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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.

JOINT ABSTRACT OF RECORD FOR HEARING UPON EXCEPTIONS TO THE SPECIAL MASTER'S REPORT ON RE-REFERENCE.

FILED FEBRUARY 20, 1930.

GUNTHORP-WARREN PRINTING COMPANY, CHICAGO.

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CHICAGO

FOREWORD.

This Joint Abstract of portions of record, submitted by counsel for all parties, is designed to embrace material not sufficiently appearing in the Special Master's Report on Re-reference, filed December 17, 1929, in the Special Master's Report on Original Reference, filed November 23, 1927, or in the Joint Abstract filed herein January 24, 1928, and it is intended for use on the hearing on exceptions to the Special Master's Report on Re-reference.

It is understood that counsel may refer, in their briefs or in their argument, to portions of the record that may be inadvertently omitted from this Joint Abstract.

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JOINT ABSTRACT ON RE-REFERENCE.

CHICAGO, ILLINOIS, March 25, 1929.

Page of Record.

Defendants' counsel suggested that the Special Master and complainants' counsel and experts visit the North

Side Sewage Disposal Works under operation, and the West Side Sewage Disposal Works under construction. To this suggestion the Master and complainants agreed. Accordingly, the Master and counsel and expert witnesses for both parties visited said plants during the afternoon of March 25, 1929.

9787 **Major General Edgar B. Jadwin,** called by the Special Master, Chief of Engineers of United States Army, testified:

The questions put by the Master to the Chief of Engineers as shown by the Master's letter of February 22, 1929, and the Chief of Engineers' answers thereto, appear at pages 90 to 96 of the Special Master's Report on Re-reference.

Cross-Examination by Attorney General Ward of New York.

I have been Chief of Engineers since June, 1926. I
10017 have never had charge of the Chicago District as District Engineer nor as Division Engineer. The investigations made which resulted in the testimony I gave yesterday, were through consultation with subordinates, rather than through any personal inquiry, largely. I have personal contact with certain phases of the problem by virtue of being senior member of the American Section of the Joint St. Lawrence Board, and the question was up before the Board; but the bulk of the data that I have gotten has come from my assistants or through them.

I am not a sanitary engineer, and have passed very little upon sanitary problems. I have had charge of a
10018 large amount of work, and there has been some sanitary work come up in connection with that. But it has

not been of as complicated a character as the one under consideration. In France I had general charge of the construction of service supply, which included the wharves, channels, railroad construction, construction and modification of hospitals. Along with that there came more or less water supply construction, and a little sewage disposal, but it was done on the simplest possible plan with the idea or thought that the war would not last long and we were not building for permanency. None of that work involved the amount of pollution in large running streams that might become objectionable or might carry disease to the inhabitants. The answer I gave was intended to be the answer to the question put in the last paragraph of the Master's letter.

10022 Without any reference to sewage in the river, how much water is required for navigation, is a mighty serious question, and I would like to take a little time with my officers in preparing an answer to that. Several questions come in there, and several hypotheses, which we will probably take up. One is whether you block off the Chicago River and consider it merely as an arm of Lake Michigan, or whether you take into consideration the fact that Congress has already authorized the improvement of the Illinois, and the only way they can get the water is through the Chicago River, and whether we are to consider that there will be possibly other conditions, and I would rather not answer it extempora-

10023 neously. I will be very glad to give you an answer after I have worked over it, but we usually work over those things in that way. I should give my opinion after consulting the District and Division Engineer and the Board of Engineers. I have them here, and am perfectly willing to do that.

The Master: General Jadwin is here not as an ordinary expert. He is Chief of Engineers of the War De-

partment and naturally he feels his answers to those questions are with a sense of official responsibility in advising me and the Supreme Court of the mature opinion of the War Department. He feels that he should not be required to give an answer on an important question without having opportunity to consider the matter carefully. It is not at all the case of an ordinary expert on cross-examination as to his qualifications. He is the Chief of Engineers of the United States Army.

Mr. Ward: It is difficult for me to cross-examine the
10024 gentleman and also his advisers.

The Master: You can have any officer whose opinion appears to be underlying that of the General, at any time.

General Jadwin (continuing): I testified that under the present conditions the diversion required to make the flow of water in the river sufficiently healthful for sailors and men on vessels, was 7,250 c. f. s., plus the water supply, and I included in that answer the Calumet system, and I do not in my own mind divide the amount of diversion between that required by the Calumet system and the Chicago River. As to the process of reasoning by which I reached the figure of 7,250 cubic feet per
10025 second, the diversion is going on now and has been going on under a permit issued in 1925, and provided for 8,500 cubic feet a second as being the proper amount needed for that purpose; that is, 8,500 plus the water supply. It provided for a progressive reduction at a rate of 250 cubic feet per second, which would bring it to 7,250 cubic feet per second at the end of this year. I understand from the Division Engineer that the program is being carried out substantially as prescribed, so I start with that amount. From any evidence that I have, that is the amount that is now needed.

You ask me whether my conclusion is based upon san-

itary knowledge and reasoning or upon the amount that is now being used or may be used under the permit. 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 Engi-
10026 neers, and Major Putnam was the District Engineer. Major Putnam studied it carefully. General Taylor authorized him to employ a firm of expert sanitary engineers to assist him in the matter, Alvord, Burdick & Howson, and they were expert people competent and disinterested. They made a very careful study which has been before us and taken into consideration by my assistants in their progressive study of the diversion.

In determining that amount of diversion, I took into consideration the amount of water needed for navigation of the river below, and for the preservation of sanitary conditions there as well as the Port of Chicago, from the standpoint of navigation, but did not consider the standpoint of taking care of the health of Chicago. People on board boats need substantially the same protection as the people in the city. There is quite a running par-
10027 allel in there for a long distance. Then they are separated. Whether in reaching the conclusion that a diversion of 7,250 cubic second feet, in addition to the pumpage, was based in part upon what I thought was necessary for the maintenance of navigation and the health of the navigator in the lower streams, as well as the Chicago Port, I think an analysis will show that it does contemplate taking care of the navigation in the upper Illinois, in view of the fact and from this point of view, that through navigation on the Chicago River must pass through that place, and if the navigators are not
10028 protected there, it would hamper the navigation on the Chicago River.

As to whether the statement contained in my answer to the question in the Master's letter, contemplated also protection of fish life in the lower river, that fish life came in the Alvord, Burdick & Howson Report. My statement did not contemplate that for the purpose of protecting fish. The sanitary engineers used that as a measure of suitability of water for navigation. I mentioned that in my report.

As to the extent of this diversion which I say is necessary, being based in part upon the protection of fish life in the Illinois River, the diversion is not for the sake of fish but for the sake of navigators. The sanitary engineers used that in their report as a basis of measure.

In my determination of the amount of 7,250 c. f. s., I had in mind that part of the sewage would be purified and part would not, as was contemplated by the program under which the Sanitary District was working and of which the District Engineer kept the Department advised. In reaching that figure of 7,250, I did not analyze what proportion of the sewage would be purified. I had those figures and they were mentioned. I did not check or analyze them.

10029 I took 7,250 c. f. s. as being about the status that the works would naturally be expected to be at the end of this year.

10030 My recollection is that the program called for 85 per cent purification. I think that might be considered what was in my mind. My understanding is that the experts figure 4,167 as being the amount under certain conditions. I took 5,000 c. f. s. for reasons that I undertook to set forth in my answer. It is difficult to take a thing of that kind so closely as to say 4,167 c. f. s. It seemed to me that the question of the rate of the growth of the city and of the fact that the metering program is not being lived up to, should be taken into consideration.

The rate of growth of the city and the posible changes in the amount of industrial waste, and various other contingencies that we could not foresee exactly, would be added to the result, and would result in a larger amount
10031 being needed rather than a smaller. I added a little less than 20 per cent, being the round figure of 5,000 c. f. s. I had another matter in mind. They are taking there now this 8,500 plus 1,000, which makes about 10,000 and we are cutting the amount down to approximately half, including the water supply. That is a very big change. It has to come down progressively year by year, but before we get there, unless the rate of development has changed from the present rate, many years will have elapsed, and many of these conditions which cannot now be specified exactly will have developed themselves. Therefore, it may be necessary when that time comes, or whatever develops, we may have to change the amount. And the phraseology that I used was intended to be such that if the Master adopted it, or adopted that idea, and the Supreme Court adopted it, there would be a flexible clause in there, so that the amount might be determined as conditions develop. If it is found to be more than needed, it could be reduced; if it was found to be less than they required, it could be increased. I was further influenced by the fact that if we should put too small an amount and the Federal Government should require the city or the Sanitary District to go to the expense of putting in machinery to get along with a smaller
10032 amount, and then found later they would have to have a larger amount, we might have put the Federal Government in the position of having required an unreasonable expenditure of money.

10033 So far as assuming the failure of Chicago to meter its water would be continued or would be cured in reaching my estimate of 5,000 c. f. s., it is our thought that it

shall be cured. I believe that Chicago will come to metering, but if they do not, they will be deprived of that much water for other purposes.

I considered in fixing the figure of 5,000 c. f. s., gates or locks in the river to prevent the back-up of the water of the Chicago River into the Lake. Whether there should or should not be locks and gates, did not have any effect on my conclusion as to 5,000 feet per second, but I would like to answer that a little more fully, if I may.

10034 The question of the location of works of that kind is a controversial one, of a technical character. The location may depend upon the amount of diversion. If there is a very large diversion it is doubtful whether you need those works. If a very small one, the necessity becomes more pressing. The manner in which they operate will vary. The works spoken of yesterday would probably operate the best under a small diversion. After

10035 the Master and the Court have determined the amount of diversion, then my thought is that this question of gates could be taken up and solved technically. It will then be easily determinable. The gates are in the present permit. That condition should be continued. Whether

10036 or not they should be put in there at 7,250 c. f. s., I don't know. I don't know whether the gates are necessary with a diversion of 7,250 c. f. s. and that of 5,000 later. That is under discussion at the present time. The District Engineer has prepared plans which were forwarded from the District Engineer through the Division Engineer. I have not seen the report, but will take it up and be glad to report upon it. As to my having given consideration in my testimony to whether my conclusions were with or without gates or locks, they considered that gate question fully in other connections, but that gate question is to come right along and to be studied and is now in process of being studied.

In considering the amounts of diversion, I included the question of navigation on the Great Lakes as well as the interests involved in the Chicago River and the lower waters. Navigation on the Great Lakes was the primary thing that started the Department to consider this ques-
10037 tion. As to whether my statement that I considered the interests of navigation on the Great Lakes in discussing this diversion of 7,200 feet now and 5,000 feet later, was in connection with my idea that the interests of navigation should be protected, not by stopping diversion here, but by putting compensation works elsewhere in the Great Lakes, I felt that it was necessary to be complete and to be sure that I was responsive to the questions in the Master's letter. I was on the St. Lawrence Board and the question came up of how navigation should be protected with diversions of different amounts. You can protect the interests of navigation on Lakes Michigan, Huron, Erie and Ontario, at Lake Erie, by
10038 works of that kind. You can make a raise that is exactly equal to the fall that is due to the diversion. The reason that the diversion was objectionable to the people on those Lakes was that it was causing a lowering of lake level, and therefore shallower channels. That is one way of doing it, and it seemed to me it was proper that it should go into that general consideration. It is a relatively inexpensive way if there were no other questions involved. There are other questions involved which I do not know should be discussed here or not.

Further Cross-Examination by Mr. Jackson for Complainants.

10039 If the controlling works were shut down at Lockport, there would be greater available depth for navigation in the Chicago River than now obtains, and no place where the depths would be less than now obtains. In de-

termining the quantity of water necessary for navigation in the Chicago River, the nuisance factor and the quantity of water for flotation are two questions involved, but it seemed to me that the nuisance one was the determining one in this case, so far as the Chicago River is concerned. Of course we would have to have enough water to float vessels. If you consider merely the question of depths or quantity of water for flotation of ships, you are barring out quite a large part. If you close it off, you will bar off navigation coming up from the water-
10040 way. They cannot navigate the Chicago River if they do not get there. Boats could come into the Chicago River from the Lake anyway. Disregarding the question of boats coming into the Chicago River from the Illinois River or passing from the Chicago River into the Illinois River, and considering only the question of depths of water in the Chicago River for the flotation of ships, the cessation of the diversion would not affect the depth of water there, on a cross-section, or flotation element, but it takes boats to make navigation as well as channels, and that is what we are working on now. I have recently let contracts on this Illinois River Project authorized by Congress, which will make it possible for boats to come through and navigate the Chicago River for a depth of 9 feet.

10041 Outside of the question of the increased rate of deposit which could be taken care of by dredging, the question of whether you would need any water for navigation directly from Lake Michigan so far as the use of the Chicago River by shipping on the Great Lakes, etc., is concerned, is merely a nuisance question. I am not an expert in the field of nuisances, in the sanitary sense. but certain of these matters come over my desk. My predecessor employed these expert sanitary engineers for advice on the question, and it passed through our dis-

trict and division engineers. That does not make us sanitary experts.

10042 I am not quite sure whether there was any nuisance condition inimical to navigation on the Chicago River, as such, during the seasons of 1925 and 1926. But I think there was complaint. But I am not sure. I could get that quickly from my District Engineer who was preparing to testify as to the physical and historical conditions.

Col. Schultz, who was in the room, District Engineer, was asked the question as to whether conditions in the river were inimical to navigation for those years, and he said:

> "I considered the conditions quite offensive to navigation at the present time. In 1925 and 1926 navigation was going on but it was offensive. The river was covered with scum. No self-respecting person would ride on the river if they could avoid it. They did it because conditions demanded it."

General Jadwin (continuing): Complainants' Exhibit

10043 1 entitled "Diversion of Water from Lake Michigan, 1923," pages 59 and 60, states:

> "As far as navigation on the Chicago River and the Drainage Canal is concerned, if the flow at Lockport were entirely throttled and the power house gates closed, so as to permit no diversion from Lake Michigan, conditions would be decidedly improved."

I do not think that is entirely correct. I do not find that this is signed. It is apparently a summation for use and information. I do not think the statement is

10044 quite right in the way we are looking at it now, but from what that man had in mind in writing that, it is probably correct. He had something different in mind from what I had in mind. I think he had in mind that shutting off the sewage from getting down there, there would be no offense from sewage. I have in mind that

if you shut off the connection, you shut off the navigation already authorized by Congress, which we are doing under the existing project.

As to whether Major Putnam had in mind that if the diversion were shut off the current would be decreased in the Chicago River and the river would be more easily navigated, I thought that Major Putnam had in mind that he would not let anything go down there. I took the statement in the exhibit to mean that he was going to put the Illinois River strictly on its own, with its own water.

10048 The amount of diversion in 1925 and 1926 was less than 7,250 c. f. s. I do not think any part of sewage treatment plants were in operation in 1925 and 1926. I do not know what part of the sewage of Chicago was treated on a 100 per cent equivalent basis in 1925 and 1926.

10049 If the program is carried out by the Sanitary District by December 31, 1929, sewage will be receiving complete treatment on the equivalent of 100 per cent basis of

10050 approximately 1,300,000 population. My understanding is that there is needed this amount, 7,250 c. f. s., plus pumpage, to make the waters reasonably satisfactry for navigation at the end of this year, and I base that largely on the testimony and reports of Col. Weeks and other officers who have studied it.

"Q. Now, when you come to your 5,000 figure at the end of complete treatment, General, you are again dealing solely with a nuisance factor as far as navigation on the Chicago River physically is concerned; are you not?

A. I think that— My recollection is that if the nuisance factor is taken care of, that the flotation conditions will be there, sir.

The Special Master: What was that answer?

A. If the nuisance factor is taken care of, sir, the flotation conditions will be all right, also."

If there is no diversion from the Lake that involves the assumption about blocking off the river at Lockport.
10051 As to ignoring my policy with respect to the Illinois River I am not bringing in my policy but I think I must recognize the policy of Congress.

"Q. I wish you would tell me as a scientific man what the fact is. If the policy of Congress controls, the Court will tell us that.

A. Then may I ask your question? To repeat the question, sir?

Q. When complete treatment at all the plants in Chicago has been attained, you will not need any diversion as far as the flotation question is concerned in the Chicago River?

A. I don't get that absolutely clearly. I think you would, Mr. Attorney General. I don't— My mind is not— I am not quite sure I grasp the question you are putting, but if I do, you would need some for flotation.

Mr. Jackson: Q. For what purpose?

A. Well, because water will be going out and going down the Canal and down the Illinois River.

Q. Well, I am assuming there is not any going down there, General.

A. Well, I think the fact is that there is. We are
10052 carrying out that project now.

Q. But will you just take my assumption and answer on the basis of the assumption that there is not any going down there?

A. If there is none going down, if you block that off completely, then you do not need water, additional water for flotation."

There is a very light draft present navigation from Lake Michigan to the Mississippi. It comes in through the Hennepin Canal and the Illinois River and through the Sanitary Canal. Congress has authorized the deep-

ening of the Illinois to 9 feet to meet with this deeper channel which the State of Illinois is now putting in. They are spending a large sum in building five large
10053 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; 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 improvement, largely along where the DesPlaines River is. That has already been authorized and is a thing which we can finish on our part 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 and is going to be completed. If the improvement for navigation in the Illinois River as provided were completed, the shutting off of the flow or discharge to the DesPlaines River would decrease the navigational dimensions intended in the river, very much. You would not have a nine-foot channel after all this work was
10055 done. To get that nine foot channel without any of that water, you would have to add three locks and even then we would not have enough water for lockage. We would have to have about 1,000 cubic feet for lockage discharged from the Sanitary Canal into the DesPlaines River. That would, however, not take care of the nuisance factor, and we would have to build the extra locks. That is, it would require 1,000 feet in addition to the water in the Illinois-DesPlaines Watershed to take care of the waterway. That is from an outside source. Con-

gress 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, and that maximum limit would call for, as I remember it, a diversion of about 4,500
10057 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 as I remember it, Congress had that larger sum before them. Congress had the report of the Chief of Engineers 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. The lowest flow is in the summer. As to whether there is little or no navigation
10058 in the winter, the river freezes as far as Peoria. I don't know how much further it freezes.

As to my being familiar with the nature of the effluent of these complete treatment plants with reference to containing residual oxygen, I have seen the effluent, but I am not a sanitary expert.

I do not agree with the statement made by Mr. Pearse before the Rivers and Harbors Committee of the 68th Congress, First Session, 1924, appearing at page 1640, reaffirmed at page 5423 of the record, as follows:

> "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
> 10059 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."

My reason for not so agreeing is that we got our view from Messrs. Alvord, Burdick & Howson, whom we paid for an independent sanitary study and opinion, and we have not seen anything to cause us to make a further study. If their conclusions are seriously questioned and the Master wishes a further study, we would be glad to have it done, but we are following the lead of Messrs. Alvord, Burdick & Howson on those sanitary matters.

I do not remember whether we instructed Alvord, Burdick & Howson to report upon a standard which would permit a thriving fish life in the upper Illinois River. My understanding was that they took that as one of the standards of knowing that the water was pure. I don't know whether that was the instruction of
10060 the Department. It was given before I became Chief of Engineers. As to thriving fish life being necessary for navigation, fish are not essential to the navigators. As to whether the standard which will permit a thriving fish life and the standard which will prevent any objectionable nuisance are the same, I understood that the standard for thriving fish life was as low as could be gone to be sure that water did not have so much foul matter in it as to become putrid and unreasonably offensive to navigation. I did not understand that it was so there would be enough surplus oxygen in the water to support a thriving fish life, rather than that there should be no
10061 nuisance. I gathered that that was just a gauge. If the water supported fish life, it would be safe for navigators.

Neither now nor when all the treatment plants are completed, will there be any diversion necessary as a matter of providing adequate depths, is not true on the Chicago River, because you are losing sight of this au-
10062 thorized project of Congress. I was directed by the Special Master to answer, ignoring the Illinois Water-

way and limiting myself for the moment to the Chicago River. It is true that neither now nor when all the treatment plants are completed, will there be any diversion necessary as a matter of providing adequate depths in the Chicago River. That is correct referring simply to depths of the Chicago River. But if you mean simply depths in the Chicago River, it is true. If you limit your navigation to the Chicago River and accept the thought of barring out of it that navigation which I think should come through there, then the sole problem is what dilution, if any, will be requred for the effluents of complete treatment plants to prevent an active nuisance in the Chicago River as far as the Chicago River is concerned. I think it is correct that as to the quantity of dilution water from the Lake, if any, which is necessary when complete treatment plants are in operation, in order to prevent any active nuisance, I am not an expert and am not able to advise. But I used a sanitary engineer in getting information for that, and straight up through my
10064 District and Division Engineers. I don't know whether it would be possible to pump water from the Lake into the upper end of these streams at Wilmette, etc., to obtain dilution to prevent nuisance to navigation, but I will look that up and answer you later, conferring with the officers in my Department.
10067 But a question like the determination of the location of control works might take us several months to answer.

Inquiries by Special Master.

We cannot be ready with an answer to that question of the location of control works at this session.

The position of the control gates to prevent storm water from entering into the Lake under the conditions that have been described, would depend on the extent of the diversion, which location would be determined after it is determined what diversion, if any, is to be allowed.

That consideration did not enter at all into the estimates of 3,200 or 5,000 cubic feet per second under the conditions prescribed.

Before I can be prepared to say where I want control gates to prevent storm water going into the Lake, the diversion should be prescribed.

10068 I should desire time to formulate an answer as to where I would consider it appropriate from the standpoint of the War Department to have the control works, on various hypotheses. If I knew what the Master's decision was to be, or the Court's decision, I could go on that figure. Otherwise the only thing I could do would be to take care of a number of figures.

A good deal has been said in the course of my examination this morning as to my estimate in the ultimate requirement of a diversion of 5,000 c. f. s. I have stated heretofore in my testimony the premises I made in reaching my estimate of the ultimate requirement of a

10069 diversion, but if I considered the needs of the Chicago River proper and local navigation on the Chicago River proper, exclusively, then a total diversion of 3,200 c. f. s. measured at Lockport would be enough, and the 3,200 feet includes pumpage at about 1,600 cubic feet per second, which would leave on that basis, considering the total flow at Lockport and the safe-guarding of the Chicago River proper, a diversion of about 1,600 c. f. s. as compared with 8,500 c. f. s. under the present permit.

