sewers pertaining to the above described sewage treatment works should be completed within the time allowed for the completion of the sewage treatment works, respectively.

(g) That in the foregoing estimate allowance is made for ordinary contingencies, but not for strikes or other occurrences beyond the control of the Sanitary District or its contractors.

(5) That the diversion by the Sanitary District of water from Lake Michigan should be reduced on July 1, 1930, to an annual average diversion of 6,500 c. f. s., in addition to domestic pumpage.

(6) That subject to the approval of the Secretary of War upon the recommendation of the Chief of Engineers, pursuant to the applicable statute, controlling works should be constructed by the Sanitary District for the purpose of preventing reversals of the Chicago River at times of

storm and the introduction of storm flow into Lake Michigan; that for this purpose the Sanitary District should immediately submit plans for such works to the Chief of Engineers of the War Department; and that such controlling works should be constructed by the Sanitary District within two years after receiving the authorization of the Secretary of War.

(7) That when such controlling works have been constructed, the diversion by the Sanitary District of water from Lake Michigan should not exceed the annual average of 5,000 c. f. s. in addition to domestic pumpage.

(8) That there should be provision in the decree for an appropriate examination of results from time to time as the work of sewage treatment progresses to the end that there may be such further reduction of the diversion by the Sanitary District as may be found to be feasible pending the completion of the sewage treatment works.

(9) That, after the installation of controlling works as above provided, and on the completion of all the sewage treatment works above described, and in the absence of competent action by Congress in relation to navigation lawfully imposing a different requirement, the diversion by the Sanitary District of water from Lake Michigan should not exceed an annual average of 1,500 c. f. s. in addition to domestic pumpage.

(10) That by the term "diversion" in the foregoing conclusions is meant the flow diverted by the Sanitary District exclusive of the water drawn by the City of Chicago for water supply purposes and entering the Chicago River and its branches or the Calumet River or the Chicago Drainage Canal as sewage. Such diversion is determined by deducting from the total flow at Lockport the amount of water pumped by the City of Chicago into its

water mains and, as so computed, it includes the run-off of the Chicago and Calumet drainage area.

(11) That provision should be made in the decree for an examination of results after the completion of the sewage treatment works so that there may be such further or other relief in respect to the diversion of water from Lake Michigan as may be found to be feasible.

Recommendations as to the decree.

In their proposed findings both parties include provisions with respect to the times of completion of the sewage treatment works. The defendants, however, suggest that the Court should merely find the works necessary to be installed, in order practicably to dispose of the sewage of Chicago, and that then the constituted administrative agencies of the Government, the Chief of Engineers and the Secretary of War, may act. It is suggested that the Court should not enter a mandatory or coercive form of decree; that if the Court declares what works shall be installed and the time within which they should be completed, it must be assumed that out of respect to the Court the State of Illinois and the Sanitary District will perform what the findings conclude they should do, unless obstacles arise which make such compliance impossible; and that the Court should retain jurisdiction until the works are installed and in operation.

The Court will undoubtedly give to this suggestion the consideration which is thought to be appropriate. As its opinion, pursuant to which the order of re-reference was made, is understood to contemplate directions as to the diminishing of the diversion, these directions will properly be found in the decree. But, as such provisions will necessarily depend upon the times fixed for the completion of the sewage treatment works, and as the terms of the decree will follow the findings, as finally confirmed or modi-

fied by the Court in this respect, it would not be a matter of substance to exclude from the decree provisions as to the times of completion. Accordingly, they are included in the form of decree proposed.

It is recommended that the Court should retain jurisdiction as there are questions which it is impossible to dispose of at this time in full justice to the parties; as, for example, with respect to the extent to which the diversion of water from Lake Michigan by the Sanitary District may be reduced below 5,000 c. f. s., in addition to pumpage, after the installation of controlling works in the Chicago River and pending the completion of the sewage treatment works, and also with respect to any further or other provisions as to the diversion which may be found to be appropriate after the sewage treatment works have been completed and the results of their operation with respect to the effluent and the condition of the navigable waters have been observed. As construction work will be conducted on a large scale for several years, and unforeseen contingencies may arise, it would also seem to be important that there should be opportunity for the parties to come before the Court at any time to obtain such further directions as the facts may warrant.

To the end that the rights of all parties may be protected, there should be some measure of supervision as the contemplated work progresses. If it is deemed to be impracticable, in view of the long period involved, to appoint a commissioner for this purpose, provision may be made in the decree for the filing at stated periods by the Sanitary District of reports as to the progress of the work, on the coming in of which either party may make application to the Court for such action as may seem to be suitable. It is suggested that the Sanitary District should file semi-annual reports with the Clerk of this Court.

On the basis of the conclusions above stated, and in accordance with the direction of the order of re-reference, the following proposed form of decree is submitted. No recommendation is made as to costs.

Proposed form of decree.