10070 That is, I assumed that the 1,500 c. f. s., augmented by the natural run-off of the Calumet and Chicago watersheds, would give this average flow of 3,200 c. f. s. at Lockport which included everything.

I heard brought out yesterday a very high per capita here for pumping. My thought is to fix the amount, and there is quite a question in there. Then, if they do not come to a reasonable amount of metering, they would

suffer in dilution. I simply show a basis of comparison taking the safe-guarding of navigation in the Chicago River proper and the total flow at Lockport. The 3,200
10071 c. f. s. per second on that basis is the total which has to be compared with 8,500 c. f. s., plus Chicago pumpage, or a total of approximately 10,000 c. f. s. The 3,200 is compared with the 10,000 c. f. s., and if you take 1,600 off of one and 1,600 off of the other, then you have 1,600 as compared with 8,500.

10206 The instructions to me were that I was to prepare answers to several questions which yesterday required more time for study. The first is the answer to a question which appears at pages 10063 and 10064 of the record,—whether 1,000 cubic feet per second of lake water pumped into the North Branch, and 2,000 cubic feet of water pumped into the South Branch, permitted to mingle with the effluent and proceed out into the lake, would prevent any nuisance to navigation.

10207 The answer is, it would prevent a nuisance to navigation in the Chicago River, provided it were introduced into the branches and their forks at the heads of navigation; that sewage treatment is approximately 85 per cent complete, and that a gate or other barrier be placed to prevent back-flow from the Sanitary Canal of the undiluted effluent from the plants discharging into the Canal.

The other question that I was to answer is found on pages 10019 and 10020. The question was reshaped by General Ward. As reshaped, the question is:

> "Disregarding any sewage or pollution in the stream, how much diversion is necessary to maintain navigation in the Chicago River?"

The answer to that question is no diversion would be necessary for local navigation on the Chicago River, but an as yet undetermined amount, somewhere between

1,000 and 10,000 cubic feet per second, would have to be passed for through navigation between Chicago and the Illinois River and for navigation on the Illinois River.

10214 In stating that the amount of diversion was undetermined and might be anywhere from 1,000 cubic feet to 10,000 cubic feet, I meant that it was undetermined because Congress had not yet definitely prescribed a plan of improvement. Congress had before it from the Chief of Engineers a number of alternatives, about twenty, with the cost for each work. The price was indicated. Congress directed us to get a channel 9 feet deep and 200 feet wide, at a cost of not to exceed certain minimum, three and a half million. That three and a half million excluded certain of these alternatives, but left us free to use our best judgment in the selection of the others.

10215 The one which we thought was the best, and the one on which we are working, it was estimated would cost very close to the three and a half million dollars. That called for removing the two state dams and for getting this channel, with a diversion of approximately 4,167 c. f. s. That we are now working upon. The dams have been secured from the State, and we have opened them up so that navigation is going there. We are spending considerable money on that line. However, it was explained to Congress that if the diversion were determined at anything from 1,000 to 10,000, the plan could be adapted to that. If less than 4,167 c. f. s. diversion were determined, the plan could be adapted to it so far as water for flotation is concerned. It would be necessary, however, to restore one or both of those state dams and would not give us what we consider to be reasonably free, easy and unobstructed navigation. Each of the dams is an objection, a delay to the passage of boats.

Since January 21, 1927, Congress has directed us to make a review of that project, and certain matters have
10216 been urged and are known to be desired. We are to make a report and recommendations. Congress has not finally determined beyond the fact of authorizing and directing us to go ahead with the three and a half million dollars work which is being done.

The Special Master stated, in response to an inquiry of complainants' counsel, that he did not understand that the statement by the witness opened up again the question as to whether there has been any authorization by Congress for any diversion in the Illinois River.

10218 *Cross-Examination by Mr. Adcock for Defendants.*

With reference to the answer to the question appearing at page 10,063 and 10,064 of the record, my understanding is that the effluent from several of the plants is to be discharged into the Canal proper, and if we pump water beyond, as has been suggested by counsel for the other side, with the idea of pushing the flow that is in the South Fork out into the Lake, it would similarly push water down the Canal if there were not a barrier put there, and, similarly, if there were not a barrier put there, the effluent which comes into the Canal, which is larger than that to come in in the North Branch, it would work back, and it would get to be almost purely undiluted effluent, and it would interfere with the proposition that he set up. Under my assumption, the effluent discharged west of the barrier would be discharged by means of the Sanitary Canal into the DesPlaines River. It would accumulate and have to work its way down into
10219 the DesPlaines, assisted by the rainfall in the Illinois and DesPlaines basins. Most of those plants, when the system is completed, as I understand it, do not empty

into either the Chicago River proper or the North or South Branch. One plant at least, that is, the West Side, and the other, empty largely into the Sanitary Canal or the South Fork of the Chicago River. There are a number of maps there that will illustrate that.

I would think that it would kill all navigation to have
10220 the effluent that would be discharged from these different plants, flow on into the Chicago River and to the Lake; that is, navigation would not be, according to the wording and spirit of the law, reasonable, free, easy and unobstructed. That is the thing we feel navigation is entitled to, in accordance with the spirit of the law, and this would not be so. It is my understanding that 1,000 and 2,000 c. f. s. that Mr. Jackson has proposed, would take care of what came into the Chicago River and its branches, so far as they were concerned.
10221 I had to put that barrier in to shut off that effluent. Similarly, I make no answer at all as to the effect of the water supply in Lake Michigan. I think that 1,000 and 2,000 c. f. s. would take care of it in the South Fork and North Fork of the Main River, which is primarily the effluent from the North Side Plant.

Further Cross-Examination by Mr. Jackson for Complainants.

10222 If part of the effluent was discharged into the Drainage Canal and permitted to run the other way, navigation would be killed. I don't know the comparison of the quantity of suspended solids in the effluent of an activated sludge plant with the quantity of suspended solids in ordinary river water. Taking the Wisconsin River
10223 near its mouth, I don't know how they would compare. I am not sure it would be clearer as far as vision goes. I don't know the comparison of suspended solids. There is a very large amount of solids in the Mississippi at

times; also the Wisconsin. However, it is not as dirty a river as the Mississippi. I don't know specifically.

As to the St. Louis River at Duluth, I don't know. I imagine that would have less, but am not sure. I mean suspended solids.

10224 I cannot say from fishing in any of these rivers that they are not freer or that they have more solids than the effluent of an activated slulge plant, partly because I have not fished on many of them, and particularly I have not fished on the Illinois River where the effluent is. But I could get you the figures on the amount of sediment presented by those different rivers. It is my understanding that the effluent from activated sludge plant is not stable. As to its containing available oxygen, nitrates or nitrates, you are getting into details of sanitary en-
10225 gineering, and I would prefer to get a sanitary engineer for that. But it is my understanding that such effluent needs water to dilute it so it will be gotten out of the way.

With reference to the statement appearing at page 229 of Complainants' Exhibit 233 for identification, as follows:

> "Almost as clear as drinking water and quite as harmless as it finally leaves the plant through an outlet and into and through an artificial channel which discharges into the Chicago River",

I do not understand that the effluent from activated sludge plant is as harmless. That is what I get from my people.

My understanding is that this effluent needs a considerable amount of water to get it out safely. It is my understanding that the effluent from an activated sludge plant is detectable. I have seen very little of it, but what
10227 I have seen was none too attractive to me. It did not have an odor that attracted me to it. I had the impression that there was a slight odor that was not pleasing

to me. I have seen very few activated sludge plants, but my recollection is that it was not entirely pleasant. I think very much more expert or exact testimony would be
10228 obtained from some one else. I am basing my conclusions on the understanding that this 85 per cent material needs considerable amount of water, and that it has to have a certain amount of time to work out. It is only 85 per cent, and it does not get to where it works itself out in the ordinary air until it gets down to about Peoria, and it is my understanding from my assistants that that is the way it will be. The matter came up in the
10229 conference and several voiced that view. It was discussed in our conference around the board, and it seemed to be the general accepted opinion. I think Colonel Schulz was one who voiced that view, and Colonel Pillsbury was another one of them. It is my understanding that the effluent of an activated sludge plant is not stable. As to having given any consideration to how long the effluent would retain the characteristics of stability that it did have after its discharge my understanding was that
10230 the effluent ought to be worked out of the South Branch in something like two days, and it ought to have water in it, enough to carry it down to about Peoria in about five days, until it got air enough to clear it up. I do not have the figures as to the amount of effluent that would be dis-
10231 charged directly into the Drainage Canal. The amount of water that I consider necessary to add to the effluent was 5,000 cubic feet per second, including the water that is pumped. The amount of the effluent will probably be somewhat variable, depending upon the amount of water that is pumped. At present there is a high amount. I don't know whether the stability of an effluent depends upon two things; one, the oxygen demand of the effluent, and, second, whether there is a sufficient amount of available oxygen to satisfy it. As to how I can then de-

termine whether this sort of effluent is putrescible or will form a nuisance, I got my figures largely from my con-
10232 ferees. While none were sanitary experts, I had the report of the sanitary engineers to whom I referred before, and have a copy of that report. With reference to how I arrived at the figure of 5,000 c. f. s. as necessary to preserve stable conditions, if I do not know what the oxygen demand of the effluent was, or the quantity of available oxygen in the effluent to satisfy that demand, or what oxygen would arise from aeration of the flow of the effluent, I explained to the court yesterday in reply to a question of General Ward, that I obtained that 5,000 c. f. s. by adding a factor of safety to 4,167 c. f. s., and
10233 this 4,167 c. f. s. was worked out quite carefully by the sanitary engineers who were employed to find that amount for us, and to find it in a disinterested way. With reference to that figure being the amount that would sustain a thriving fish life, it is my understanding that that is the amount that is necessary to make navigation reasonably free, easy and unobstructed; that the people on the boats are entitled to have easy, free and unobstructed water to travel on, and in some way, between the district engineer and the sanitary engineers, they brought in the matter of water that would support thriving fish life, to fulfill the conditions of safety for navigation. With reference to its being my understanding that a standard of water conditions which would support a thriving fish life and that a standard of water conditions which would produce no nuisance, are the same, it is my understanding that they took the standard of water to support a thriving fish life as a test for water which would be safe and secure for navigators. We are anxious to have these waters safe for navigators, and we do not feel that they should be forced to come in and take a chance on the question of life and death, as to whether or not a given

stream is safe for them to travel on, and this figure was reported to the District Engineer by these gentlemen,
10234 who were paid a good round sum to work that out. The District Engineer reported to us and it passed through the Board, and we based our recommendation on it. I don't know of my own knowledge whether or not a standard which will permit thriving fish life and a standard which means merely the absence of a nuisance, constitutes the same thing. If it is found that navigation will be reasonably free, safe and unobstructed and still fish could not navigate up it, it would probably meet our conditions.

10238 Storm water overflows into the harbors of other cities on the Great Lakes. That is, it flows into the rivers tributary and then goes through such rivers out to the
10239 lake and through the harbor. I have heard it said by my assistants that navigation in some of the other harbors on the Great Lakes is not satisfactory; that the water is in an objectionable condition in some of them. If you wish the details about any one of them, I should be glad to put on one of my assistants who has had that particular harbor under his jurisdiction. Col. Schultz, who is the Division Engineer for the entire Lakes, and who lives at Cleveland, is here. Col. Jones, also, who was formerly District Engineer at Buffalo. My understanding is that the water is particularly bad here at Chicago because it has in it this large amount of sewage, a larger amount than we have at other places where the storm water and sewage flows into the Lake.

"Q. You do not think that if the sewage here was treated to the point—given complete treatment—to the highest known stage of the art, there would be any more sewage in the river than there would be at Cleveland, before treatment, or at Buffalo, do you?

A. I do not know how much there is at Cleveland or

at Buffalo. But I have gentlemen here who have been stationed at those places. And I do know that it has been a source of concern here, and that they have wanted extra water to keep it from going into the lake and interfering with the water supply.

Q. Navigators have not been interested in that, have they?

A. My understanding is that it has been to prevent the water supply being polluted out in the Lake.

10241 I would like to ask my Division Engineer as to whether navigators in the Chicago River have complained of current in the river and have not complained of pollution. Col. Schultz is here, and I can get the information from him right now, if you want.

10242 *Special Master interrogates Gen. Jadwin.*

I stated that a certain amount of the effluent would go into the Chicago River and certain other parts would go into the Sanitary Canal. I regard the Sanitary Canal as beginning at Robey Street and continuing to Lockport. There is a continuous flow from the Chicago River right through the Sanitary Canal at present. If the flow were stopped by preventing any water from going down, say at Lockport, then there would be a continuous flow from the Sanitary Canal into the river under the present conditions without any gate. The distinction between the Sanitary Canal and the river with respect to the part of the effluent that went into the river and the part that went into the canal and the difference it makes, entered into it in this way. Mr. Jackson was supposing pumping water into the upper end of the North Branch, and then at a point on the South Branch near the upper end, and I switched that in view of the spirit of the question, and assumed a certain amount of water, and the question would that keep the Chicago River pure, and I said that

it would in my opinion, provided several things, one of which was to put a barrier where the river now joins the Canal so the Canal with its large amount of effluent could not work back into the river. The water in the Canal, largely effluent, would then be flowing through the gates at Lockport. There would be a slow flow largely
10244 effluent, and continuous. It would have also such rainfall as occurred in the territory, in addition. The contemplated barrier at the entrance to the Canal at Robey Street was merely a fiction that Mr. Jackson had of the Chicago River being by itself. If you did not have such a barrier and the physical conditions remained as they are now, but you provided for the stoppage of the diversion entirely and the flow of the effluent, whether received in the canal or the river, into the lake, then you would have to pump in sufficient water in order to take care of that effluent coming down from the canal into the river.

The answer to the question as to the amount of water which should be pumped in in order to provide conditions that would be satisfactory to navigation, did not include taking care of the entire effluent that would reach the
10246 river in that way from the Canal. I answered the question on a hypothesis relating solely to the river, and on the assumption that there is a barrier between there
10247 and down the river. My understanding, however, is that if you arrange it so that all the effluent got into the river right close to it and put this amount of water up above it so that the water would follow it out into the Lake, it would keep the Chicago River reasonably free, easy and unobstructed. And when I say "above it," I mean somewhere so that all of it came out towards the Lake, if you wanted to do that. The limiting point would be where the last one of these effluents came into the Canal. If the water were pumped in at that point, it

10248 would take care of the effluent so far as the river is concerned. Then it would go out into the Lake, and that is entirely another question, as I understand it.

Further Cross-Examination by Mr. Jackson for Complainants.

Whether 2,000 second feet could be introduced through the Calumet Sag Channel to the Drainage Canal and out the river, I have not differentiated in the amounts between the Calumet and the Sag, but in some way I understand you want to put this water where the last effluent comes in.

There is one pumping station at the upper end of the North Channel; one at 39th Street; then there is the Calumet Sag Channel, which comes through and joins with the Drainage Canal. Whether you could circulate water through the Calumet Sag Channel and out again, raises a question as to the carrying capacity of the Calumet Sag, and the length. I see no reason why you could not send through the Calumet Sag Channel the amount it would carry. You could in some way get up there by some
10250 adequate channel. If the capacity of the Calumet Sag is 2,000, you would have a total pumpage of 5,000 second feet from the three sources, 2,000 at 39th Street and 1,000 at Wilmette. I would have to check as to whether the introduction of that water into the Chicago River
10251 would permit a thriving fish life. It is my impression that you could provide in that way the amount that the sanitary engineers said was necessary, but I give that answer subject to possible correction.

The Master asked whether counsel for either complainants or defendants desired to examine either Col. Schultz or Col. Pillsbury who were in attendance, and counsel for both stated they did not.

11292 Washington, April 19, 1929—10:00 o'clock A. M.

Maj. Gen. Edgar B. Jadwin, resumed:

Direct Examination.

General Jadwin's answer as to controlling works, which questions were put to him when he testified in March, 1929, appears in the Master's Report in full, pages 108 to 116, inclusive.

Cross-Examination by Attorney General Ward of New York.

The statement that I have given was prepared in co-operation with my associates. In making this statement we have considered that the sewage or the effluent went into the river. I have assumed that Chicago will continue to
11311 discharge its sewage into the DesPlaines River. I have given no consideration, so far as this statement is concerned, to what the condition of the Chicago River would be if Chicago carried its sewage elsewhere. In my mind a little thought to that question has been given, but not very much. If Chicago did not empty its sewage or the effluent thereof into the Chicago River, none of this nuisance would necessarily come about, and we would have simply what water was needed for navigation. It would
11312 be more than lockage. It would be the amount that we needed to keep up the flotation of the boats down through the authorized project. If the sewage or effluent were not discharged into the Chicago River and you were willing to exclude from the Chicago River the navigation thereon under authorized projects which would come up there from the Illinois River and Mississippi System, no diversion would be necessary to maintain navigation in the watershed of Lake Michigan. But it is my under-

standing that we considered the navigation projects already authorized by Congress. If Chicago did not dump its sewage into these rivers, no diversion would be necessary for the navigation of the Chicago and Calumet Rivers, excepting the navigation connected with the Illi-
11314 nois River. If navigation connected with the Illinois River is cut out, there would be eliminated a large part of the navigation that we are looking forward to under the present authorization by Congress. Eliminating that navigation, no diversion would be required except for the nuisance factor of the sewage.

There is a lock at Lockport through which vessels are locked. I think it is 14 feet in depth and 600 feet
11324 long, 110 feet wide. A very small amount of water is necessary for each lock. The total amount for lockage would depend on the total number of vessels that you would have. I would have to check back as to whether 100 or 200 cubic feet per second would handle all the vessels.

Further Cross-Examination by Mr. Jackson for Complainants.

11407 There has been no act of Congress other than what was disclosed at Chicago, in response to the questions asked by the Special Master. The last act of Congress is the one that authorized this expenditure on the Illi-
11408 nois River up to $3,500,000.

Referring to Senate Document No. 130, 69th Congress, 1st Session, whether it was the report pursuant to which the appropriation or authorization of the $3,500,000 was placed in the bill, is a little hard to answer. That report was made at that time, but it does not tell the entire story. There was a prior report just immediately prior to that which was a full report and had in it the report of the Board of Engineers. This is Docu-

ment 4, 69th Congress, 1st Session, being Complainants' Exhibit 18. That report made certain recommendations.
11409 Congress usually when it adopts a project refers to it by the number of the document so that we will know that a specific project is adopted. In this case it did not give the number of the document, but it appropriated not to exceed $3,500,000 for the Illinois River, with a view to securing a channel 9 feet deep and 200 feet wide, so that it makes it a little hard to say that Congress did follow that report. The sum of $3,500,000 is mentioned, but they did not refer to that paper as they usually do when they want to adopt a project as recommended by the Department.

Page 3 of Complainants' Exhibit 18 shows a table and a method of developing a 9-foot channel with 200 feet width, with any flow from 1,000 mean annual average up to 10,000. Under one plan the required channel could be obtained with a mean annual diversion of 1,000 second feet, and that could be obtained for an expenditure of $2,666,000. The third paragraph of the report of
11410 Gen. Taylor contained in Senate Document 130, 69th Congress, 1st Session, is as follows:

> "The Board states that if it is felt that the former recommendation of the board might be interpreted as fixing any permanent diversion, a solution may be found in changing the recommendation so as to propose that a project for a channel 9 feet by 200 feet be adopted, and that the department be definitely authorized, not only to provide it for existing conditions of low water flow, but also, and without further reference to Congress, to continue to provide it, by suitable changes in the works of improvement, if the low-water flow be reduced within the limits contemplated by the table on page 3 of House Committee Document 4, Sixty-ninth Congress, first session. The estimates in that table assume that the works corresponding to a given estimate are undertaken *ab initio*. On that basis a lim-

iting authorization figure would be $2,666,000, the estimated cost of providing the channel by canalization with the least flow contemplated in the table.
11411 If, however, the low-water flow should be reduced by successive steps, and at each step certain works had to be provided appropriate to the then existing flow, the necessity might arise for modifying some part of the work in a manner which would somewhat increase the ultimate cost. The amount of such increase can not be accurately estimated, since it is unknown at what rate and by what steps the flow may hereafter be reduced; but it is estimated that the cost under such conditions might reach $3,000,000, or $3,500,000."

It was not, exclusively, pursuant to that recommendation above stated from that report that the figure of $3,500,000 was placed in the Rivers and Harbors Bill of 1927. General Taylor specified $3,500,000 to cover one contingency. Congress put a limit of $3,500,000 but did not follow the practice of referring to this paper by number as it usually does when it wants to adopt the project recommended by the Chief of Engineers.

11413 Complainant's Exhibit 249, being Senate Document No. 130, 69th Congress, 1st Session, received.

I did not testify yesterday in any sense as a sanitary expert with reference to municipal water supplies.

Referring to my statement in what is denominated as Paragraph B of my testimony, concerning the location of control works near the river mouth, appearing on page 11298 of the transcript, where I say that a diversion of 1,500 to 2,500 c. f. s., would be less than would be required to prevent nuisance to navigation, I assumed that that amount would be made up of effluent from sewage disposal plants and runoff water. I understood that the effluent from the sewage disposal plants would be offensive to and a great nuisance to navigation. I am not sure
11415 whether I ever saw the effluent of an activated sludge

disposal plant. I don't know much about it. I have a clear idea in my mind that it needs the addition of a given amount of water under such conditions to take care of the effluents and make it so that it ceases to be an unreasonable nuisance and obstruction to navigation when it gets down the Canal and down the Illinois River. That was determined for us by our experts and reported by our District Engineer, and we have been accepting that so far.

11416 The effluent is some 85 per cent purified, and the 15 per cent impurities are the things that bring about the objectionable conditions. I have gone down the river when the water was so cold that we wore overcoats, and it was a very offensive place to be. I have not seen the Illinois River with nothing but effluent in it. For the de-

11417 tail of what the objectionable characteristics are in sewage effluent that obstructs navigation, I will have to refer you to the report of Alvord, Burdick & Howson. I am accepting the fact that it will be, unless there is that much water with it, that it becomes an unreasonable obstruction to navigation.

As to the basis of any judgment of my own, we have a man, a District Engineer in Chicago, who at the time this matter was handled was Major Putnam, and he was directed to report on the matter of the project referred to us by Congress. He came to the conclusion that to make a satisfactory report it would be necessary to take into consideration the disposal of the sewage. He felt that he should have an expert for that, and hired with the authority of my predecessors, Alvord, Burdick & Howson, whom

11418 we considered to be able and disinterested experts, and they recommended to him that under the conditions which they specified, the expected growth of population and the probable efficacy of the sewage disposal plant, it would need a certain amount of water, about 4,167 cubic feet, to

make the sanitary conditions reasonable. Major Putnam concurred in that report and we have assumed that amount to be proper and have had no reason for changing it so far. As to that being the sole basis of any judgment I have with respect to nuisance, I have the further point that if it is a nuisance to the people of Chicago living along the banks, it would probably be a greater nuisance to the people traveling on boats, because they are closer to the water. As to whether that gives me any basis on which to form a judgment, if I do not know whether there is going to be a nuisance to the people living along the banks after the works have been accomplished, my opinion is based solely on those reports, and
11419 I am giving it as an official position. So far as information goes, my opinion is based solely upon this report of the sanitary engineers I have mentioned. Nothing has since been brought to our attention to cause us to make any further study that would look to any change. As far as any positive facts are concerned, my opinions depend upon the reports of Major Putnam and Alvord, Burdick & Howson. Major Putnam was not a sanitary expert, but he was our representative and he is presumed to have kept quite close touch with these people that he hired, and probably to have gotten further into the sub-
11420 ject there than we did here. The report was on the basis of not having a nuisance, abolishing a nuisance and also a thriving fish life. The report states as follows:

> "This standard to be the lowest that will prevent the occurrance of nuisance in the Des Plaines and Illinois Rivers, and will permit a thriving fish life therein."

I do not know definitely that to permit a thriving fish life, there should be retained a residual of three parts per million of dissolved oxygen. I have heard that figure given. I don't know that in a good activated sludge

effluent there is twenty parts per million available dissolved oxygen, of which fourteen is in the form of nitrates and six in the form of dissolved oxygen. I have seen that statement, but I cannot certify to its being exactly correct.

As to whether only three parts out of the twenty parts per million of available oxygen in such an effluent are available to support fish life, while twenty parts are available to prevent nuisance, I can state all I know in a word. Therefore I refer to page 26 of Major Putnam's report, Document 4, Complainants' Exhibit 18, as follows:

> "The consulting engineers are of the opinion that no appreciable nuisance will result if the following standard is maintained: Liquid discharged by the Drainage Canal, as evidenced by the average of representative samples taken for any 30 consecutive days, shall (a) be practically free from solid deposits in two hours; (b) shall contain not less than three parts per million of oxygen, and enough to equal or exceed the biochemical oxygen demand of said liquid
> 11422 for five days, when incubated at 20 degrees C.
>
> Whether adherence to this standard will produce exactly the results desired or not is unknown, but in view of the present extremely unsatisfactory conditions prevailing, with upward of 4,000 cubic yards of settleable solids being dumped into the Illinois each day, and with periods of several months each year with no oxygen whatever present in the effluents, there is no question but what conditions will be improved materially.
>
> It should be understood that other sources of pollution are tributary to the Illinois River, and that with no contamination whatever from the Sanitary District of Chicago, conditions in the Illinois will not be satisfactory until the rest of the communities now discharging their sewage in the System carry out satisfactory sewage treatment programs of their own. It so happens that the adoption of a standard that no appreciable nuisance will result, carries with it the restoration of conditions that will permit fish life to thrive."

This statement was made by Major Putnam making a report to us after having the report of Alvord, Burdick & Howson, and after working with them. That
11423 is the most exact information I have. I don't think the Major claims to be a sanitary expert, but I think by virtue of his being on that District he has gotten further into it and knows more about it, or did when he wrote that, than we know personally. He had the full advantage of the advice of these experts to whom he was giving a good fee to give him disinterested information, and I haven't found anything contrary to that so far. I have not made any investigation since that time. There is nothing in the report which they submitted to him contrary to that. I made no assumption as to whether there would be visible suspended sewage in the effluent. As to whether I considered there would be any nuisance from that standpoint, I am relying on the reports made by our experts as to the amount of water that is needed to take that effluent, whatever it is, coming out of that plant, assuming it has 85% purification, and get it so it will not be an unreasonable nui-
11424. sance. In reaching my conclusion with reference to nuisance to navigation, I did not consider whether there would be visible suspended particles in the water or effluents. I have some little thought on that, but I am not a sanitary engineer, and I followed the report. It is my understanding that the principal way in which the nuisance would arise would be from putrid odors. As to whether my judgment that there would be nuisance to navigation is based upon the assumption that the effluent of a sewage disposal plant would give off offensive odors, I believe that these effluents will give off, under certain conditions, offensive odors, but I am basing my view as to it being a nuisance on the report of these experts as han-

dled through one officer who represented us in the mat-
11425 ter. As to whether the things which I considered to give rise to the obstruction to navigation was my assumption that there would be offensive odors arising from the sewage effluent, I imagine it would be the same things that would make it objectionable to the people on land and perhaps in a somewhat higher degree because navigators are closer to the water. What they are trying to do is to get the whole nuisance down to a condition where it will not be unreasonable. As to the basis of my judgment that these effluents would create a nuisance and obstruction to navigation, it is the fact that it is held to be unsanitary, according to this report, for the people of Chicago, and it would certainly be a little more so for the people on boats. We paid these people to study it for us and to make a report and we are offering it in good faith. As to whether my judgment was based on the assumption that there would be an odor obstructive to navigation, I imagine the odor would be there, but we hung to this report where these people found that it would make conditions unsanitary for the City of Chicago. If it would be unsanitary for Chicago, it would be more so for our people on the boats. Whatever that may be, whether something gets in the water or something in the air, I do maintain that we must have for navigation as
11427 sanitary conditions as the people on shore have. As to whether I mean that there should be no odor, I mean that there should not be anything that unreasonably interferes with navigation. Unsanitary conditions interferes with navigation; that is, the unsanitary conditions that will result if you do not dilute that effluent to a certain extent which the experts have prescribed. As to whether I think the effluent will give off an odor, I understand (I am not a sanitary engineer) that after the effluent has had

several days to work, if not properly diluted it will make unsanitary conditions. I imagine that it will give off an odor and some gas that would not be healthful for people to breathe. I am not an expert on that, but if you want me to and if the Master wishes to, we will hire some expert to get a formal report for you in a regular way on that.

11428 "Q. No, I do not want to bother you, General. I would just like to get at the basis of your judgment, so I may better understand what you mean by interfering with navigation.

A. I think I have given that to you, Mr. Jackson. I do not want to claim a knowledge of any more of it than I do, and I do claim to have the right of determining our position on that. If it is unsanitary for people on shore in Chicago, it is probably equally so or more so for people on boats."

Our experts said it had to be diluted to a certain extent or it would be unsanitary to people on shore at different 11428 places. As the effluent goes down the river, after several days it would probably be worse farther down. That is what I am told. All I know is what I am given in 11429 this report. The only thing I have with reference to the effluent from a nuisance standpoint is, and I am very positive in the view, that we must have sanitary conditions in the water. I am not a sanitary engineer.

"Q. You do not pretend to know what the character of that effluent would be, from the standpoint of visible matter, from the standpoint of floating material, from the standpoint of odor, or from the standpoint of any other sanitary test, do you?

A. I know some little about it, but not very much, and I would prefer not to put what little I know out com-

pared with the formal report which has been made out with great care and which we paid for.

Q. If you want to claim that you have some independent knowledge,—I am not talking about this book—some independent knowledge of your own, as a basis for stating there would be a nuisance arising from the sewage effluent, from the standpoint of visible suspended material, from the standpoint of odor, from the standpoint of floating material, or any other standpoint you want to mention, then I want you to tell me what your independent knowledge is.

A. I have no desire to make any claim at all, Mr. Jackson, other than I have made.

Q. Then you are basing anything you say upon this report, are you?

A. On the report of the experts we hired to study it for us."

11430 I am basing what I say upon this report. Sewage goes into the harbors at practically every place on the lake.

As to when I first discovered that it was necessary to have water which was not polluted by sewage or sewage effluent in the way or to the extent that I have been informed by this report in order to navigate a ship it came

11431 to my mind as clearly as it has come and as I have endeavored to express it, finally and fully, in connection with the preparation for this case. I had knowledge before that some waters were offensive to navigators. My attention was directed seriously to the fact that there was

11432 an amount that should not be exceeded, in connection with this report of Major Putnam, and I have become more specifically interested in the thing in connection with the answers to questions that have been asked in

this trial. I do not realize that there would be no comparison between the polluted condition of the Chicago River which has obtained under the jurisdiction of the War Department for the last thirty years; and what would obtain if complete sewage treatment were installed at Chicago with no diversion. My understanding is that with complete sewage treatment and no diversion, the pollution in the Chicago River would be lessened. I have
11433 not seen the pictures that were introduced in evidence of the pollution in the Chicago River. I never have been on the Manchester Ship Canal. It is one of the important canals of the world. I do not know whether the water in that canal is composed entirely of the flow from sewage works at Manchester with treatment of only 33⅓%. I understand there has been successful naviga-
11434 tion there. I said the controlling works at or near the northern terminus of the Sanitary Canal would impede through navigation. It would be one more lock and
11435 would probably delay a boat there a half hour, 30 to 40 minutes. The navigation contemplated there under the project is about 9,000,000 tons; so a half hour's delay would be quite a serious matter. There are 50 locks on the Ohio River and 15 on the Monongahela, but the bulk of navigation comes in the lower half of that river and goes through not to exceed seven of them. However, the largest and most successful river navigation in the United States is on the Monongahela. As to whether one less lock would increase the quantity of navigation, it would save whatever delay that amounts to, reducing the cost
11436 of transportation, which would in turn affect the cost of the product.

11437 Referring to Defendants' Exhibit 1406, being an airplane picture of Chicago, there is a black appearance.

I don't know of my own knowledge, but if there was sewage effluent from activated sludge plants only, I would imagine that the dark portions showing the river on the picture would be lighter, and if you get this amount of water in there, then it will be better for navigation. I
11438 don't understand that the effluent from activated sewage purification plants is dark like this.

"Mr. Jackson: Assuming that it is perfectly clear.

The Special Master: And sparkling.

Mr. Jackson: And sparkling is right. Odorless, I was going to say.

The Witness: I think it is, but I am not sure about it.

By Mr. Jackson:

Q. If we assume that it is—

A. Assume that it is clear, yes.

Q. And non-putrescible, it would be greatly superior for navigation to the condition that you have in Chicago now, would it not?

A. I am not sure about that. Do you not get into the question of quantity there? If you get a larger amount of that and do not dilute it properly, and hold it for several days, my understanding is that it gets pretty bad."

Assuming that the effluent from an activated sludge plant is clear, odorless and contains no suspended matter, and also stays odorless indefinitely, I do not see that it would be an objection to navigation. If it simply cannot do any harm, then it cannot do any harm, but it is my understanding that there is still material in the effluent that may become obnoxious.

Cross-Examination by Mr. Adcock for Defendants.

11441 In Document Number 4, page 3, Complainants' Exhibit 18, there is one assumption where there is an expenditure provided for of $3,465,000 for the improvement of the Illinois with a diversion instantaneous maximum of 6,050 cubic feet per second and an annual diversion of 4,167 second feet, an open channel improvement. In making my answer to Mr. Jackson's question as to the project now provided for by Congress, I considered that Congress left it up to us to determine the best plan for getting a channel 9 feet by 200, provided that we were not to expend more than $3,500,000. I considered that plan among others when the plan we were working on was
11443 adopted. I did not select that one as being the one that I thought was best for us to take.

I am referred to paragraph 4 of Document 130, 69th Congress, 1st Session, which follows paragraph 3 I mentioned in the cross examination by Mr. Jackson. This paragraph is as follows:

> "4. The following recommendation, embodying the above proposal, is accordingly submitted:
>
> 'The board recommends modification of the existing project for the Illinois River so as to provide a channel with least dimensions of 9 feet in depth at the low water and 200 feet in width, from the mouth to Utica. Under present conditions of low water flow, the provision of such a channel, by dredging and by the partial removal of the two State dams and the retention and minor alteration of the two Federal locks and dams, is estimated to cost $1,350,000, with $126,000 annually for maintenance. Future re-
> 11444 duction in the flow would involve additional expenditures. It is understood that Congress, if it approves this recommendation, will thereby have authorized the department to undertake any works covered by the estimates in the table on page 3 of House Document 4, Sixty-ninth Congress, first session, which

may be necessary in the future to provide a channel of the dimensions specified, and will have authorized the necessary expenditures therefor, up to a limiting total for new work of about $3,500,000. The above recommendation is subject to the following conditions: That the State of Illinois transfers to the United States, without cost, all rights and titles in the two State-owned dams on the Illinois River; that local interests furnish the United States without cost all necessary areas for the economical disposal of material dredged in creating and maintaining the channel: Provided further, That no work on the Illinois River shall be carried out according to the project herein outlined, with the existing or any subsequent diversions, until the Secretary of War and the Chief of Engineers shall have received satisfactory assurances that local interests will at the same time provide an equal depth for through navigation in the Illinois waterway.' ''

11445 I took that paragraph into consideration in answering Mr. Jackson's question, but that was not the determining point. However, we did endeavor when we were selecting the projects, in accordance with the authority of Congress, to consider practically everything that we had reported to Congress on the subject. That gave us a great variety of projects, and we considered that the best one for us to adopt under that authority was neither the one that Mr. Jackson has mentioned nor the one that you have listed, but it is fairly similar to it. It is not far removed from the one that you have listed, namely, the one that I mentioned first. It is the one substantially shown on page 3 of Document 4, 69th Congress, 1st Session, 10th item, State dams out, instantaneous maximum diversion Lockport cubic feet per second 6,050, average annual diversion at Lockport cubic feet per sec- only 4,167. We consider further that that is not expected to cost the full $3,500,000; that the Department would be

11446 free to modify that plan if it thought best, provided it did not exceed the expenditure of $3,500,000.

11447 That project includes in general the retention of the Campsville and LaGrange locks and the removal or opening up of the Copperas Creek and Henry Dams, and a considerable amount of excavation. We are leaving the Campsville and LaGrange locks substantially as they are. We have already opened the Copperas Creek and the Henry Lock. We have already made I think it is four large contracts for excavating, as contemplated by the project. The work is proceeding under some or all of those contracts.

"Mr. Jackson: If I correctly understand, we are not trying the issue as to whether there is any contention of subsequent authorization of Congress for any diversion in the Illinois River.

The Special Master: No, I don't understand that there is any subsequent authorization—just one of the acts of 1927. Am I right about that?

Witness: You are right, yes, sir, as I understand it."

11448 Defendants' Exhibit 1413 received in evidence, being Document Number 417, 69th Congress, 1st Session, H. R., entitled "Pollution Affecting Navigation or Commerce on Navigable Waters."

It was submitted on June 4, 1926, to the Committee on Rivers and Harbors by the Chief of Engineers, and was made pursuant to Section 9 of what is known as the Oil Pollution Act of Congress. Section 9 is as follows:

11450 "Sec. 9. That the Secretary (of War) is authorized and directed to make such investigation as may be necessary to ascertain what polluting substances are being deposited into the navigable waters of the United States, or into non-navigable waters connecting with navigable waters, to such an extent as

to endanger or interfere with navigation or commerce upon such navigable waters or the fisheries therein; and with a view to ascertaining the sources of such pollutions and by what means they are deposited; and the Secretary shall report the results of his investigation to the Congress not later than two years after the passage of this act, together with such recommendations for remedial legislation as he deems advisable: Provided, That funds appropriated for examinations, surveys, and contingencies of rivers and harbors may be applied to paying the cost of this investigation, and, to adequately provide therefor, the additional sum of not to exceed $50,000 is hereby authorized to be appropriated for examinations, surveys, and contingencies of rivers and harbors."

In the first part of the report there is the following statement:

"Polluting substances which are being deposited directly or indirectly into the navigable waters of the United States or into non-navigable waters connected therewith, may be divided into two general classes: (A) Domestic sewage; (B) Industrial wastes."

On page 11 of the report there is a table entitled "Navigable Waters of the United States and Non-Navigable Waters connecting therewith into which Polluting Substances are being Deposited to such an Extent as to Endanger or Interfere with Navigation, Commerce or Fisheries." The table is divided into different columns. The first column gives the city or locality, second is entitled "Waterway," the next one is entitled "Principal Sources of Pollution," the next one is entitled "Effect on Commerce or Navigation," the next one is entitled "Effect on Fisheries." The table shows 127 harbors or waterways, of which all are polluted either with domestic sewage, industrial wastes of various kinds or both. The column

headed "Effect on Commerce and Navigation" does not indicate any effect from such pollution on commerce or navigation in 102 of these harbors or waterways. The nature and extent of the interference on commerce or navigation on the other 25 harbors or waterways, are shown in the following excerpts from said table;

Locality	Waterway.	Principal Sources of Pollution.	Effect on Commerce or Navigation.
New York City, Harbor and Bay	Lower Hudson River, East River, Harlem River, Bronx River, Gowanus Creek, Newtown Creek, New York Bay (upper and lower) and Flushing Bay	Domestic sewage; industrial wastes of many kinds from factories, chemical plants, gas plants, ship repair yards, oil from storage plants, refineries, distribution plants and shipping (739 million gallons of sewage per day and 48,500,000 gallons trade wastes per day in 1920).	Sewage sludge causes shoaling of creeks, bays and slips. Is removed by the municipal agencies. Pleasure boating interfered with. Oil creates potential fire hazard.
New York Harbor	Kill Van Kull and Arthur Kill	Domestic sewage; industrial wastes from oil refineries, asphalt and chemical plants.	Pleasure boating eliminated. Oil creates extra fire hazard.
New York Harbor	Newark Bay, N. J.	Domestic sewage; industrial wastes, oil tar, etc.	Pleasure boating curtailed.
"	Hackensack River, N. J. and tributaries	Domestic sewage; industrial wastes from oil refineries, gas plants, pulp mills, soap factories, etc.	Pleasure boating curtailed. Oil creates a potential fire hazard.
"	Passaic River, N. J., and tributaries	Domestic sewage; industrial wastes of many kinds, particularly oil and tar wastes.	Pleasure boating curtailed. Oil creates a potential fire hazard.
"	Elizabeth River, N. J.	Domestic sewage; industrial wastes from gas plants, asphalt plants, etc.	Pleasure boating eliminated.
"	Rahway River, N. J.	Domestic sewage, industrial wastes, oil, tar, asphalt, chemicals.	Pleasure boating curtailed. Oil creates extra fire hazard.
"	Raritan River and Bay, N. J.	Domestic sewage, industrial wastes, oil, acids, dyes, etc.	Pleasure boating interfered with.
Keyport, N. J.	Keyport Harbor, N. J.	Domestic sewage, industrial wastes from Raritan Bay.	Pleasure boating curtailed.
Philadelphia, Pa. to mouth	Schuylkill River	Industrial wastes, oil and tar.	Fire hazard to shipping.
Above Philadelphia	Schuylkill River and tributaries	Domestic sewage, industrial wastes—culm acid mine drainage.	Culm deposits cause shoaling. Dredging done by private canal companies.

Pittsburgh, Pa. to Portsmouth, Ohio	Ohio River	Industrial wastes from mine drainage, washeries, steel mills, creameries and tanneries.	
Pittsburgh, Pa.	Upper Ohio River, lower Allegheny River, Monongahela River, Youghiogheny River and tributaries	Domestic sewage. Industrial wastes from metal trades, coal mines, oil wells and refineries, paper mills and tanneries.	Injurious to metal hulls, boilers and metal navigation structures.
Akron and Cleveland, Ohio	Cuyahoga River	Domestic sewage; industrial wastes from packing houses, steel mills, tanneries, asphalt plants, chemical plants, paint factories, oil refineries and rubber reclaiming plants.	Oil endangers shipping in Cleveland Harbor.
Detroit and Dearborn, Mich.	Rouge River, Mich.	Domestic sewage, industrial wastes of many kinds.	Deposits cause shoaling which interferes with commerce unless removed.
Gary, Ind., and vicinity.	Calumet River, Little Calumet, Grand Calumet and tributaries	Domestic sewage, industrial wastes from steel mills, chemical plants, refineries, gas plants, etc. (Total 493,520,000 gallons per day.)	Causes shoaling; interferes with pleasure boating.
Chicago and vicinity	Lake Michigan	Domestic sewage; industrial wastes of various kinds (198,850,000 gallons per day).	Causes shoaling in Calumet and Indiana Harbors; deposits removed periodically by local authorities.
Chicago, Ill.	Chicago River and branches	Domestic sewage; industrial wastes from packing houses, tanneries, chemical plants, metal trades, gas plants, etc. (total 727,765,000 gallons per day).	Sewage sludge causes shoaling which necessitates dredging periodically.
Northern Illinois	Illinois River, Ill.	Domestic sewage, industrial wastes of many kinds (total from sources on Illinois River 61,106,200 gallons per day; total including tributaries, 1,448,552,700 gallons per day).	Some shoaling caused by deposits; pleasure boating interfered with.
Joliet and Northeastern Illinois	DesPlaines River, Ill., and tributaries	Domestic sewage, industrial wastes (total from sources on DesPlaines River, 11,228,000 gallons per day; total discharging into DesPlaines River from all sources 1,336,346,500 gallons per day).	Pleasure boating interfered with

11472-h Page 23 of said report contains the following:

"The subject of pollution of waterways is one that is engaging the active attention of State and municipal governments throughout the United States. The investigation clearly indicates an awakened interest and an earnest desire to meet and overcome a condition which through lack of adequate control in the past has been permitted to exist and grow until public opinion has become generally aroused."