(After formal parts and confirmation or modification of findings):

1. That the defendant Sanitary District of Chicago complete and place in full operation the North Side Sewage Treatment Plant and Batteries A and B of the Imhoff tanks at the West Side Sewage Treatment Plant (as outlined in the program proposed by the Sanitary District of Chicago) on or before July 1, 1930.

2. That the defendant Sanitary District of Chicago continue the operation of the Calumet sedimentation sewage disposal plant.

3. That the defendant Sanitary District of Chicago complete and place in full operation the Calumet Sewage Treatment Plant (as outlined in the program proposed by the Sanitary District of Chicago) on or before December 31, 1933.

4. That the defendant Sanitary District of Chicago complete and place in full operation the West Side Sewage Treatment Plant (as outlined in the program proposed by the Sanitary District of Chicago) on or before December 31, 1935.

5. That the defendant Sanitary District of Chicago complete and place in full operation the Southwest Side Sewage Treatment Plant (as outlined in the program proposed by the Sanitary District of Chicago) on or before December 31, 1938.

6. That the foregoing requirements as to times of completion include allowances for ordinary contingencies but not for strikes or other occurrences beyond the control of the Sanitary District or its contractors.

7. That on and after July 1, 1930, the defendants, the State of Illinois and the Sanitary District of Chicago, their employees and agents, and all persons assuming to act under the authority of either of them, be and they hereby are enjoined from diverting any of the waters of the Great Lakes-St. Lawrence system or watershed through the Chicago Drainage Canal and its auxiliary channels or otherwise in excess of an annual average of 6,500 c. f. s. in addition to domestic pumpage.

8. That subject to the approval of the Secretary of War upon the recommendation of the Chief of Engineers, pursuant to the applicable statute, controlling works shall be constructed by the Sanitary District of Chicago for the purpose of preventing reversals of the Chicago River at times of storm and the introduction of storm flow into Lake Michigan; that for this purpose the Sanitary District of Chicago shall forthwith submit plans for such works to the Chief of Engineers of the War Department; and that such controlling works shall be completed and placed in full operation by the Sanitary District of Chicago within two years after receiving the authorization of the Secretary of War.

9. That when such controlling works have been constructed and placed in operation, the defendants, the State of Illinois and the Sanitary District of Chicago, their employees and agents, and all persons assuming to act under the authority of either of them, be and they hereby are enjoined from diverting any of the waters of the Great Lakes-St. Lawrence system or watershed through the Chicago Drainage Canal and its auxiliary channels or otherwise in excess of an annual average of 5,000 c. f. s. in addition to domestic pumpage.

10. That after the installation of controlling works as above provided, and on the completion of all the sewage treatment works as outlined in the program proposed by the Sanitary District of Chicago, and in the absence of

competent action by Congress in relation to navigation lawfully imposing a different requirement, the defendants the State of Illinois and the Sanitary District of Chicago, their employees and agents, and all persons assuming to act under the authority of either of them, be and they hereby are enjoined from diverting any of the waters of the Great Lakes-St. Lawrence system or watershed through the Chicago Drainage Canal and its auxiliary channels or otherwise in excess of an annual average of 1,500 c. f. s. in addition to domestic pumpage.

11. That the provisions of this decree as to the diverting of the waters of the Great Lakes-St. Lawrence system or watershed relate to the flow diverted by the defendants exclusive of the water drawn by the City of Chicago for water supply purposes and entering the Chicago River and its branches or the Calumet River or the Chicago Drainage Canal as sewage. The amount so diverted is to be determined by deducting from the total flow at Lockport the amount of water pumped by the City of Chicago into its water mains and as so computed will include the run-off of the Chicago and Calumet drainage area.

12. That the defendant the Sanitary District of Chicago shall file with the clerk of this Court semi-annually on July first and January first of each year, beginning July first, 1930, a report to this Court adequately setting forth the progress made in the construction of the sewage treatment plants and appurtenances outlined in the program as proposed by the Sanitary District of Chicago, and also setting forth the extent and effects of the operation of the sewage treatment plants, respectively, that shall have been placed in operation, and also the average diversion of water from Lake Michigan during the period from the entry of this decree down to the date of such report.

13. That on the coming in of each of said reports, and on due notice to the other parties, any of the parties to the above entitled suits, complainants or defendants, may apply

to the Court for such action or relief, either with respect to the time to be allowed for the construction, or the progress of construction, or the methods of operation, of any of said sewage treatment plants, or with respect to the diversion of water from Lake Michigan, as may be deemed to be appropriate.

14. That any of the parties hereto, complainants or defendants, may, irrespective of the filing of the above-described reports, apply at the foot of this decree for any other or further action or relief, and this Court retains jurisdiction of the above-entitled suits for the purpose of any order or direction, or modification of this decree, or any supplemental decree, which it may deem at any time to be proper in relation to the subject matter in controversy.

Respectfully submitted,

CHARLES E. HUGHES,
Special Master.