Page 24 contains the following:

"2. The pollution of waterways affects not only the fisheries therein but also the public health, sports, and various forms of outdoor recreation. The waters are used by the general public for domestic, commercial, industrial, recreational, and other purposes.
11472-i They have been used for the disposal of domestic and industrial wastes since the settlement and industrial development of the United States began. What constitutes the highest and most economic use of a waterway aside from its use as a public highway of commerce is a problem the solution of which involves a study of local conditions and the proper adjustment of the various conflicting interests of the locality. The growth and industrial development of a locality may depend upon the use of its streams for economical disposition of its domestic and industrial wastes; and should the pollution of streams in such a locality be prohibited, the future development of the section might be seriously impaired. As a general rule the value of the products of the fisheries is small as compared to the total value of the products of all the industries which use the waters for other purposes. The problem therefore resolves itself into a determination of the use of each waterway which will result in the greatest benefit to the community. It is believed that should the Federal Government undertake the control of pollution generally there might be a tendency on the part of State and local authorities to relax their efforts to study the problem and to enforce local laws, with the result that the entire problem would be left to the Federal Government, which would be confronted with the ne-
11472-j cessity for providing a large organization to cope with the many local problems which would arise."

On page 26 there is the following statement from said report:

"3. In general the injuries caused by polluting substances in non-tidal waters do not, except in the Pittsburgh area, directly affect commerce or navigation in the sense of making more difficult or expensive the movement of water carriers, the handling and transshipment of freight, or the creation, operation, and maintenance of navigable channels. The direct injury resulting from pollution in nontidal waters is rather to the public health, to fish, and other wild life, animal and vegetable, and to outdoor forms of recreation, such as bathing and boating, together with the land and property values which depend thereon.

"4. Water-borne commerce and navigation may be held to be indirectly affected on this latter basis, for in a sense they are affected by almost any important activity of the public.

"From the point of view of the indirect effects of pollution on commerce and navigation arising from the direct effect on the public health, fisheries, and recreational activities. I am not prepared to state whether Federal legislation is justified on the basis of the interstate commerce clause of the Constitution, this being a matter of legal construction. I do consider that the pollution of non-tidal waterways is a matter of interest and concern to the body politic and should be dealt with in some manner by the Nation, by the States, by municipalities, or by public opinion.

"5. Oil pollution directly endangers commerce and navigation at some of the larger seaports and one of the lake ports by reason of fire hazard resulting from the accumulation of oily discharges on the surface of the water and on wooden wharves, piers, etc. It fouls boats and equipment. The Federal Government has already asserted an interest in this kind of pollution by the enactment of the oil pollution act, 1924. However, that act applies only to the discharge of oil from oil-burning or oil-carrying vessels.

"8. While at present there appears to be only

one port on the Great Lakes in which oil pollution is sufficient to endanger commerce, nevertheless, due to the importance and extent of this commerce and the probable increase in the number of oil-burning and oil-cargo vessels, oil refineries and terminals, pollution from this source may increase unless con-
11472-l trolled."

On page 25 the said report contains the following statement:

"B. COMMERCE AND NAVIGATION

"1. The direct injuries resulting to commerce and navigation from the discharge of polluting substances into the navigable waters of the United States, or into their non-navigable tributaries, are in general restricted to:

"(a) Chemical action on steel hulls, or other parts of vessels, and upon the metal parts of locks, dams, or other navigation structures. This is due to acids from mine drainage and washery wastes, and from the effluent of industrial plants engaged in the manufacture of steel and steel products. Serious injury from this source appears to be restricted to the vicinity of Pittsburgh.

"(b) Sewage sludge and other substances in suspension may cause the shoaling of channels in overpolluted and restricted waterways. These deposits are as a general rule satisfactorily removed by local agencies responsible for the pollution, before interference with commerce or navigation.

"(c) The creation of a fire hazard by oily discharges.

11472-m "This appears to be limited at the present time to tidal waterways in the vicinity of New York, Philadelphia, and Galveston, and to the Great Lakes Harbor at Cleveland."

Document 4, Complainants' Exhibit 18, contains the following statement:

"13. The question turns essentially on the phrase 'capable of treating the sewage.' The question is, what degree of treatment is to be considered satis-

factory? The discharge from any form of sewage-disposal works capable of application to a great city like Chicago is an undesirable addition to a river; that is, it will decrease the purity of the river water. Depending on both the form of treatment adopted and the flow of the river, the effect may in the general case be anything from a very slight tainting of the water, quickly disappearing to a gross and even dangerous nuisance. It is wholly a matter of degree.

11472-n

"14. To give any specific answer, therefore, the department was forced to assume some arbitrary standard. That followed was one which would assure that there should be no appreciable nuisance in the Illinois or DesPlaines River due to Chicago sewage. Based on this assumption, a report was obtained from a firm of expert sanitary engineers, which estimates certain sewage treatment works necessary with certain diversions to produce the required result; these figures, and some additional ones, are submitted by the district engineer. If the works should be made somewhat less efficient or the diversion decreased, or both, some nuisance would presumably develop. How much nuisance, defined as above, the authorities are prepared to tolerate is a matter beyond the knowledge or purview of the board. It is also to be noted that, even with Chicago's sewage satisfactorily handled, there would still be a material nuisance in the river due to other sources of pollution.

"15. It appears that treatment for a 1945 population to give the desired degree of purity can be handled by a suitable combination of the activated sludge method, Imhoff tanks, and trickling filters for diversions as great as or greater than 4,167 second-feet (annual average). For a diversion somewhat less than 4,167 second-feet (the exact figure has not been determined) it would become necessary to have recourse to sand filtration. Treatment can thus be provided for diversions at least as low as 1,000 second-feet. For zero diversion it would be necessary to deliver the effluent into Lake Michigan. The district engineer's report contains cost estimates for

11472-o

the various methods. The cost increases rather slowly as the diversion decreases to the point (somewhere below 4,167 second-feet) where sand filtration becomes necessary, then it increases more rapidly."

* * *

"34. It is evident that any program of sewage treatment should look to restoration of better conditions in the DesPlaines and upper Illinois River. Almost universally, public sentiment is rapidly forming against further pollution of streams and is going to require the removal of most of it as soon as practicable. For this reason, in planning the necessary works for the Sanitary District of Chicago, it was felt wise to assume that a material improvement of conditions in these streams would be one of the objects to be attained, and accordingly an investigation was directed along the lines of determining a reasonable pollution standard.

11472-p "35. The consulting engineers are of the opinion that no appreciable nuisance will result if the following standard is maintained:

> 'The liquid discharged by the drainage canal, as evidenced by the average of representative samples taken for any 30 consecutive days, shall (a) be practically free from solids deposited in two hours; (b) shall contain not less than three parts per million of oxygen and enough to equal or exceed the biochemical oxygen demand of said liquid for five days when incubated at 20 degrees C.'

"Whether adherence to this standard will produce exactly the results desired or not is unknown, but in view of the present extremely unsatisfactory conditions prevailing with upward of 4,000 cubic yards of settleable solids being dumped into the Illinois each day, and with periods of several months each year with no oxygen whatever present in the effluent, there is no question but what conditions will be improved materially. It should be understood that other sources of pollution are contributory to the Illinois River, and that with no contamination whatever from the Sanitary District of Chicago conditions in the Illinois will not be satisfactory until the rest of

the communities now discharging their sewage into the system carry out satisfactory sewage treatment
11472-q programs of their own. It so happens that the adoption of a standard that no appreciable nuisance will result carries with it the restoration of conditions which will permit fish life to thrive.

* * *

"38. The consulting engineers are of the opinion that no methods of sewage treatment known to be practicable will maintain the pollution standard unimpaired if the gross average flow at Lockport is as low as 2,000 cubic feet per second. The combined oxygen demand on the effluents from plants providing the most complete practicable treatment known is considerably in excess of the supply available in 2,000 cubic feet per second. For small-scale operations, sand filtration has been known to provide practically 100 per cent treatment, but the consulting engineers doubt the efficacy of this method on as extensive a basis as would be required for Chicago's sewage, particularly with practically no diluting water available as a factor of safety."

* * *

"46. The results of this study are decidedly contrary to a continued diversion of 10,000 cubic feet per second. On the other hand, they do not favor programs of reduction which result in final diversions as low as 3,000 cublic feet per second or lower (annual averages). The conclusions drawn indicate
11472-r that the resources of the Nation, capital, fuel, and labor, will be conserved to the best advantage by reducing the gross annual average diversion to 4,167 cubic feet per second, or thereabouts, by the year 1935, and maintaining it at that point thereafter."

* * *

"56. An annual average diversion of 4,167 cubic feet per second involves no difficulties in the way of provision of adequate sewage treatment at Chicago. Average diversions materially less than this amount will require the adoption of sand filtration on a large scale, or disposal of effluents in Lake Michigan, either of which methods might not prove successful."

General Jadwin, continuing:

11472-r *Cross-Examination by Mr. Adcock for Defendants.*

I read this from Document 4, Complainants' Exhibit 18, 6,050 c.f.s. continuous diversion and 4,167 c.f.s., as if I were saying something on a par with the physical features of the project and with the cost. I don't consider that these figures are formally adopted in the same way
11472-s that I do feel we are authorized to construct the works, and our selection of them I understand to be perfectly definite, legal and proper. It does follow, however, that there is a larger diversion than this amount coming now, and the question as to what water should be diverted is not acute from the point of view of a navigation project there in that sense. Congress did say positively that it was not adopting any diversion that precluded us from establishing as a legal diversion 4,167 or any other legal diversion, but it did leave us, subject, of course, to further action of Congress, or subject to the decree of the Supreme Court or any court that would have jurisdiction, to let an amount of water go down there under permit, or if not a formal permit, to an amount that would produce 9-foot navigation, until and unless it is definitely changed by order of the Court or Congress. If we are barred from that by the Supreme Court, that would be one thing. We could not change the amount, the exceptional amount that would fit into that project properly, until there is some order of Congress. Congress is perfectly free to make it anything it wants to above or below, provided they give us money to change the works accordingly. We have so constructed the works to bring
11472-t about practically a minimum of cost if there is a change. If Congress wants to make it smaller, they can add locks. The two locks with dams now are old and inefficient. If they want to have a larger diversion they

can have us remove the Campsville and LaGrange locks. If Congress wants a smaller diversion, it would probably accomplish it by adopting a project which would order us to build more locks and dams. Part of the channel is canalized, and part is an open flow, which would practically result in turning all or almost all of it to get the lowest diversion, into an entirely canalized channel.

I was asked if I was familiar with Document 417, being the report on pollution of navigable waters. In answer I said that I am aware of its existence, as I was in the chain of command when it was prepared. I know there is such a paper and I have known some parts of it, certain phases of it were before me when it was being prepared; but I have not all of it thoroughly in mind at
11472-u present. It has been a long time since I have seen it. It was prepared when Gen. Taylor was Chief of Engineers and I was Assistant Chief.

As to the action taken by the Chief of Engineers in connection with the sewage pollution of New York Bay by the Passaic Valley Sewerage Commissioners in 1910, with reference to the purification of the sewage so that it would not be offensive to navigation when discharged into the New York Bay, I haven't the details of that in mind, but I do know of such a case. I know something about it and I think on one occasion subsequent to that I acted in the chain of command on some of the details of the work at the outlet. My understanding is that there was a case of this kind and that it was finally settled by the introduction or the establishment of works which made the output so that it was deemed at the time it would be unobjectionable, but I would ask that not very much stress be laid on that without giving me opportunity to verify it from the record. It seems to be questionable.

It was my understanding that this 85% purification

under the program left the residual of 15% of organic matter which would substantially represent the raw sew-
11472-v age of 15% of the population treated by these purification plants. That is, it purified it 85% and left the equivalent of 15% of the material in there.

I do not know of my own knowledge whether the sewage purification works at storm times take only a volume equal to 150% of the ordinary sewage flow and whether the balance spills untreated into the channels of the Chicago River or of the Canals of the Sanitary District. I think I have heard a statement made by one of my assistants to that general effect, but I do not recall the percentage, whether it was the 150 that you speak of. I think I recall that one of my assistants advised me that there was a part of the raw sewage dumped into the river on such occasions.

The following is from paragraph marked "B" of my testimony yesterday:

11473 "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."

means:

"What we mean by that is that, as the diversion is decreased, the ratio of the effluent to the pure water is relatively increased. The more diversion we have, the better the effluent is handled. The less fresh diversion we take, the higher the percentge of effluent there is."

At another place yesterday I made the following statement:

"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 prac-

tically 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."

I meant in the foregoing statement that for a flow of zero or 1,000 or 2,000 second feet annual average at Lockport, it would be necessary after each storm to take water from the Lake in order to discharge the polluted water into the channels. Otherwise it would work in and out.

11475 "Q. And that would be objectionable to navigation?

A. I do not think that I have said that, Mr. Adcock.

Q. Well, I will withdraw that.

A. We were answering that question and trying to give the physical conditions without going into the question of whether that amount.

Q. (Interposing) If you did not go into that, I will not ask you about it.

A. All right."

I have made no calculation as to the amount of water that would be required to be withdrawn from the Lake to displace that storm water after the storm had ceased,

11476 to prevent that alternation, but I have already indicated that it is almost impracticable to prevent that alternation with any of those small diversions. You have to go up, as I remember it, to something like 6,000 c.f.s. or more.

When I stated yesterday:

"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,"

in speaking of "none of the control works," I included both the control works that might be built at the mouth of the Chicago River and those that might be built at the northern terminus of the Canal.

In using the words:

"considerable amounts of water other than storm water,"

11477 I intended to embrace in that expression sewage effluent. There would also be required water from the lake to push this other water along.

Re-cross Examination by Mr. Jackson.

With no flow at Lockport, and control works at the northern terminus of the canal, the effluent would go into the lake except in time of storm or immediately before or after. The entire discharge would probably amount to 1,000 c.f.s.

Complainants' Exhibit 249, about which General Jadwin was interrogated on cross-examination, being Report of Board of Engineers for Rivers and Harbors, June 16, 1926, is as follows:

COMP. EX. 249.

SENATE

60TH CONGRESS *1st Session* — DOCUMENT No. 130

REPORT OF BOARD OF ENGINEERS FOR RIVERS AND HARBORS

LETTER FROM THE CHIEF OF ENGINEERS, IN RESPONSE TO A LETTER OF THE CHAIRMAN OF AND A RESOLUTION OF THE COMMITTEE ON COMMERCE DATED JUNE 14, 1926, SUBMITTING A REVIEW OF ITS REPORT PUBLISHED IN RIVERS AND HARBORS COMMITTEE DOCUMENT NO. 4, SIXTY-NINTH CONGRESS, FIRST SESSION.

JUNE 16 (calendar day, JUNE 17, 1926.—Referred to the Committee on Commerce and ordered to be printed.

WAR DEPARTMENT,
OFFICE OF THE CHIEF OF ENGINEER,
WASHINGTON, June 16, 1926.

Hon. W. L. Jones,
Chairman Committee on Commerce,
United States Senate.

MY DEAR SENATOR: 1. Referrring to letter of the chairman of the Committee on Commerce of the

United States Senate, dated June 14, 1926, inclosing a copy of a resolution of the committee dated June 14, 1926, requesting the Board of Engineers for Rivers and Harbors to review its report, published in Rivers and Harbors Committee Document No. 4, Sixty-ninth Congress, first session, with a view to clarifying its recommendations, I inclose herewith the report of the board, dated June 15, 1926, in response thereto.

2. The board states that it was not its intention to commit the Government in any way regarding the legality or permanency of the existing diversion. It calls attention to the specific statement in paragraph 22 of its report printed in House Document No. 4, "that it would be premature definitely to fix the diversion at this time."

3. The board states that if it is felt that the former recommendation of the board might be interpreted as fixing any permanent diversion, a solution may be found in changing the recommendation so as to propose that a project for a channel 9 feet by 200 feet be adopted, and that the department be definitely authorized, not only to provide it for existing conditions of low water flow, but also, and without further reference to Congress, to continue to provide it, by suitable changes in the works of improvement, if the low-water flow be reduced within the limits contemplated by the table on page 3 of House Committee Document 4, Sixty-ninth Congress, first session. The estimates in that table assume that the works corresponding to a given estimate are undertaken *ab initio*. On that basis a limiting authorization figure would be $2,666,000, the estimated cost of providing the channel by canalization with the least flow contemplated in the table. If, however, the low-water flow should be reduced by successive steps, and at each step certain works had to be provided appropriate to the then existing flow, the necessity might arise for modifying some part of the work in a manner which would somewhat increase the ultimate cost. The amount of such increase cannot be accurately estimated, since it is unknown at what rate and by what steps the flow may hereafter be re-

duced; but it is estimated that the cost under such conditions might reach $3,000,000 or $3,500,000.

4. The following recommendation, embodying the above proposal, is accordingly submitted:

The board recommends modification of the existing project for the Illinois River so as to provide a channel with least dimensions of 9 feet in depth at low water and 200 feet in width, from the mouth to Utica. Under present conditions of low water flow, the provision of such a channel, by dredging and by the partial removal of the two State dams and the retention and minor alteration of the two Federal locks and dams, is estimated to cost $1,350,000 with $126,000 annually for maintenance. Future reduction in the flow would involve additional expenditures. It is understood that Congress, if it approves this recommendation, will hereby have authorized the department to undertake any works covered by the estimates in the table on page 3 of House Document 4, Sixty-ninth Congress, first session, which may be necessary in the future to provide a channel of the dimensions specified, and will have authorized the necessary expenditures therefor, up to a limiting total for new work of about $3,500,000. The above recommendation is subject to the following conditions: That the State of Illinois transfers to the United States, without cost, all rights and titles in the two State-owned dams on the Illinois River; that local interests furnish the United States without cost all necessary areas for the economical disposal of material dredged in creating and maintaining the channel: *Provided further,* That no work on the Illinois River shall be carried out according to the project herein outlined, with the existing or any subsequent diversions, until the Secretary of War and the Chief of Engineers shall have received satisfactory assurances that local interests will at the same time provide an equal depth for through navigation in the Illinois waterway.

5. After due consideration of the above mentioned report, I concur with the board.

H. TAYLOR,
Major General, Chief of Engineers.

WAR DEPARTMENT,
THE BOARD OF ENGINEERS FOR RIVERS AND HARBORS,
WASHINGTON, D. C., June 15, 1926.

Subject: Illinois River.

To: The Chief of Engineers, United States Army.

1. This report is submitted in response to the following resolution, adopted June 14, 1926:

Resolved by the Committee on Commerce of the United States Senate, That the Board of Engineers for Rivers and Harbors be, and hereby is, authorized and requested to review its report, published in Rivers and Harbors Committee Document No. 4, Sixty-ninth Congress, first session, with a view to clarifying its recommendation.

2. The letter of the chairman of the Committee on Commerce, transmitting the above resolution, contained the following paragraph:

It is the understanding of this committee that in submitting its report, the Board of Engineers for Rivers and Harbors did not intend to make any recommendations which would have any bearing upon the question of diversion and if such be the case, it would be well if the board could so revise its report as, to make this matter clear beyond question.

3. It was not the intent of the board, in its recommendation contained in its previous report, to commit the Government in any way regarding the legality or permanency of the existing diversion. It recommended certain work in the Illinois River, estimated at $1,350,000 to obtain a channel 9 feet by 200 feet from Grafton to Utica, and pointed out that, if existing conditions were changed, corresponding changes in the cost of providing the channel would result. The board submitted a series of preliminary estimates based upon various assumed diversions, from 1,000 cubic feet per second to 10,000 cubic feet per second (annual average measured at Lockport). It compared these estimates, with the resultant national benefits which it appeared would arise from a through 9-foot channel from Chicago to Grafton, and found that the cost of the navigation project was reasonable on any of the bases investigated.

4. The board also referred to the various interests affected by diversion of water from Lake Michigan. It found that these were important, and in some cases conflicting, and that all the data were not at hand accurately to evaluate them. It therefore gave its view (par. 22) "that it would be premature definitely to fix the diversion at this time."

5. If it is felt that the former recommendation of the board might be interpreted as fixing any permanent diversion, a solution may be found in changing the recommendation so as to propose that a project for a channel 9 feet by 200 feet be adopted, and that the department be definitely authorized, not only to provide it for existing conditions of low-water flow, but also, and without further reference to Congress, to continue to provide it, by suitable changes in the works of improvement, if the low-water flow be reduced within the limits contemplated by the table on page 3 of House Committee Document 4, Sixty-ninth Congress, first session. The estimates in that table assume that the works corresponding to a given estimate are undertaken *ab initio*. On that basis a limiting authorization figure would be $2,666,000, the estimated cost of providing the channel by canalization with the least flow contemplated in the table. If, however, the low-water flow should be reduced by successive steps, and at each step certain works had to be provided appropriate to the then existing flow, the necessity might arise for modifying some parts of the work in a manner which would somewhat increase the ultimate cost. The amount of such increase cannot be accurately estimated, since it is unknown at what rate and by what steps the flow may hereafter be reduced; but it is estimated that the cost under such conditions might reach $3,000,000 or $3,500,000.

6. The following recommendation, embodying the above proposal, is accordingly submitted:

The board recommends modification of the existing project for the Illinois River so as to provide a channel with least dimensions of 9 feet in depth at low water and 200 feet in width, from the mouth to Utica. Under present conditions of low water flow, the provision of such a channel, by dredging and by

the partial removal of the two State dams and the retention and minor alteration of the two Federal locks and dams, is estimated to cost $1,350,000 with $126,000 annually for maintenance. Future reduction in the flow would involve additional expenditures. It is understood that Congress, if it approves this recommendation, will thereby have authorized the department to undertake any works covered by the estimates in the table on page 3 of House Document 4, Sixty-ninth Congress, first session, which may be necessary in the future to provide a channel of the dimensions specified, and will have authorized the necessary expenditures therefor, up to a limiting total for new work of about $3,500,000. The above recommendation is subject to the following conditions: That the State of Illinois transfers to the United States, without cost, all rights and titles in the two State-owned dams on the Illinois River; that local interests furnish the United States without cost all necessary areas for the economical disposal of material dredged in creating and maintaining the channel; provided further, that no work on the Illinois River shall be carried out according to the project herein outlined, with the existing or any subsequent diversions, until the Secretary of War and the Chief of Engineers shall have received satisfactory assurances that local interests will at the same time provide an equal depth for through navigation in the Illinois waterway.

For the board:

EDGAR JADWIN,
Brigadier General, Corps of Engineers,
Senior Members of the Board.

Pursuant to conference between counsel and the Special Master, it was agreed that the defendants on the re-reference should proceed initially with the offering of evidence and testimony.

Thereupon the program of the Sanitary District for sewage treatment works was presented by various witnesses substantially as set forth in the Master's Report on Re-reference at pages 6 to 17, both inclusive.

The program of defendants as testified to by witnesses and appearing in exhibits will not be repeated in this abstract, but only such portions of the testimony and evidence will appear as are required for consideration of the exceptions filed by both parties.

Where the qualifications of witnesses have been stated sufficiently by the Master in his Report on Re-reference, they will not be repeated in this abstract.

March 1929—at Chicago.

Langdon Pearse, on behalf of Defendants:

Chief Sanitary Engineeer of Sanitary District of Chicago. Testified in former hearings in 1927.

9860 This program that I have outlined is somewhat more extensive than that outlined in 1926, by the addition of a large number of intercepting sewers required by the change in policy of consolidation, by the addition of certain collateral intercepting sewers, in an endeavor to pick up all the sewage practically possible, in order to follow out, as the engineers understood it, the instructions of the Supreme Court. Thus some sewers have been provided which we had heretofore considered might be omitted for many years to come, which additional sewers re-

lieve small areas and small parts of the river such as the slips and other light areas of sewage that would go into them from small sewers. These additional interceptors will cost several millions of dollars which were not originally contemplated and would probably have been omitted with a larger diversion.

9873 The purpose of the installation and placing in operation of various treatment plants, is to provide what we call complete treatment of the sewage and industrial wastes originating in the Sanitary District of Chicago and entering its waterways; that is, the greatest practical degree of treatment. The works when installed will not provide 100 per cent purification of the sewage. 100 per

9874 cent purification is not practical. Practical degree of purification is 85 per cent. At times on monthly averages it may be 90 or even 92 per cent for activated sludge process.

The interceptors in general are planned along the lines indicated of bringing to the plants the dry flow, with the addition of storm water of 50 per cent to 60 per cent.

9890 According to defendants' program, the effluent of the North Side Works will go into the North Shore Channel immediately east of the plant; of the West Side Works will be into the Main Channel West of 52d Avenue; the Southwest Side Plant into the Main Channel almost directly south of the West Side Works; and of the Calumet Works, into the Calumet Sag Channel at a point just west of the controlling works at Blue Island, its eastern terminus.

9891 By effluent, I mean the sewage after it has undergone the treatment provided in the plants, whether it be tanks and trickling filters or activated sludge process. It is the liquid that comes from the plants and is discharged into the channel. Sludge is a term defined as the solids separated out from the sewage in the treatment processes. It is a mixture of solids and water, varying in consist-

ency from the activated sludge, which may have 98 to 99% of moisture; to the Imhoff tank sludge that may be of 83 to 87% of moisture, probably nearer 87 than the lower figure.

The sludges contain both mineral and organic matter. The organic matter in the activated sludge will be higher in nitrogen than with the Imhoff tanks. That is the reason why in our Southwest Side Plant we have included a plant for the preparation of activated sludge for its sale as fertilizer, to take advantage of the higher nitrogen content of that portion of the total sludge of the
9892 District.

The sludge in some instances is to be disposed of on land, for which the Sanitary District has reserved an area west of the West Side Works and immediately north of the Main Channel. That area lies between the Des-Plaines River and the Channel, and is largely unsuitable for other purposes. It is rocky and rough. The area consists of about 900 acres. We do not expect to dispose of it with the moisture content that it has when it comes from the tanks.

The sludge will be flowed out of the underbodies of the tanks and pumped by an air ejector to the drying beds, where it will be exposed from one to two weeks, drying down to 45 to 60% of moisture, and then it will be stripped from the beds and loaded into dump cars and taken away.

9893 This sludge is of a porous material, resembling somewhat loam in the garden, with a certain amount of peaty characteristics, and the material can be dumped in piles of upwards of 20 feet deep and handled by a dragline at the side of the dump, and eventually will consolidate.

The Calumet sludge will continue to be dumped for some time at the north end of the property where the plant is located, but it will be necessary ultimately to provide other areas.

This program contemplates the discharge of all these effluents with the storm water down the rivers and channels of the Sanitary District, ultimately to reach the Des-Plaines River just above Joliet, and then pass to the Illinois and Mississippi Rivers, and I assume that in
9894 laying out this program there would be controlling works of some type placed at the mouth of the Chicago River or near the northern terminus of the Main Drainage Canal, to prevent any discharge of sewage or effluent from the sewage works, or storm water into Lake Michigan from the Chicago River.

When I have spoken of 85% treatment, there is a balance of 15% which represents 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. This statement is based upon a test of the reduction of the biological oxygen demand.

9895 I hesitate to express a definite opinion as to the exact reductions that can be made in the diversions of water from Lake Michigan during the period of construction because of the size of the problem and the unknown features concerning the effect on the waterways of the residual suspended matter that may come from the plants in the 15% purification that cannot be reached; the overflows from the sewers and oil and other matter that may reach the river from different sources. I believe such reductions should be predicated upon the work as accomplished when the treatment works are completed and put into operation, and that a period of observation and definite reduction can then be determined.

The period of completion of the works is a subject now of judgment, and the effect of the works when completed

likewise, to such a degree that I feel that a direct opinion is very speculative.

9896 In the operation of the works, while data are available to tell what the probable effect will be of this sewage reaching it, the question will come in the result of the effluent on the waterways of the District and the setting forth of the residual flows that must be allowed to take care of those effluents. That will differ in actual accomplishment, in winter and in summer, according to the condition of the seasons, each year, and will differ in the plants to some extent themselves. And it will differ with the number of storms each year.

Cross Examination by Mr. Jackson.

9899 The program which I have proposed is based on the discharge of the effluents and storm water into the Mississippi River watershed, and such diversion of lake water in addition thereto as might be necessary to keep up a standard suitable for the purposes of navigation in the Port of Chicago. If the sewage effluent is to be put into the Lake, there would have to be added, in my opinion,

9900 extensive chlorination of all these effluents, and if the storm water discharge is to go into the Lake also at all times, as well as sewage effluents, there immediately comes up as part of the problem, whether it be done by the District or the city or some other agency, the protection of the water supply, the changes in tunnels, the operating of filters, and other matters, in order to make the result as a whole of the same degree of effectiveness to the community as we have attained, or contemplate, as regards sewage treatment and the protection of the water supply.

9903 There are those two alternatives available in the sense that they are alternative plans for the disposal of the sewage of the Sanitary District. I do not personally re-

gard them as equally effective because I believe that the first plan for discharge of the sewage treated, and storm water in addition, into the Mississippi Valley watershed, is more effective in protecting the water supply, bathing beaches and the other uses of the water along the front of the City of Chicago.

If, however, that was not permitted, then the discharge of the effluents and storm water would go into the Lake, and as such it is an alternative plan. It will, however, in my opinion, destroy the use of certain bathing beaches. It is quite likely to cause foul conditions in the so-called Harbor of Chicago off Grant Park and cause other local disturbances of that character which do not arise in the other plan. Further, it necessitates the expenditure of a
9904 greater sum of money by the community.

I think that the water supply for the city will eventually be filtered, regardless of whether the sewage is diverted from the lake or not; but if the sewage be not diverted from the lake, the filtration works would probably have to be more extensive and necessarily more complete, because of that factor of added pollution which would have to be taken care of in their design.

If the metering of the water produces a reduction in the use of the water, the metering of the water would make a saving to the city both in the cost of operating the present water works and in the cost of any proposed filters. My opinion is that the metering will reduce the water consumption. It will undoubtedy reduce the consumption in certain quarters of the city and that will be beneficial in reducing operating expenses.

Nothing passes through the sewage treatment plants but sewage from the area tributary. In my opinion, the plan that I have outlined 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.

If the effluent goes to the Lake, it is important to consider what should be done then for the purpose of purifying the water for drinking purposes.

9909 The first element in the problem is the full treatment of the sewage.

I cannot say that if the total domestic water supply of Chicago were metered so as to reduce the water consumption per capital to 160 gallons stabilized, how much that would reduce the normal dry weather flow of the Sewage Disposal Plants in c.f.s., because I have never made the calculation and would not attempt to. It would probably reduce the flow per capita to the plants. Exactly how much is a hard matter offhand to estimate
10166 without study of all the factors involved. It would be necessary to relate the effect of the water supply to
10167 other flows that come into the sewers, and which of those vary, on each of the projects, and I would not care to express an opinion other than that I have indicated, that the flows will be reduced. I do not think it is entirely fair to assume a ratio of reduction from 220 to 160 per capita, because that would depend on what other elements are in each of those sewers as increasing the amount of water, and other factors that come in. The water supply is somewhat varying. I do not carry in my head the proportion for these different parts. That is why I will have to calculate the amount of the reduction coming to the plants, assuming a reduction of water consumption from 220 to 160 gallons per day. I have not applied the design con-
10169 dition of 220 gallons per day water supply, but the estimate of the sewage flow was in the design at the plants. That is the reason I have been explaining to you that if you desired the information, I would be glad

to make a calculation based on the data on which the designs are made. I told you that one of the plants was designed in this program for 250 gallons per capita daily sewage flow.

To determine the relation of the sewage flow per capita to the per capita consumption of water, it would be necessary to get the basis of the design in order to see what we had allowed on that particular area for the water.

10170 If the water supply were metered, and assuming that the plants are designed now to treat 850 c.f.s. of the storm flow above the dry weather flow, the metering of this water supply would permit a greater amount of the storm flow to be treated. How much, I have not computed.

10171 It is not entirely true that there would have to be a rain with a runoff in excess of 1,000 or 1,200 second feet, assuming metering, before there would be any storm water overflows, because that will depend on the actual volume traveling in the sewer at different seasons of the year. In so far as the capacity is available in the sewer to carry the storm water, there will be no overflow. The intercepters will take more than the plants, as of 1945. I have not made any calculation of how much less dry weather flow we would have if there were complete metering. We have made stud-

10172 ies on various assumptions of what might happen, assuming various gallonage that might occur, and we are still trying to get at the probability of what gallonage will occur.

10281 The distance between the northern and southern limits if the Sanitary District is approximately 36 miles. The width of the territory of the Sanitary District is about 15 miles. You may have in this area a rainfall which will cause an overflow from the sewers into the river

and might not at the same time have rainfall which would cause overflow of all the different outlets throughout the area of the Sanitary District. The extent of storms over the whole area is subject to variation. I have come to the office in the morning from my home where we have had a smart storm upon the North Shore in Winnetka,
10282 and found that men living on the South Side reported no rain.

Harrison P. Eddy, recalled, for Defendants.

(A Sanitary Engineering Expert, testified on former hearings in 1927.)

9911 *Direct Examination by Mr. Adcock.*

9930 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
9931 River or at the head of the Drainage Canal. Whether or not there can be early reduction of the diversion or a reduction in the diversion during the period of construction, depends upon what shall be the criterion. The conditions at the present time are by no means sanitary, either in the canal or down the river. If the basis be that there should be no improvement in those conditions due to diversion of water, in other words, that the sanitary conditions be maintained in status quo, then it might be possible to make a reduction in diversion in proportion to the population, and the population equivalent of industrial wastes for which treatment is provided from time to time.

9932 I do not believe it is practicable at this time, before these works are completed and in operation, to determine the exact amount of reduction that should be made from

time to time as the different units in this program of construction are put in operation. Neither is it practicable to specify definitely with relation to the time of completion as by dates, because that is an indeterminate thing. It would be possible to specify a reduction in accordance with the population provided for in treatment plants as and when completed. In reaching the above conclusion as to the reduction during the period of construction, I am taking into consideration the interests of public health and the maintenance of navigation.

9933 With complete treatment of all the sewage, the quantity of water required to provide waters in the Port of Chicago suitable and attractive to navigation, is a very difficult and impossible thing to estimate with accuracy. It can be determined from time to time after the works have been put in operation. And in my judgment it would be wise to have that determined from time to time by a properly authorized and qualified person. That is, some 9934 person appointed by the court who has had experience and who can observe the operation for a reasonable time and from his observation conclude what actually should be done.

The discharge of the effluent from the various works to be completed under the program 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 intensity as the distance from the mouth of the river increased, due to the dilution and oxidation which would take place in 9935 the waters of the Lake. And in reaching the above conclusion, I assumed that the storm water would be discharged to the DesPlaines River, and that the effluent

from purification works in dry weather time would flow into the Lake.

10294 I have made a study as to the standard that water should be in order that it may be reasonably free, easy and unobstructed, so far as navigation is concerned. I have studied the Canal system of the Sanitary District, the waters into which the effluents from the treatment plants and the storm discharges will flow. I have made some estimates of the velocity of flow at different points; the time taken for the water to flow from the treatment plants to various other points. I have taken into consideration the temperature and the dissolved oxygen of the lake water if used or diverted for purposes of making the effluents and the waters in the Canal system suitable for navigation. I have considered the conditions which surround such waters in a community of this kind, the use of the waters and the application of the conditions to navigation. I have drafted several conditions which seem to me to be or represent a reasonable standard for these waters for navigation.

10295 The *first* is that the water should be practically free from visible suspended particles of sewage matter coming from sewage treatment plants.

2, the water should be practically free from oil, grease, color and suspended matter.

3, the water should not be obnoxious or offensive to, or injuriously affect the health of passengers and persons employed on vessels or other property used in connection with navigation.

4, the water should not create odors of putrefaction of organic matter.

5, the water should not be of such composition as to result in an excessive growth of water plants.

6, the water should not cause discoloration of paint on, or otherwise injure, vessels and equipment or other property employed in connection with navigation.

7, the water should contain at least three parts per million of dissolved oxygen.

10296 My reasons for each one of those elements mentioned are:

10296-A With respect to visible suspended sewage matter coming from treatment plants, my thought in that is that there should be nothing coming from the treatment plants which would be recognizable as of sewage origin to give offense to sight; that the suspended matter should not be present in such form as to be noticeable or visible in the waters, which would mean that large deposits of suspended matters might result from the presence of such matter in the water.

With respect to freedom from oil, grease, color and suspended matter, my reason for the reference to oil is partly because of its effect upon the paint and the appearance of vessels, partly on account of the odor, and partly on account of the danger of fire.

It is more or less common to have oil discharged on to waters in harbors and waters frequented by large numbers of boats or vessels in a port of this kind. There have been serious fires, and in my judgment the conditions here ought to be such as to preclude that possibility in so far as practicable.

Grease on the surface of the water is objectionable. It is certain to reach the water at certain times from dis-

10297 charges of storm flow. I do not think it will reach the waters with the effluents from the treatment plants so as to be objectionable, but it is unsightly; it collects on boats and on piers. It decomposes and causes more or less odor.

Suspended matter should be practically absent in the sense of being present in such quantities as to form objectionable deposits which would create a great demand for dissolved oxygen.

Suspended matter must be discharged into the waters from the plants and also from the sewers at time of storm overflow. But in my judgment they should not be present in sufficient quantity to cause serious deposits. They will cause some deposits.

I should have said in connection with oil that oil is certain to come from shipping itself, from the runoff over the surface of the ground as well as from storm discharges.

With reference to the third point, the waters should not be obnoxious or offensive to, or injuriously affect the health of passengers and persons employed upon vessels. Men are obliged to work on the vessels. They are obliged to work on piers, in slips, and any offensive or obnoxious condition will be objectionable to them and will in my judgment affect the general problem of navi-
10298 gation. Passengers are not invited to embark and disembark under conditions of obnoxious and offensive odors. I think the waters would not be attractive to navigation under those conditions.

The waters should not create odors of putrefaction of organic matter. That is somewhat similar to the previous point, but applies more particularly to the actual decomposition of the organic matter which will exhaust the dissolved oxygen and create the offensive and obnoxious odors to which I have referred, which may also come in a measure from grease and oil which reaches the waterways.

The waters should not be of such composition as to result in an excessive growth of water plants. In my judgment it is going to be very important to so operate

these treatment plants as not to produce conditions which will encourage a prolific growth of water plants. It is possible to operate plants of either type, either the activated sludge or the trickling filter, in such a way as to turn out effluents with very large quantities of nitrates present. Those nitrates are the source of plant food and the plants grow in enormous quantities. They die after a short period. They decompose in much the same manner as any other organic matter, and tend to deplete the supply of dissolved oxygen.

10299 It is, therefore, in my judgment advisable to so operate the plants as to produce a minimum of nitrates. This applies particularly, of course, to the warmer season of the year. During the winter, spring and the late fall that is not material. But during the warmer season of the year, from the first of June perhaps until the end of October, the nitrates should be kept just as low as is practically possible.

The water should not cause discoloration of paint on or otherwise injure vessels and equipment or other property employed in connection with navigation.

It is a more or less common experience in navigable waters which are seriously polluted to have hydrogen sulphide produced by the decomposition of organic matter, and paint, light colored paint on vessels and other property turned dark color or even black under some conditions. I consider that that would be a detriment to navigation.

The water should contain at least three parts per million of dissolved oxygen.

There must be dissolved oxygen if there are not to be putrefactive and offensive and obnoxious conditions. Under some conditions I would expect it would be advisable

10300 to have a larger portion than three parts per million,

but under these conditions I am assuming that the volume of water drawn from the lake can be varied more or less from time to time and that three parts per million of dissolved oxygen, which represents only thirty per cent of the saturation value of the water during the warm season is a sufficient margin of safety and is no more than is necessary to assure satisfactory conditions.

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 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.

10301 The effluents from the plants will contain dissolved oxygen. I should assume during warm weather that possibly five parts per million would be present in the effluent, but this material which I speak of, although it seems very small as is expressed in parts per million, and a very small proportion of that originally present, yet in the aggregate from a community of this size, it is an enormous production of suspended matter, for the decomposition of which oxygen must be supplied if putrefactive conditions are to be avoided.

The nitrates in this effluent cause the growth of algae and other water plants. They should be kept as low as possible, and the plants can be efficiently operated so as to avoid a large proportion of nitrates. Assuming

10302 efficient operation, the nitrates could be kept between one-half of one part and perhaps one and one-half parts with an average during the warm season of about one part or less of nitrates. Any proportion of nitrates will accelerate the growths of water plants. A low proportion of nitrates such as I have suggested will tend to minimize that difficulty. On the other land, with that low nitrate, the reduction in the original organic matter in the sewage will not be quite as great, and some oxygen will be required to prevent putrefactive conditions under that method of operation. But in my judgment that will produce the least demand for oxygen from water, if any be available by diversion from the lake.

In the event the effluents from these sewage purification plants provided for under the Sanitary District program are discharged through the Canal and the Des Plaines River, there will be required some water from the lake in order to maintain the standard which I have suggested as necessary for navigation in the waters of the Port of Chicago.

10303 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 cubic feet per second 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.

The 2,000 cubic feet per second I mentioned would be from the lake and exclusive of the effluent which came from the treatment plants. That is, that 2,000 second
10304 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 runoff, and such water as is drawn from the ground or other sources for industrial purposes, which is probably a large amount. 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.

10305 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.

10307 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.

10308 I explained in my earlier testimony that the volume of water now being abstracted is not adequate to preserve, or to provide sanitary conditions; and that this series of quantities which I am about to give is predicated simply on a proportionate reduction from the present 8500 cubic feet per second, in accordance with the progress in the program of sewage treatment.

The first reduction I suggest for Jan. 1, 1930 is 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; and under those conditions in 1930 the reduction would be from 8500 c.f.s to 6500 c.f.s.

10309 The next date I have set is January first, 1936 which is the date for complete treatment at the Calumet plant. At the West Side plant there will be, then, sedimentation for the entire tributary population; that is all the sewage which is produced and which ought to go to that plant is receiving treatment by sedimentation. The North Side plant will provide complete treatment for the entire tributary population. The Southwest Side plant will provide sedimentation for all of the sewage of that district, produced within that district. At that time I think the flow could be reduced to 4500 c.f.s. The next stage would naturally be when the flow dropped—when

complete treatment is provided. There might be a small drop, a decrease for a very short time, between the completion of the West Side plant, and the Southwest Side
10310 plant. I have not figured that.

The entire program should be completed by the end of 1944, in which time I am allowing two years for unexpected and unforeseeable delays. I have actually set down the figures as closing at the end of 1942. My estimates and figures are based on controlling works being in place to prevent back-flow into the lake. It would
10311 be necessary to have those controlling works installed as soon as the amount of diversion was less than would be required to protect the lake from the storm flow. The figures I have given are based solely upon the progress of the treatment of the sewage. The flow ought not to
10312 be reduced until the controlling works are in, which applies to January 1, 1930, and I do not think it is possible to install the controlling works by that time. If there are no controlling works, then on January 1, 1930, the present amount of 8,500 c.f.s. diversion is necessary. That amount will be required to prevent reversal of flow into the lake. I should think it would take at least two and possibly three years to install controlling works. The work of building the treatment plants will go on at the same time. Assuming that controlling works were installed, and that it took two years to install them, my estimate of a diversion of 6,500 c.f.s. on the basis I have
10313 stated, would be applicable to January 1, 1932. If the reductions I have mentioned were made, the conditions in the river would be maintained substantially as they are now. The diversions I have mentioned would not be sufficient to cause an improvement in conditions down the river.

In naming the 2,000 c.f.s. to be diverted from the lake as necessary when this construction program is com-

pleted and in operation, I took into consideration the conditions of navigation in the Port of Chicago only. I did not take into consideration what additional water might be required to maintain conditions suitable for navigation in the DesPlaines or Illinois Rivers or the waterways of those rivers. As to that subject I testified in 1927.

10314 May I amplify my answer on the question of the ultimate quantity of water? I did not state, I think, that that 2,000 c.f.s. is based upon the population as of 1945. Taking that into conisderation, the diversion is equivalent to one-third of a cubic foot per second, per thousand persons, based upon the human population, and the industrial wastes equivalent population. I think one-third of a cubic foot per second is 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.

It is my judgment that it would be better to fix the amount of reduction after these different works are put in and there has been an opportunity to observe the effect of the operation.

I have made the best estimate that I can; but there are so many undetermined and undeterminable factors in the problem that I think it would be wise, if practicable, to allow that to be determined after the works are in operation.

Cross Examination by Mr. Jackson.

I don't know that the standard of quality of water for navigation that I stated as required in the Port of Chicago obtains in any other harbor on the Great Lakes. There is navigation there, but I don't know whether the

10318 navigation is free, easy and unobstructed. If the standard which I set up for the quality of water for naviga-

tion is adopted as the standard, I don't know that navigation in any harbor of the United States on the Great Lakes is not free, easy and unobstructed. I don't know that all harbors on the Great Lakes are subject to the vicissitudes of storm water overflows and runoffs. I do know, however, that some of them have storm water discharges into them. I should think in Detroit that storm water overflows are discharged and dumped into some one else's river and carried away from the port or harbor. It is also true of Buffalo that the storm discharges go into a river and the water carries it away from the harbor. The storm water from Detroit is diverted from the watershed very efficiently and effectively, being carried in a swift river of about 2½ feet per second ve-
10319 locity. Detroit is in the watershed of the Detroit River.

10428 **Horace P. Ramey,** recalled, for Defendants.

Direct Examination by Mr. Adcock.

I am assistant chief engineer of the Sanitary District, which is the same position I occupied when I testified last in 1927.

Plans were first submitted for controlling works at the mouth of the Chicago River to the War Department in November, 1927. I testified on January 13, 1927 (Rec. 3642) that at that time plans had been submitted.

10434 I have made calculations of the average rainwater runoff of the Chicago River Drainage Area in a state of nature, and what it would be if the City of Chicago were not here. The natural runoff for the Chicago River Drainage Area is about 193 c.f.s. annual average. I applied the increase of 14 per cent to the square mile
10436 in the Chicago River Watershed that are sewered, giving us an increase of 63 c.f.s., or a total of 256 c.f.s. as

of today, average annual. Sometimes the runoff would be up as high as 10,000 or 12,000 c.f.s., quick runoff depending on the intensity of the rainfall. I have made a calculation of the rain water runoff of the Little Calumet River that would be diverted to the Calumet Sag Channel under the program of the Sanitary District with reference to providing for complete purification of sewage in that region, and the discharge of the effluent and storm waters. The runoff in a state of nature under such conditions of the tributary Little Calumet River Watershed is 273 c.f.s. average yearly. Under present conditions such runoff would be 287 c.f.s.

Defendants' Exhibit 1397.

The pumpage of the Chicago Waterworks System in 1854 was .91 c.f.s. and increased yearly to 465 c.f.s. in 1899. The pumpage for the years 1900 to 1926, both inclusive, is shown by the Master's Original Report, pages 22-23. The pumpage for the years 1927, 1928 and 1929 was 1421, 1565 and 1625* c.f.s., respectively.

10491 *Cross Examination by Mr. Jackson.*

10497 The capacity of the Calumet Sag Channel is 2,000 second feet.

The capacity of the Wilmette Pumping Plant is 1,000
10498 second feet. The 39th Street Pumping Station was designed for a capacity of 2,000 c.f.s. lake water. Those pumps, however, have not been operated in some years. With the lake at zero and flood over the whole area, the capacity of the Main Channel above the Sag is 8,000 c.f.s.

*NOTE: Domestic pumpage for Villages and Towns within Sanitary District not obtaining water supply through the Chicago Waterworks, about 60 c. f. s. additional.

10513 **Major R. W. Putnam,** for Defendants.

Direct Examination by Mr. Adcock.

Reside at Riverside, Illinois; am consulting engineer in connection with river and harbor and other maritime engineering works; was educated at the United States Military Academy at West Point, graduating into the Corps of Engineers. After two years instruction at the United States Army Engineers School at Washington,
10514 D. C., in river and harbor and other engineering works, I had military experience in the Corps of Engineers in this country and abroad, up to 1921, when I became United States District Engineer at Chicago, and so remained until 1926. From the summer of 1926, for the next year and a half, I was engaged by the Commercial Club of Chicago in a survey of the water transportation in the Chicago region, with a view to working out a plan for future terminal arrangements to take care of the growing traffic by water in this district. Since that time have been in private consulting practice in connection with harbor construction, intakes, dredging, harbor planning, etc. Have been in the Engineer Corps since 1913, when I graduated from the Military Academy. I was
10515 United States Engineer at Chicago when the permit of March 3, 1925, was issued. I made studies of navigation conditions at Chicago. I made a report for the Commercial Club with reference to harbor conditions.

If controlling works are located in the Drainage Canal or the Chicago River between the mouth of the Chicago River and some point in the Drainage Canal east of Crawford Avenue, I believe they can be so operated as not to
10516 hamper the interests of navigation materially. That storm water may be kept out of Lake Michigan providing there was a flow at other times towards the Des-Plaines River through the Drainage Canal.

I am basing my conclusions on the present conditions of navigation, that is, between the mouth of the Chicago River and the Chicago Drainage Canal near Crawford Avenue, and also upon my views as to the future situation with respect to the development of water transportation on that branch of the group of waterways here as related to port development there or elsewhere.

10518 The question of transportation on the Chicago River or any portion thereof is complicated by the fact that it is a part of a system of harbors, canals, and rivers at the southern end of Lake Michigan, which can not be considered separately, or individually, in any problem such as transportation, but must be considered collectively when we wish to evalulate the effect of any such proposition as is contemplated in controlling works on commerce.

In the study prepared for the Commercial Club of Chicago, I considered the present and future navigation problem as it was affected by or would affect the lake front harbors in this vicinity, from Racine, Wisconsin, on the north, to Michigan City, Indiana, on the east, including the lake front harbors in between those points of which there are nine, Racine, Kenosha, Waukegan, Chicago, South Chicago, Indiana Harbor, Buffington, Gary and Michigan City.

Several of the harbors referred to are interconnected by rivers and canals, thus forming a complete system of port facilities, which, as I stated before, must be considered collectively in matters relating generally to navigation conditions in this vicinity, or specifically as to navigation on any portion thereof.

The Chicago harbor, for instance, is utilized by lake
10519 steamers carrying largely package freight and passengers. It is at the mouth of the Chicago river, which

has been improved by the United States Government, and is also used by lake steamers carrying freight and passengers, the navigation on the Chicago river being carried on by lake steamers carrying all classes of freight, and the Chicago river also being navigated, with its river and canal connections.

The Chicago river in turn leads into the Drainage Canal, which reaches to the navigable waters of the Des-Plaines and the upper Illinois.

South Chicago and Calumet Harbor are located at the southern limits of Chicago, within the city limits of Chicago, and are improved and maintained by the United States for the accommodation of ships serving the large industries located there, and actually is the more important harbor development in the Chicago region as measured in terms of tons, received and shipped, some 10 million to 15 million tons of commerce being shipped and received in that section.

The Calumet river for a distance of six miles has been improved by the United States, and at the end of this improvement we find the Forks of the Grand Calumet, or the junction of the Grand Calumet river with the Little Calumet river, both of which are considered navigable waters of the United States, the Grand Calumet
10520 river having been improved as far as the city of Hammond, some years ago.

The Little Calumet is now navigable in fact between the end of the Government improvement, some six miles inland, to Blue Island, where the Sag Canal is intersected, and with that Sag Canal we have connection with the Drainage Canal, forming a belt system of connecting waterways between the Chicago harbor and the Calumet harbor.

About six miles to the southeast of the Calumet har-

bor is the Federal improvement known as Indiana Harbor, an artificial port development, consisting of a breakwater, anchorage basin, and canal, serving large industries located on the banks of the canal, and at the mouth of the canal.

This development ranks second in importance of those in the Chicago region, and its commerce is rapidly growing.

The inner end of the Indiana Harbor canal has a connection with the Grand Calumet river, which, as I stated previously, also joins the Little Calumet river, and through the Little Calumet the interior system of belt canals previously referred to.

It is apparent that the system is quite complex, and yet very related and complete.

The published commercial statistics show that the
10521 combined water-borne commerce of the seven public harbors varies between 15 and 20 million tons annually, with a value of 300 million to 400 million dollars. The passenger traffic for these public harbors amounts to about 1,400,000 annually, and showing over a million passengers arriving and departing from the terminals in the city of Chicago.

Gary and Buffington are private harbor developments, and their commerce is composed largely of ore and limestone, and is of considerable importance so far as the tonnage movement is concerned.

In addition, there is an intra-belt movement on the Drainage Canal, and in the Chicago river, amounting to from 500,000 to 600,000 tons annually. This is composed of petroleum products from the Texas Refinery on the Drainage Canal, and shipped to different places on the Chicago river. It is composed of stone for building and material purposes, and some package trade that is lightered back and forth.

This commerce does not get to the lake front, but is confined to the Chicago river.

In round numbers, allowing for such divergence as might occur, the total freight—water-borne traffic in the Chicago region at the present time varies from about 20 million tons to 25 million tons annually, with a value of between $400,000,000 and $500,000,000.

10525 I would consider the port of Chicago as consisting of those navigable waters which are so connected physically and so inter-related commercially and industrially as to form a complete unit from a transportation point of view, water transportation point of view. To be specific, that would include Waukegan harbor, Chicago harbor, Chicago river and its branches, the Chicago Drainage Canal, the upper Desplaines river, the Sag Canal, the Calumet river and its branches, the Indiana Harbor canal and Indiana Harbor, Gary and Buffington Harbor.

The zone known as a unit for industrial and commercial transportation, is the Chicago metropolitan district, or the Chicago region. It includes Waukegan on the

10526 north, Joliet on the west and Gary on the east. These points are all connected by the Outer Belt Line and offer equal transportation from a rail point of view, which has its bearing on the question of water transportation. Within this area the switching rates are uniform.

10527 If all discharge to the DesPlaines River ceased now, a situation would be produced in the Chicago River and its branches, the mouth of the Chicago River, the waters of Lake Michigan adjacent thereto, the waters connected with the port in South Chicago, unfavorable and detrimental to navigation.

10528 In the first place, take the Chicago harbor. Most of the passenger traffic, all of the passenger traffic is handled by passenger boats either at the Municipal Pier on

the lake front or the mouth of the Chicago River just east of the Michigan Boulevard bridge.

Passenger traffic on lake steamers out of Chicago is entirely or almost entirely of a recreational nature. That makes it peculiarly susceptible to unfavorable conditions such as rough weather, or under the assumption, unsanitary conditions, unsightly or unsavory situations in the water, and the pollution resulting from immediate shut-off of water into the Desplaines River would, in my estimation, be reflected in a very marked decrease in passenger transportation.

Now, these passenger transportation boats are also package freight carriers, and any effect on one portion of the business of the combination boat will be reflected
10529 in the total advantage of the boat operators and the operations involved, and in such way will unquestionably, in my mind, interfere with the package freight business.

Then, still assuming the present conditions, as I take it, we would have, in my estimation, effects which occur from pollution that would tend to increase the wages of those engaged in construction of harbor works, construction of piers, affecting labor and the wages of crews, tugs and harbor craft operating continuously in those waters.

I believe that the present shutting down of flow into the Desplaines River would result in sufficient sludge content to interfere seriously with the operation of vessels as regards their boilers and feed water systems and condensing equipment and so on, and might possibly
10530 result in serious conditions in the mechanical operations of the boats as a consequence thereof.

Assuming that by the year 1940, 1941, 1942 or 1945 all of the sewage waste within the limits of the Sanitary

District were treated to 85% purity, and that the 15% residual would be the same practically as raw sewage of a population representing 15% of the total population served by the treatment works, that the population of the Sanitary District with its industrial equivalent would be 6,500,000, that the effluent from these sewage purification works would flow into the lake at all times, together with storm flow and raw sewage that might be discharged from the sewers during storms, I think we would have the same adverse effects as far as naviga-
10531 tion is concerned, including oil pollution in addition. By oil pollution I refer to the quantities of oil in the Chicago River resulting from leakage from oil-burning boats, Diesel engine boats and tank barges and every possible source, which would create a fire hazard of considerable importance. The effect would be along the lines I have mentioned with respect to stopping the flow at the present time. In other words, briefly, the nuisance factor would affect passenger transportation and the wages of operators of boats, labor engaged in har-
10532 bor works, and so on.

A flow of less than 4,000 second feet in the river and Drainage Canal to the DesPlaines will affect adversely the future coal movement in these waterways. The consumption of coal by the plants of the Commonwealth Edison Company, being the principal user of coal, is entirely dependent upon their size, which in turn is limited by the amount of water in the Chicago River available for condensing purposes.

10535 There is only pleasure craft now that would be shut off from passing from the Chicago River to the Sanitary Canal into the DesPlaines River if there were no discharge to the DesPlaines River. There would be no means of getting the pleasure craft into the DesPlaines

without water. Each time that you lock a boat through, it would take that amount of water out. That would not be enough to change the flow back from the lake.
10536 As far as present navigation is concerned, on the present Illinois River, the low water flow is ample for lock-
10537 age. The depths would be sufficient with the discharge
10538 to the DesPlaines cut off. There would be insuffcient depths in the Illinois River below Utica with the diversion cut off, that is, for flotation of the navigation now
10539 operating. The natural low water flow is somewhat in the neighborhood of 400 second feet or thereabouts. That spread over the bottom of the bed of the river does not give a depth of 6 feet or more which the present
10540 boats require. The present commerce on the Illinois River below Utica consists of pleasure commerce, pleasure boats, and also boats using that river for commercial purposes.

10542 *Cross Examination by Mr. Jackson.*

The Chicago and Calumet Harbors are connected through the Chicago River, Chicago Drainage Canal, Sag Canal, the Little Calumet River and the Calumet River. A small vessel would not go around by the lake. A large
10543 one would. You would have to have pretty nearly a row-boat to go around the other way.

The following from page 40 of Complainants' Exhibit 18, Document Number 469, is a correct statement:

> "There are 12 movable bridges over this improved part of the Calumet River. The narrowest bridge draw is 60½ feet in width, and as there are five draws narrower than 90 feet in width barge floats could not operate to advantage except in single column. In view of the existence of fixed bridges with available head room of 16½ feet over the Sag channel neither river towboats nor standard channel cargo barges of the Mississippi River type could get

into the Calumet River, except by way of the Chicago River and Lake Michigan, so that their use is practically out of the question now."

10544 and that statement is true so far as the standard general cargo barges of the Mississippi River type and towboats are concerned.

In 1927 there was no commerce between the Calumet Harbor and the Chicago River by way of the Calumet Sag Channel. That is true of 1928.

Indiana Harbor is interconnected with the Chicago and Calumet Harbors by way of the Indiana Harbor Canal to the Grand Calumet River. The westerly part of the Indiana Harbor Canal has been turned back by the Gov-

10546 ernment and its improvements abandoned. I have described all of the harbors which are physically interconnected by interior waterways, and there is no commerce between them.

Chicago sewage has no appreciable effect upon navigation of the harbor at Gary, Indiana. The same is true of the harbors of Buffington, Indiana Harbor and Waukegan so far as involves the waters, but not the ships. This sewage affects the commerce between those ports and the Chicago River but not the waters in the

10547 harbors mentioned. There is no commerce between Gary and Chicago River at present, and consequently there is no effect upon present commerce. The difference in the relationship so far as water navigation is concerned between Chicago and Waukegan and the relationship between Waukegan, Racine and Kenosha, is a matter of railroad service as connected with the port operation. The relations between the ports are affected

10548 by sewage in the Chicago River. There is lake commerce movement between Waukegan and Chicago, such as package freight and passengers; probably 20,000 and 30,000 tons per year of package freight. Sewage in the

Chicago River affects the operation of boats on those
10549 waters, regardless of where they come from or where they go. About 2½ million tons a year of the commerce from Waukegan to Gary in all of these ports is carried on the Chicago River. I have a definite recollection as to this up to 1926. My approximation was based on a recollection of a 5-year period. In this 2½ million tons of freight I am including traffic that comes to the lake front but does not enter the river. I have not the figure for the river itself for that is not reported separately.

I know of no case of any disease contracted by a boat passenger or employee from navigating water contain-
10550 ing sewage plant effuent. I don't know that the wages
10551 of seamen or other persons are higher on "Bubbly Creek" than elsewhere. The wages of dock hands at the Municipal Pier are not less than those on the river.

I would not say that the traffic on the Chicago River steadily and sharply declined from the date of the opening of the Drainage Canal for many years, substantially in the same ratio as the quantity of water taken from the
10552 lake increased. The traffic did not decline for several years after the Drainage Canal was opened, when there was some other cause which brought that about. Not to my knowledge has the enticing condition of the Chicago River been a controlling factor in the amount of navigation on the river from 1890 to date. I think it would be a factor in the future.

I understand that sewage at Milwaukee was formerly all discharged untreated into the river there, and that in the last year or two it was carried at normal times to
10553 a sewage disposal plant. The wages of the river men at Milwaukee have not decreased since that time. I did not find that there was a marked increase in navigation and traffic in the Milwaukee River after sewage was

taken out of it. I did not investigate the phase of the question as to whether there was trouble to vessels navigating the Port of Milwaukee due to the discharge of the effuent all in one spot at Jones Islands at the Milwaukee Harbor entrance. It might have given me broader information.

There is some pleasure boat traffic down at Utica. The condition of the river at Utica has been bad, from a pollution standpoint. The pleasure boating, such as
10554 there is, at Utica, is entirely through traffic. There is no other way for these pleasure boats to go from Lake Michigan to the Mississippi except by way of these polluted waterways. Therefore it is a case of necessity, so far as they are concerned.

10555 I have not figured at all any length in the neighborhood of the mouth of the Chicago River to which the present or future pollution would extend, but I don't think there is much doubt but that the question of length is entirely one which would show that the distance in the Illinois River would be longer than the distance of the pollution in the mouth of the Chicago River. I do not think the reduction of 2,000 c. f. s. diversion would
10556 have any effect on navigation on the Chicago River. I don't think the reduction of 3,000 c. f. s. would have much effect. I will qualify that statement, however, by an exception as regards storm flow.

The following statement from Complainants' Exhibit
10557 18, page 21, is correct:

> "As far as the requirements of navigation are concerned, no additional flow is necessary from Lake Michigan during flood stages on the Illinois River other than required for lockages at Lockport, and not any is necessary during the winter months when the season is closed to navigation."

That statement applies, of course, to the Illinois River.

The following statement from page 37, Complainants' Exhibit 1, November 1, 1923, is correct:

> "There has been practically no current in the river * * * in its original condition. As a result, navigation was comparatively simple where ample depth and width of channel existed. The introduction of current in the river by the Sanitary District has been a distinct disadvantage. While current may not exceed one and one half miles per hour, there are places and times where currents of three and four miles an hour have been observed.
>
> "Sometimes a large vessel gets caught in one side of the draw of a swing bridge, and becomes un-
10558 manageable as a result of the current. Vessels have been known to collide with each other or with the fenders of bridges or dock walls. For the same reason there is a damage of an indefinite valuation which is directly chargeable against the Sanitary District."

The following statement from Complainants' Exhibit 1, pages 59 and 60, is correct:

> "As far as the navigation of the Chicago River and the Drainage Canal is concerned, if the flow at Lockport were entirely throttled, and the powerhouse gates closed, so as to permit no diversion from Lake Michigan, conditions would be decidedly improved. The current which now averages one and a half miles per hour in some bridge draws is as high as four, and would be practically eliminated, making navigation therefore simpler, and especially for the larger vessels, whose passage through a narrow drawbridge is apt to increase the current materially."

There was no Federal project for navigation between
10559 LaSalle and Utica up to 1927. I don't know whether work has actually been done or not on that stretch. The work has been authorized.

10560 The pleasure boat traffic at Utica would be subject to a degree of pollution. I think a layman would be able to detect it. Pollution would discourage that traffic,

which would be reflected in an actual decrease. If the diversion were reduced the depths would be less at Utica but not sufficiently less to affect pleasure boats. I am referring to the reduction of 2,000 second feet in diversion that is, from 8500 to 6500 second feet. The reduction of 2,000 second feet would not affect the traffic right at Utica, because it utilizes the Illinois and Michigan Canal; but if you are referring to the traffic going by Utica, the effect of such a reduction would be in the lessening of depth in the Illinois River after you leave the Illinois and Michigan Canal. 4½ feet is the present depth of water in the Illinois and Michigan Canal. That has not obtained con-
10562 tinuously for the last five years. The reduction of 2,000 second feet in the present diversion would have a tendency to decrease the passenger boat traffic at Utica. I don't know whether there was less tarffic in 1925 and 1926 when the total flow at Lockport was 8250 c.f.s. than there was this last year. When you say I haven't anything to base my opinion on, I state that I have, as a person who has actually navigated this water in pleasure boat craft, and I have had my own personal reaction in reference to that. I navigated these waters in
10563 1923. A reduction of 2,000 c.f.s. would put the conditions back to what they were in 1923, 1924 and 1925, when diversions were lower than they are now.

The lock at Lockport has been operated for yachts-
10564 men, pleasure boat people, who desired to make the through trip. I don't know how many times it was operated. I would say not over 100 or 200 times a year. I doubt whether there were that many. These are gasoline launches. The draft was not six feet. A 6-foot launch could not get through there.

I know of eight operations of oil burning boats worthy of mention, operated on the Chicago River. The boats as I remember them are—Carson, Pirie, Scott operates

10565 a Diesel tug; constant daily service. Great Lakes Dredge & Dock operates three or possibly four Diesel tugs, large size. The United States Government operates three or four vessels burning oil. The construction Materials Company has a large Diesel electric barge in operation. The Manitowoc Portland Cement Company has a Diesel-driven cement boat making regular stops at this port, and there is a boat just launched that will be down here shortly that will also ply these waters, utilizing Diesel engines.

The following harbors on the Great Lakes are free from any sewage or sewage effluent in the navigating channels: Duluth, Superior, Ashland, Wisconsin, and Manitowoc, Wisconsin, Calcide, Michigan, possibly Fairport, Ohio. These can be classed as comparatively free
10566 from pollution. I don't say that the City of Manitowoc does not discharge into the river, but I do say that the pollution there is small. I am speaking in a comparative sense. The river is large enough to take
10567 good sized vessels. The river at Manitowoc has been improved. The level of these artificially improved rivers or harbors depends on the level of the lake. I don't know of any major harbor where the sewage is not discharged into the river or harbor. It is not my opinion that if that condition had not obtained, navigation and total commerce on the Great Lakes would be greater than it is now. Sewage of Duluth and Superior goes into the harbor, but the situation is comparatively insignificant. The population of Duluth and Superior is around 125,000. I don't know just what the flow of the St. Louis River is. I would not say it was very large. I am not familiar with the currents in that body of water. It is pretty extensive and has two entrances and is a rather complicated situation.

Redirect Examination by Mr. Adcock.

10569 In referring to the effect of pollution of navigable waters by sewage or other wastes, and the effect upon wages of that condition, I had reference to what I consider as rather a difficult situation in Chicago, as concerns the operation of vessels. Seamen are very thoroughly organized and quite alert to take advantage of conditions which will tend to better their pleas or demands for increased wages. If we decrease the attractiveness of the work, making the men work under comparatively offensive conditions, this would be reflected in the increase in wages or in a decrease in the class of personnel involved, either of which reflects into the cost
10570 of operation of vessels. Reducing hazards of navigation upon the lake has an effect upon the wages of seamen. It affects the attractiveness and would affect the class of personnel or the wages, in my estimation.

The removal of pollution of navigable waters, so far as possible, whether they are here at Chicago or at Cleveland or at other places, would create better conditions. Likewise, the building or placing of lighthouses or buoys at points on the lake, helps navigation and reduces the hazard. Yet it would be difficult to evaluate exactly how much the installation and operation of a particular lighthouse or buoy would affect navigation.

As United States Engineer at Chicago, I had occasion to enforce Section 13 of the Rivers and Harbors Act of
10571 1899 with reference to the placing of refuse in navigable waters. As United States Engineer at Chicago in 1925 or so, I had occasion to make a report under a resolution or act of Congress of 1924 with reference to pollution of navigable waters.

If there were reduction in diversion here at Chicago, the pollution of the Chicago River and Branches and

Canal and lower rivers would be greater. To that extent it would have an effect upon navigation. I didn't have
10572 in mind any large reduction in the diversion before the controlling works were completed and in operation. A reduction in the flow between 2,000 and 3,000 second feet might bring about conditions making the installation of controlling works desirable so far as navigation is concerned, and to that I am only referring, as I have in mind the effect of storm flow. I am not taking into consideration the question of public health.

10573 With reference to the quotation from pages 59 and 60, Complainants' Exhibit 1, I was referring to the case of maneuverability of ships. I did not refer to the question of pollution or nuisance conditions as affecting navigation. I was referring also in Complainants' Exhibit 1, page 37, to the current which was created by the diversion.

The paragraph quoted by Mr. Jackson on cross examination is a part of a whole page of discussion in that
10574 report of effects of changes of the Sanitary District on navigation conditions in the Chicago River. The
10575 paragraph immediately below that one starts out "The Sanitary District has improved conditions on the river."

The upper ends, or lower ends, whichever way you want to put it, the extreme ends of the south fork were in process of being filled up while I was District Engineer. Bubbly Creek was at the west end of the south fork, or was part of the west arm of the south fork. I was never in
10576 Chicago when Bubbly Creek was in full operation, and never experienced any smell from it.

The waters of the lake along the shore at Chicago are used for various purposes by boats and craft of different kinds navigating them. There are many pleasure craft, yachts and launches plying about those waters from one yacht harbor or launch harbor to another, and from one

port to another. The United States Government has a life saving station at the mouth of the Chicago Harbor, a lighthouse depot there and an engineer depot.

The Little Calumet River dredging was finished within the last year or so. Prior to that time no boats of any
10577 particular draft could pass through it. Both as regards draft and width, boats having 12 feet draft may pass through the Little Calumet. They have had headroom to a limited extent. Clearance of bridges over the Calumet Sag Channel is 16½ feet, which is as great a clearance as exists in bridges over the Chicago River, which clearance we generally call the legal clearance in Chicago. There are quite a number of boats which pass along the Chicago River without the necessity of having the bridges raised or moved. There are many boats that may now pass along the Calumet Sag Channel or the Chicago River and its branches, and navigate without interference from bridge clearances. Boats may be
10578 designed for that purpose. There is a boat being completed right now that will be operating through that this coming year. Many industries are located along the canal and the different branches of the Chicago River that require water transportation.

Re-cross Examination by Mr. Jackson.

I do not thing the hazard to seamen in navigating the Chicago River since the opening of the Drainage Canal has been greater by danger of currents pushing them on bridge piers, than by the possibility of being overcome by offensive smell. We had complaints in regard to occasional brushing against bridges or knocking into a bridge fender, or something of that character. It was the difficulty of navigating in that current. I never have known
10579 a seaman inquiring whether there was sewage dis-

charged in the harbors between which the vessels were going to ply on which he applied for employment.

DEFENDANTS, EXHIBIT 1399.

Be It Ordained by the Board of Trustees of the Sanitary District of Chicago as Follows:

Section 1. The Sanitary District of Chicago does hereby offer and agree to pay its share of the cost of regulating or compensating works to restore the levels or compensate for the lowering of the Great Lakes System of Waterways if and when constructed, due to any diversion of water from Lake Michigan By The Sanitary District of Chicago which may now or hereafter be determined by competent authority.

Section 2. The Sanitary District of Chicago hereby offers and agrees to furnish a guarantee that it will pay its share of the cost of performing the work specified in Section 1 of this ordinance, in such form and in such amount, and under such terms and conditions as the Supreme Court of the United States may determine.

Passed Mch. 15, 1929.

Defendants' Exhibit 1400, being paragraph 74 of the Cities and Villages Act of Illinois:

10585 DEFENDANTS' EXHIBIT 1400.

"The City or Village Government shall have jurisdiction upon all waters within or bordering on the same, to the extent of three miles beyond the limits of a city or village, but not to exceed the limits of the state."

The following is a condensation of the testimony and evidence offered by complainants on re-reference so far as deemed necessary to supplement the statement of complainants' program and evidence in the Master's report on re-reference and so far as deemed necessary to a consideration of the exceptions filed by both parties:

Washington, D. C., Monday April 15, 1929.

L. R. Howson, recalled for Complainants:

Sanitary engineering expert. Testified in prior 1927 hearings.

10648 From a study and consideration of the Chicago sewage disposal and water supply problems, I have arrived at a 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 which would
10649 not be detrimental to the Chicago water supply.

(Details of Complainants' program are stated in Master's Report, 18-20.)

10656 This program does not contemplate any flow at Lockport after its completion. The completion of this program, with no flow at Lockport, would provide a practicable method for the disposal of the sewage of the Sanitary District by means other than lake diversion without detriment to the Chicago water supply. There are modifications or additions to this program which would
10657 be practical, particularly with reference to the water supply. It would be practicable to abandon the intakes that are close to the mouth of the river and move those to a more remote location; or it would be possible to even stop the use of all four of the present intakes and build one large intake at a remote location, if that were thought desirable somewhat along the lines of what was termed

a super-intake in testimony presented here before. That would be a very material improvement over the present standard of the existing water supply for Chicago. Such an addition as a new water intake or super-intake is not necessary to prevent detriment to the present water sup-
10658 ply. It would be practical to construct such a new intake if the city of Chicago desired to do so.

I have made estimates of the reduction of the quantity of diversion which would be practical from time to time during the course of carrying out of this program for substitution of another means of sewage disposal without lake diversion, which I have outlined. 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 8,500 c. f. s. direct diversion to 6,500 c. f. s.

10659 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 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 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 5,000 c. f. s. plus pumpage on December 31, 1932 and to 3,000
10660 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 which I have outlined will be completed, the entire flow at Lockport can be cut off.

In reaching my conclusions that with the completion of the program which I have outlined, it will be practical to terminate the flow at Lockport, I considered the effect both upon the public health and navigation in the Chicago River as part of the Great Lakes-St. Lawrence system. The completion of this program will produce a situation which will be satisfactory from both viewpoints.

Assuming the completion of the program that I have outlined and as summarized in Exhibit 238, and no flow at Lockport, there would not be any visible or visual suspended particles recognizable as of sewage origin in
10663 the Chicago River coming from the sewage treatment plants. The conditions which would then obtain would be greatly superior in that respect to the conditions now obtaining in the Chicago River.

Assuming the completion of the program outlined by me and summarized on Exhibit 238, with no flow at Lockport, there would not be any odors arising from the waters of the Chicago River due to the putrefaction of the organic matter contained in the sewage effluent.

Assuming completion of the program outlined by me and summarized on Exhibit 238, with no flow at Lockport, there would not be any grease, oil or sewage material on the surface of the Chicago River due to the flow from the sewage treatment plants. In that respect the conditions in the Chicago River would be materially improved
10664 over the conditions now obtained.

Assuming the completion of the program which I have outlined and summarized on Exhibit 238, the waters of the Chicago River would not be offensive or injurious to the health of passengers or persons employed on vessels or persons working on the docks.

Assuming the completion of the program which I have outlined and summarized on Exhibit 238, with no flow at Lockport, the condition of the waters of the Chicago

River would not be such as to result in an excessive growth of water plants. The growth of water plants can be practically controlled where waters do produce them. If they should appear, they can be controlled.

About 3 parts per million of dissolved oxygen are required to maintain a thriving fish life. A standard for water which requires conditions that will permit the maintenance of a thriving fish life and one which requires the absence of nuisance are not at all the same. The fish life
10665 is a much higher standard. A standard which requires the maintenance of a thriving fish life is not one which is ordinarily adopted or accepted to satisfy health requirements or to prevent interference with navigation.

Assuming the completion of the program outlined by me and summarized in Exhibit 238, with no flow at Lockport, there is a practical method of providing circulating water in the Chicago River and its branches if it were so desired. Circulating water can be introduced into the existing channels through the Wilmette station, which is at the north end of the North Shore channel, and where about 1,000 cubic feet per second capacity is now available; it can be introduced through the 39th Street Station, or can be introduced by building a new circulation station on the Calumet Sag. By building that station water could be circulated through the Calumet Sag, the Drainage Canal and out through the mouth of the Chicago River.

10666 It would be possible to provide for the discharge of the effluent of the West Side and Southwest Side plants at a point in the South Branch between the 39th Street pumping station and the mouth of the Chicago River. That would involve the construction of a tunnel to carry the effluents of the West and Southwest Side plants from the plant locations near 52nd Avenue and the Drainage Canal, up the canal to a point between the 39th Street Station outlet and the Lake.

If circulating water were pumped at the rate of 1,000 second feet at Wilmette and 2,000 second feet at 39th Street, and 2,000 through the Calumet Sag, and this program were completed, the resulting conditions would support fish life. There has not been any fish life in the Chi-
10667 cago River, Drainage Canal or upper Illinois for a great many years other than right at the mouth of the Chicago River where Lake fish may come in. There have been none in the Drainage Canal or Upper Illinois River in general for approximately 100 miles.

The effluent of a modern activated sludge plant is stable, odorless and clear. The effluent of a modern activated sludge plant discharged into an open channel, without dilution, will remain stable indefinitely. There is a variation in this program which I have outlined and summarized on Exhibit 238, which would prevent the discharge of the effluent of the sewage treatment plants into the Chicago River or its branches. It is possible to build an outlet tunnel direct from the North Side plant to the Lake, and similarly one from the West and Southwest Side plants to the Lake and thus divert those effluents
10668 from the River. This diversion through tunnels would entirely remove all of the effluents from the Chicago River and its branches. It would be practical to construct outfall sewers which would accomplish that purpose, but I think it wholly unnecessary. I mean that I could phys-
10669 ically do it if I set out to do it. I did not mean that it was practicable in the sense that I would recommend doing it as an available means for the city in disposing of its sewage at this time.

Assuming a mean annual flow of 1,000 c. f. s. at Lock-
10670 port for navigation purposes, the completion of the program, outlined by me and summarized on Exhibit 238, would provide a practical method for the disposal of the sewage of the Sanitary District of Chicago without det-

riment to the Chicago water supply and without creating any nuisance to navigation in the Chicago and Illinois Rivers.

Assuming a diversion or flow of lockage water, not exceeding a mean annual average of 1,000 c. f. s. at Lockport, the completion of this program would still provide a practical method for disposal of the sewage at Chicago from the standpoint of the interests of navigation and of public health.

Assuming that there were provided a mean annual flow of 1,000 c. f. s. at Lockport for navigation purposes, that would not require any modification of the program summarized in Exhibit 238, other than the final flow on its completion. It would not affect the estimates of time required for completion or the reductions in the quantity of diversion which would be practical during the course of such construction. The only effect would be that the final flow would be 1,000 c. f. s. instead of zero at Lockport.

10672 If the Chicago water supply were completely metered, the quantity of the sewage effluent of the Sanitary District would be approximately 1,000 c. f. s. in 1935.

Assuming the completion of the program outlined by me and the installation and operation of control gates so as to divert all storm water overflow, but with no diversion or flow other than at times of storm, such a program would practically provide for the disposal of the sewage of the Sanitary District of Chicago without detriment to the water supply or the navigation of the Chicago River as a part of the Great Lakes-St. Lawrence system from a nuisance standpoint.

10673 Assuming the completion of the sewage disposal program which was outlined by the Sanitary District engineers at the Chicago hearing, which contemplates the diversion of the effluents of the sewage disposal plants and

the diversion of all storm water overflow into the Des Plaines and Illinois Rivers, it would not be necessary to add any quantity of diluting water from the Lake to protect the public health or to prevent a nuisance to navigation in the Chicago River as part of the Great Lakes-St. Lawrence system.

Assuming the completion of the program that was outlined by the Sanitary District engineers at the Chicago hearing in March, the installation of locks or control gates at the mouth of the Chicago River and also at the mouth of the Calumet River so as to separate the Lake from the drainage basins to which the Chicago sewage and effluent is tributary and so as to provide for the diversion of the domestic pumpage and storm water overflow without any diluting water from the Lake, the resulting conditions would safeguard the public health and prevent any nuisance to navigation in the Chicago River or in the lower
10674 river.

Assuming the completion of the program outlined by the Sanitary District engineers of Chicago, but with no diluting water added from the Lake, a condition of nuisance would not develop in the Drainage Canal or in the lower rivers from the sewage effluent or the storm water overflows.

Cross-Examination by Mr. Adcock.

I am familiar with the proposed intercepting sewer systems and treatment plants of the Sanitary District and know that the Chicago sewers are a combined system. When there is a storm flow greater than the sewage capacity of the treatment plants, the treatment plants would be unable to take more than a part of that flow. The balance of the flow would be overflowed into the channels of the Chicago River system either at the various sewer outlets along the line of the interceptor or at the prelimi-

nary plant, depending upon the extent to which the flow
11280 is intercepted by the main interceptors. Assuming that there was more flow than the plant could handle, the point of discharge of the surplus still depends upon the capacity of both the plant and the interceptors. The plant as a whole cannot handle the capacity of an interceptor but there are parts of the plant that can handle it or be made to so handle it. When the interceptor fills up and overflows, the excess over the capacity of the interceptor goes into the River.

Examination by Special Master.

I was one of the firm of engineers who gave the War Department the information with regard to the conditions on the Chicago River and what could be done to improve it. My firm is the one to which General Jadwin referred.

What purported to be a copy of this report bearing the legend "Bulletin 23, Disposal of the Sewage of the Sanitary District of Chicago, a report to the District Engineer, U. S. Engineering Office, Chicago, by Alvord, Burdick & Howson, Engineers" was marked "Master's Exhibit B" in evidence.

11285 I am familiar with this report. I worked on it continuously and a large part of it is my own dictation. Statements in the report so far as they are matters of fact are correct, and so far as they are matters of opinion, I believe they are sound.

Redirect Examination.

In "Master's Exhibit B" there is set up the standard of water which will support a thriving fish life. That is a standard which was given me by the War Department.

11286 The total capacity of the intercepting sewers as designed in the Sanitary District is about 4,000 c. f. s. That

would mean that a rainfall run-off of that quantity could
11287 be carried to the treatment works. On direct testimony I answered no direct question as to the amount that could be intercepted, but upon inquiry from the Master as to what variations in the program might be suggested, I stated that I would suggest, as a modification, the interception of a larger proportion of the storm flow than 150 per cent allowed in the Sanitary District estimates. I believe that the preliminary treatment ought to be given up to the capacity of the sewers.

SPECIAL MASTER'S EXHIBIT B—REPORT OF ALVORD, BURDICK & HOWSON, CONSULTING ENGINEERS, TO UNITED STATES DISTRICT ENGINEER AT CHICAGO, DATED APRIL 16, 1925.

The following are extracts from said report:

Pages 1-11:

"Part I.

INTRODUCTION, SUMMARY, AND CONCLUSIONS.

District Engineer,
U. S. Engineer Office,
337 *S. Dearborn St.,*
Chicago, Ill.

DEAR SIR:

Proceeding under our instructions of January 16, 1925, we have studied the problem of sewage disposal for the City of Chicago and vicinity, including more particularly that territory embraced within the Sanitary District of Chicago.

Our study has been particularly directed to answers for the following questions:

(a) Determination of a pollution standard for the Chicago Drainage Canal for each of the following average diversions from Lake Michigan;—2,000, 4,167, 6,000, 7,500, 8,500 and 10,000 cubic feet per second; this standard to be the lowest that will pre-

vent the occurrence of nuisance in the Des Plaines and the Illinois River, and will permit a thriving fish life therein.

These diversions include the sewage flow of the Sanitary District; and they therefore represent the dry weather flow of the Drainage Canal at Lockport, approximately.

(b) Determination of the extent to which purification measures must be taken by the Sanitary District of Chicago for each of the flows specified above, in order that the pollution standard be maintained unimpaired.

(c) Determination of the most feasible method of treating the surplus pollution, and, for each flow specified, the cost of the necessary works and the operating costs thereof.

(d) The determination of the time that reasonably would be required to build the necessary works and place them in operation for each of the flows specified.

In the study of this matter the time at our disposal has not permitted original investigations. It has been possible only to view the present situation by inspection, and to study the large amount of data that has been accumulated by the Sanitary District of Chicago and other agencies, bearing directly upon the answers to the above questions. We have further brought to bear upon the study of the problem the experience of other cities regarding sewage disposal, insofar as information has been gained that would throw light upon the Chicago situation.

Upon the pages which follow we have stated the local problem in some detail, and we have discussed the various phases of it insofar as we believe is required for a general understanding of the problem, and our answers to the questions previously stated. For the benefit of those already somewhat familiar with this problem we will first briefly state our summarized findings and conclusions. We will follow this statement by a more detailed consideration of the problem, and a further statement of the conditions and the reasons leading to the conclusions stated.

SUMMARIZED CONCLUSIONS.

1st. *Present Disposal:*

The diversion of the Chicago sewage from Lake Michigan, resulting from the Drainage Canal and other causes, has effected a remarkable improvement in the death rate from water borne diseases. The sewage nuisance in the streams of the Chicago district has been reduced to a large extent.

This result has been accomplished, however, by transferring the bad conditions in Chicago to the Des Plaines and Illinois Rivers in which a crying nuisance has been created for more than one hundred miles; and by diverting large amounts of water from the Great Lakes, over strenuous objections from property owners claiming a right to the water diverted.

It is generally conceded that the present conditions should not be allowed to continue. The Sanitary District is already engaged upon remedial measures through which a large part of the sewage will be treated before discharge into the Drainage Canal.

2nd. *Population and Growth:*

In planning works for sewage disposal, it is necessary to consider the future population of the locality. It is not financially practicable to make expenditures now for a problematical future. It is necessary, however, to determine the future populations approximately and to adopt works capable of construction in units that may be increased in capacity from time to time as occasion requires, without destroying previous expenditures. Thus each dollar expended will provide a link in a complete chain of sewage disposal works.

We have examined the forecast of population as estimated by the Sanitary District of Chicago, and we believe it represents future probabilities as accurately as required for the above purpose. This estimate covering the population of the Sanitary district is as follows:

1920 census,	2,978,635
1930	3,710,000
1940	4,425,000
1950	5,140,000
1960	5,850,000
1970	6,580,000

In addition to the population in the Sanitary District, there is now (1925) a population of 180,000 in the northern Indiana cities bordering the lake and draining through the Calumet River. Under ordinary low flow conditions this drainage passes through the Sag Channel to the Main Drainage Channel and thus into the Illinois River.

The Sanitary District includes about eighty-five per cent of the total population in the greater Chicago region which includes Cook, Kane, DuPage, Lake and Will Counties in Ilinois, and Lake County in Indiana. The greater part of the outlying population has more or less effect upon the pollution of the lake and the nearby streams.

3rd. *Amount and Character of Sewage*:

The present discharge of the sewers within the Sanitary District is about 800 million gallons per day. This is equivalent to a river 100 feet wide and five feet deep flowing one and one-half miles per hour.

This sewage carries an organic load per capita greater than any other large city for which accurate figures have been available to us. This excessive load is partly due to a few great industries which produce an amount of pollution estimated by the Sanitary District to be the equivalent of about 1,500,000 people (1920).

4th. *Standard for Pollution*:

In the consideration of sewage treatment works that will be required under various drafts of dilution water from Lake Michigan, it has been necessary to fix a standard of maximum pollution for the Chicago Drainage Canal in order that reasonable sanitary conditions may be maintained in the Des Plaines and Illinois Rivers. We suggest the following as a reasonable standard:

> The liquid discharged by the Drainage Canal, as evidenced by the average of representative samples taken for any thirty consecutive days shall,
>
> (a) Be practically free from settleable solids deposited in two hours, and,
>
> (b) Shall contain dissolved oxygen equal to

or exceeding the biochemical oxygen demand of said liquid for five days when incubated at 20 degrees C.

(c) Shall contain not less than three parts per million or dissolved oxygen.

The treatment works hereinafter outlined in connection with specified dilutions from the lake will meet this standard in our opinion.

5th. *Protection of the Water Supply*:

Even under the heavy diversions from Lake Michigan in recent years and the generally favorable typhoid death rate, the quality of the water supply for Chicago has been far from satisfactory. This is due to the incidental pollution of the lake, periodic discharges from the Chicago and Calumet Rivers and other causes. Occasionally sporadic typhoid outbreaks have occurred attributable to the water. Safety is only secured by heavy dosages of liquid chlorine which are extremely objectionable to many people and which the Chicago authorities regard as closely approaching the maximum dosage tolerable.

Compared to the usual standards applicable to clean water, the water is dirty most of the time, and it is quite turbid more than ten per cent of the time. Even when comparatively clear it often contains microscopic animal organisms no doubt harmless, but very objectionable to many people.

The filtration of drinking water has been extensively practiced for more than twenty years. More than twenty million people are thus supplied in the United States. Many filtration plants handle a water polluted to a greater degree than Lake Michigan water would be under any diversions for dilution purposes considered in this report.

Chicago can secure pure clean water at all times by the filtration of its present supply. We regard this as the only means by which a satisfactory supply of water may be obtained, regardless of any practicable measures for sewage treatment or lake water diversions for dilution.

Filtration is considered as a pre-requisite to the adequate disposal of sewage in all projects considered in this report.

6th. *Metering of the Water Supply*:

At the present time ninety per cent of all water services in Chicago are served through so-called "flat rates." The pumpage of water is excessive, pressures are deficient, fire protection service is jeopardized and the costs of water supply, intercepting sewers and sewage disposal are greatly increased over what would be necessary if water waste were restricted.

Universal metering of the water services is urgent. Metering alone will

(a) Double the average pressure within the City of Chicago.

(b) Furnish *all* adequate water service where but twenty-five percent now enjoy it.

(c) Enable the present water service works with but minor extensions to serve the City for the next generation.

(d) Through the immense savings effected in deferred construction costs enable the City to install filtration works.

If universal metering of the Chicago Water Works is accomplished within the next ten years savings of from $200,000,000 to $225,000,000 will be effected prior to 1945. This amount is so great that in addition to financing the installation of meters and filtration works for the entire city, it would cover the cost of constructing the entire intercepting sewer and sewage disposal works required in the Chicago Sanitary District up to 1945 and leave a large surplus in addition.

The costs of sewage disposal are also influenced by the waste of water. If universal metering of the water works services is not undertaken, the estimated costs of the interceptors and sewage treatment works outlined in this report must be increased by an amount of from $42,000,000 to $53,000,000 depending upon the flow available for dilution and the types of plants required thereby.

7th. *Volume of Sewage*:

The total quantity of sewage to be treated in the Chicago District may be taken as approximately

equal to the total water supply. This assumes that infiltration into the sewers will be offset by that part of the water supply used for sprinkling and other purposes which do not contribute to the sewage flow.

At the present time, due to water waste, the pumpage of water in the Chicago District is excessive. The dry weather flow of sewage is correspondingly much larger than it would be if the waste of water were curtailed.

The total volume of sewage under metered and unmetered conditions has been estimated based upon the assumption that a ten year period beginning in 1925 and terminating in 1935 will be required to install meters on all water services in the City of Chicago, and that when all services are metered the sewage per capita, including industrial and all other uses, will be approximately 160 gallons per day.

Under these assumptions the following table shows the estimated quantities for each five year period from 1925 to 1945.

Million Gallons Sewage Daily.

Year	Present Conditions of Metering	Universal Metering	
1925	877	.....	
1930	1,054	777	(50% metered)
1935	1,243	662	
1940	1,437	711	
1945	1,629	769	

The installation of meters on all services will cause the sewage flow of 1945 under complete metering to be less than at the present time, when but ten per cent of the services are metered.

8th. *Intercepting Sewers:*

The Sanitary District has adopted tunnels for its intercepting sewers. This appears to be a logical conclusion in view of congestion on the ground surface.

Intercepting sewers have been built or are under construction for all areas except the West Side and the Southwest Side. The intercepting sewers to

serve these two areas will in general extend along both sides of the main channel and the north and south branches of the Chicago River beginning with Fullerton Avenue on the North Side and extending in a southwesterly direction to the site proposed for the West and Southwest Side plants along the Drainage Canal near Summit.

It is believed that with universal metering these intercepting sewers should be designed of such capacity that they will carry a flow equivalent to 375 gallons per capita per day. This is approximately two and one-third times the average flow as it is estimated to be after the installation of meters.

It is believed that a 35-year period (*i. e.* to 1960) is that for which the design of interceptors should be economically and practically made for sewers constructed in tunnel, capable of duplication in the future without excessive costs.

The 20 miles of intercepting sewers required for the West Side system have been estimated to cost $7,890,000.

The 15 miles of sewers required for the Southwest Side plant have been estimated to cost $4,495,700.

9th. *Sewage Disposal Costs in Other Cities*:

Construction and operating costs of sewage pumping stations and treatment works in other cities were compared with similar costs incurred by the Sanitary District of Chicago in certain works already built.

In making this comparison consideration has been given to the price basis when the work was done and the unit costs for labor and materials in the cities compared. We deduce the following conclusions from the comparison:

(a) Recent intercepting sewer contract costs in Chicago have been substantially double those secured in other cities under like construction conditions.

(b) The Calumet Imhoff tank plant, constructed by the Sanitary District of Chicago (after being credited with the reasonable cost of an experimental sprinkling filter and activated sludge plant), cost approximately three times the average of tank plants of similar type in other cities.

(c) The Des Plaines activated sludge plant of the Sanitary District of Chicago cost approximately three times the average cost of similar plants in Milwaukee and Indianapolis.

(d) The cost of operating the Calumet Imhoff tank plant (after being credited with the reasonable cost of operating a small sprinkling filter and a small activated sludge plant), is approximately four times that of operating similar plants in other cities when compared on the basis of cost per million gallons treated or ten times the average based on cost per capita served.

(e) The cost of operating the Des Plaines activated sludge plant of the Sanitary District of Chicago is from eight to ten times that estimated to be necessary for the operation of the activated sludge plant at Milwaukee.

(f) The cost of operating the 39th St., Lawrence Avenue and Calumet pumping stations of the Sanitary District of Chicago is approximately three times as great per unit of work performed as that of other stations of similar size and type in other cities.

10th. *Basis of Cost Estimates:*

All estimates of cost of construction and operation used herein are predicated upon labor and material prices prevailing in the Chicago District in the early part of 1925. The estimates are further based upon the average efficiency which it is practicable to secure in public enterprises of similar nature; no better and no worse than conditions recently prevailing in Detroit, Cleveland and Milwaukee.

11th. *Types of Treatment Works:*

At the present time the Des Plaines activated sludge plant and the Calumet Imhoff tank plant are in operation. The Sanitary District is also definitely committed to the construction of an activated sludge plant at the North Side plant, the construction of which is about one-third completed.

All of the estimates herein made for all amounts of flow considered are based upon the Sanitary Dis-

trict's program of adding sprinkling filters at the Calumet plant, and of building a sprinkling filter plant at the Corn Products Plant and an activated sludge plant at the Stockyards. The variations in degree of treatment required with the several flows considered, are all secured herein by applying different treatment processes to the West and Southwest Side plants.

All estimates of cost herein are in addition to contracts now let and under construction on the North Side intercepting sewers and that part of the North Side disposal plant for which contracts have thus far been let.

In our opinion the sites for prosposed sewage disposal works are well chosen.

12th. *Additional Works Required with* 10,000 *Cubic Feet Per Second Flow*:

A flow in the channel of 10,000 cubic feet per second will necessitate in addition to the sewage disposal works now constructed or under contract, preliminary or tank treatment of the sewage at the West Side plant and complete tank and sprinkling filter treatment for the Southwest Side.

The cost of additional purification works including intercepting sewers required with a total flow of 10,000 cubic feet per second is estimated at $57,415,240 to 1935 and $64,692,700 to 1945.

The cost of operation of all pumping stations and sewage disposal plants with a flow of 10,000 cubic feet per second is estimated at $4,364,000 in 1935 and $5,004,800 in 1945.

13th. *Required Works with* 4,167 *Cubic Feet Per Second Flow*:

With a smaller amount of diluting water, complete secondary treatment of the sewages at both the West and Southwest Side plants would be necessary. Tanks and sprinkling filter treatment would not be sufficient by 1945. Activated sludge treatment is required to meet the 1945 conditions with but 4,167 c. f. s. flow available.

The estimated cost of all interceptors and disposal plants required with the flow of 4,167 cubic feet per

second is $69,213,500 for 1935 conditions, and $76,583,300 for 1945 conditions.

We estimate the cost of operating all sewage pumping stations and sewage disposal plants necessary with the flow of 4,167 cubic feet per second at $5,163,100 in 1935 and $5,817,600 in 1945.

14th. *Required Works with* 2,000 *Cubic Feet Per Second Flow*:

With a flow as small as 2,000 cubic feet per second there is no practicable way of meeting the pollution standard herein suggested.

15th. *Required Works with* 7,500 *Cubic Feet Per Second Flow*:

The 7,500 cubic feet per second flow requires that a complete sprinkling filter plant be built at the West Side and tanks at the Southwest Side. This will suffice up to as late as 1947 after which filters will be required at the Southwest plant also. The estimated cost of constructing all plants under this flow is $61,477,920 in 1935, and $67,926,100 in 1945.

The annual cost of operating all pumping stations and disposal plants is estimated at $4,530,400 in 1935 and $5,137,000 in 1945.

16th. *Required Works with* 8,500 *Cubic Feet Per Second Flow*:

The required works with 8,500 cubic feet per second flow would be the same as those required for 10,000 cubic feet per second flow. The construction and operating cost would be the same as those outlined under the project in paragraph above.

17th. *Review of Expenditures Under Various Diversions*:

The expenditures for construction and operation of the treatment works required for 1935 and 1945 conditions with flows varying from 2,000 to 10,000 cubic feet per second are shown in Table 1.

Increasing the flow from 4,167 to 10,000 cubic feet per second saves but sixteen and one-half per cent in the expenditures required for sewage treatment, and but fourteen and one-half per cent in the annual operating costs.

18th. *Suggestion for Stockyards Wastes:*

The Sanitary District program contemplates a separate sprinkling filter plant at Argo and a separate activated sludge plant for the Stockyards wastes. Other cities in which the packinghouse waste per capita contributing sewage is as great as that at Chicago have found it practicable to treat this waste, mixed with the domestic sewage, at either sprinkling filter or activated sludge plants. At Chicago the Southwest Side intercepter passes almost directly by the Stockyards, which suggests the further practicability of combining this concentrated waste, after the removal of the coarse solids, with the domestic sewage before treatment.

If treatment of the Stockyards waste, mixed with the sewage of the West and Southwest Side, is practicable on stone filters, there will result a saving in construction cost of from $2,300,000 to $3,500,000. There will also result a saving in annual cost of operation of $350,000 per year, even after crediting an income of $360,000 per year from the sale of the sludge from the activated sludge plant. This annual saving capitalized at four per cent adds a further sum of $8,500,000, making the total capitalized saving between $10,800,000 and $12,000,000.

The rates of flow for dilution purposes, as stated in this report, are the estimated rates required un-

TABLE 1.

EXPENDITURES REQUIRED FOR SEWAGE DISPOSAL WORKS, IN ADDITION TO WORKS NOW BUILT OR UNDER CONSTRUCTION, WITH VARIOUS FLOWS IN THE DRAINAGE CANAL.

	Flow in Cubic Feet per Second.				
1935 Conditions	4167	6000	7500	8500	10,000
Cost of Operation.....	5,163,100	5,432,400	4,530,400	4,364,000	4,364,000
Cost of Construction.....	$69,213,520	$68,726,620	$61,477,920	$57,415,240	$57,415,240
1945 Conditions					
Cost of Construction.....	76,583,300	76,740,100	67,926,100	64,692,700	64,692,700
Cost of Operation..... (excl. fixed chgs.)	5,817,600	6,194,000	5,137,000	5,004,800	5,004,800
Adequate until	1950	1970	1945	1945	1960

NOTES:

1. All of above costs include full costs of Stock Yards and Argo plants.
2. All of above costs are based upon separate plant for Stock Yards.
3. Stock Yards plant operating costs are credited with revenue from dewatered sludge at $10.00 per ton.
4. Flow of 2000 c.f.s. inadequate for practicable treatment of Chicago wastes.

der warm weather conditions at which time the rate of diversion would necessarily be greatest. It is a fact that considerably smaller rates of diversion will be required in the cooler months of the year. Riparian owners on the Great Lakes and other parties interested are chiefly concerned with the average yearly diversion. It is believed to be proper therefore in the operation of the Drainage Canal to vary the draft of diversion water from month to month dependent upon conditions. The ability to do this will provide a large factor of safety for maintaining good conditions in the effuent channels and downstream rivers.

We have made no allowance for the fact that more or less sewage from the Indiana-Calumet region now containing 180,000 people, now reaches the Sag Canal in a more or less unpurified state. This situation must ultimately be solved by adequate purification works for this region, and a specific alowance for dilution water if the sewage continues to flow via the Illinois River.

The conclusions in this report are predicated on keeping the Drainage Canal reasonably clean of organic settlings by dredging. Very little will be required in this regard after purification works are built, and after the present deposits are removed. Several years may be required before existing sludge deposits in the Illinois River are completely eliminated.

We have given no consideration to the development of water power. We have neither included the costs thereof, nor credited benefits. Where power is required in the operations of pumping and sewage disposal we have estimated the cost thereof on the basis of electric power purchased from the Commonwealth Edison Company at their published rates.

Upon the pages which follow we have discussed the matters above treated in further detail."

Pages 12-16:

"Part II.

PRESENT DISPOSAL OF SEWAGE AND DEFICIENCES.

Chicago, and the industrial region surrounding it, occupies the Southwestern shore of Lake Michigan. The ground is comparatively low. The greater part of it lies less than 20 feet above Lake Michigan. This entire region formerly drained naturally into the lake through the Chicago and Calumet Rivers. That locality now constituting the western suburban area, however, is tributary to the Des Plaines River, which parallels the lake shore about ten miles inland, the water of which are tributary to the Mississippi river system through the Illinois River.

More than three million people now occupy this territory. It is conservatively estimated that the population will double within the next thirty years. The present flow of sewage is about 800 million gallons per day. This is equivalent to a river 100 feet wide and five feet deep flowing one and one-half miles per hour.

The shore line of Lake Michigan from Gary on the south to Waukegan upon the north is about seventy-five (75) miles in length. More than half of it is densely populated. Much of it is occupied by industries. The northern one-third of it is residential in character.

Development of Sewers.

Sewers were built as required, draining immediately to the nearest water outlet. The earliest settlement of considerable size, was located at the mouth of the Chicago river. In this locality all sewers drain directly into the river or into its north or south branch. As the population extended northward and southward, sewers were built discharging directly into the Lake. When sewers became necessary in the region adjoining the Calumet River, sewers were built discharging directly into this stream.

The construction of sewers in Chicago was begun in 1856. At this time the population was about 80,000. Thereafter the growth of the city was very

rapid. The mileage of sewers kept pace with the population for in many localities the habitation was not practicable until sewers had been built.

Early Disposal of Sewage.

Sewers discharging into the Chicago River and branches ultimately reached the lake except for a small amount, which from the earliest use of sewers, reached the old Illinois and Michigan canal by pumping, and thus passed to the Des Plaines and Illinois Rivers.

Illinois and Michigan Canal.

The Illinois and Michigan canal was completed in 1848. It parallels the Drainage Canal a few hundred feet to the south. Its water supply was obtained partly by gravity from the Calumet River and partly by water pumped from the south branch of the Chicago River. From time to time the pumping works were increased in capacity, which temporarily tended to improve the foul conditions in the Chicago River, and to divert some of the sewage from the lake.

Water Supply.

The water supply for the City of Chicago and for all its suburbs bordering the lake is taken from Lake Michigan. Public Water Works for Chicago began operation in 1856. Water was taken from the lake at the foot of Chicago Avenue about one mile north of the mouth of the Chicago River. As the occupied area of the city grew it became necessary to construct additional Water Works' intakes, and as the pollution from the sewers was constantly increasing, the intake cribs were progressively located farther from the shore.

At the present time the city is supplied through six cribs varying from two to four miles distant from the shore line.

In the years of rapid municipal growth up to 1890, the sanitary conditions in the outlet streams, particularly the Chicago River and it branches, became progressively worse. Comparatively great accumulations of filth were washed into the lake, and occasionally reached the Water Works' intakes. This

resulted in the general prevalence of typhoid fever, and occasional epidemics.

Drainage Canal.

We will not recite here all the steps that were taken to bring about an improvement in the sanitary conditions. These matters, while of general interest, are recited elsewhere, and bear only indirectly upon this problem. The most important step taken toward improving conditions was the passage of the State law creating the Sanitary District of Chicago and empowering it to construct the Chicago Sanitary Ship Canal, May 29th, 1889.

The Drainage Canal is twenty-eight miles long from the Chicago River at Robey Street to the Controlling Works at Lockport. It creates a reversal of the flow of the Chicago River, and in addition it draws in certain quantities of water from Lake Michigan, depending upon its controlled rate of flow. The flow is controlled at the foot of the Canal. This work was started in 1892 and completed January 2, 1900. The flow capacity of the main channel is approximately 10,000 cubic feet per second.

In 1907 the canal was extended beyond Lockport, a distance of about four miles to concentrate an available fall of about thirty-four feet, and utilize the same in the development of a water power in dropping the canal flow down to the level of the Des Plaines River. Since the completion of this power plant it has generally formed the means for regulating the flow of the Drainage Canal, although the flow can also be regulated at the Controlling Works, four miles upstream.

In connection with the utilization of the main drainage canal it was necessary to improve the Chicago River in order to permit the desired flow without interfering with navigation. The river was widened and deepened at various places between the years 1897 and 1920. In 1910 the north shore channel was completed connecting the north branch of the Chicago River with Lake Michigan at Wilmette. At this place a pumping station was built operating at about three feet head. This canal and pumping station serves the purpose of pumping fresh water into the head of the north branch of the Chi-

cago River, thus improving the sanitary conditions therein, resulting from the large amount of sewage received. This channel is eight miles in length and has a capacity of 1,000 cubic feet per second.

The Calumet Sag channel taps the little Calumet River at Blue Island diverting the water thereof westerly and joining the main drainage canal at Sag. This canal was completed in 1922. It has a length of sixteen miles and a capacity of 2,000 second feet.

Intercepting Sewers.

With the opening of the Drainage Canal January 2, 1900, all sewage discharging into the Chicago River and branches was diverted to the Illinois River. There remained, however, a considerable amount of sewage which reached the lake, through the sewers discharging directly therein. To stop this pollution a system of intercepting sewers along the lake shore was planned and built by the City of Chicago.

All sewage entering the lake, between the Chicago River on the north and 87th St. on the south, is now intercepted by a main sewer on Stony Island Avenue running north from 83rd St. and thence following Cornell Avenue and the shore of Lake Michigan to 39th St. At this place the 39th St. Pumping station lifts the sewage to the twenty foot sewer running west on 39th St., entering the south branch of the Chicago River. This station is also equipped with pumps to take dilution water directly from the lake for the purpose of keeping the south fork of the river clean. Plans are now under way to extend the 39th St. sewer so that it will enter the drainage canal at Western Avenue near 31st St. This will obviate the necessity for dilution water in the south branch of the river. The southern part of the Stony Island Avenue district is pumped into the Stony Island Avenue sewer by pumping station constructed and operated by the City of Chicago at 73rd St. and Stony Island Avenue.

The South Side intercepting sewer was completed in 1907.

The North Side sewers entering the lake were intercepted by the construction of sewers paralleling

the lake shore running north to Lawrence Avenue, and from Howard Avenue running south to Lawrence Avenue. At Lawrence and Racine Avenue a pumping station was constructed, discharging the sewage westward into the north branch of the Chicago River. This station is also equipped with pumps to draw dilution water from Lake Michigan for the purpose of improving the character of the water in the north branch of the Chicago River.

A similar system of intercepting sewers north of Howard Avenue lead to the Evanston pumping station at Orrington Avenue and Lake Street, which intercepts the remainder of the lakeward flowing sewers south of Wilmette and discharges the sewage into the north shore channel.

All sewage originating in the Sanitary District north of Wilmette is intercepted by a system of sewers terminating at the north shore channel and Sheridan Road. The Wilmette pumping station, located at this point, is equipped with pumps to draw dilution water from the lake for the purpose of maintaining cleanly conditions in the north shore channel and the north branch of the Chicago River.

The North Side intercepters, within the City of Chicago, became effective in 1908. The intercepting sewer system north of Wilmette became effective in 1916. The Evanston sewer and pumping station was completed in 1921.

Calumet Region.

Sewage within the City of Chicago, south of 87th Street, has heretofore been discharged directly into the Calumet River, and considerable of it still reaches the river. This will very shortly be corrected by the completion of the Calumet intercepting sewer and the pumping station at 95th Street and the Calumet pumping station at Indiana Avenue and 125th St. With the completion of these sewers all sewage south of 87th St. will be pumped into the Calumet Sag Channel after treatment, and delivered to the Chicago Drainage Canal at Sag.

The Sag Canal does not reverse the Calumet River system at all times, the flood flow of this stream greatly exceeding the capacity of the Sag Canal. Periodic discharges from the Calumet River have

been a serious menace to the water supplies, particularly those near the mouth of the Calumet. This menace will continue to a greater or less extent."

* * *

Pages 16-18:

"*Diluting Water.*

It was the original idea in the construction of the Drainage Canal that the sewage of the Sanitary District would be diluted by mixing with a sufficient amount of fresh water from Lake Michigan to render the mixture innocuous, and to assist in the natural purification of the sewage in its transit through the Drainage Canal and the river system below same.

Table 2 shows the average flow at the outlet of the Drainage Canal for each year since the canal was opened in 1900. This flow was limited in the early years by the ability to get the water through the Chicago River. Within the past ten years the flows have been more nearly up to the pollution requirements of the population served, but they have never been adequate to properly care for the sewage and trade wastes. The table also shows the estimated amounts of flow required by the State law creating the Sanitary District, under which a minimum dilution of three and one-third second feet per thousand people was required.

The above flows include the sewage, as well as the diversion, for dilution purposes. Water for both purposes is taken from the lake. The present liquid volume of the Chicago sewage is approximately 1200 second feet or about twelve per cent of a total diversion of 10,000 second feet.

Additional Dilution.

Immediately after passing the controlling works at Lockport the Drainage Canal water joins the natural flow of the Des Plaines River. The flow of this stream during the late summer and fall is usually negligible. Large flows of fresh water are, however, brought in during the flood seasons.

Below Joliet the principal tributary is the Kankakee River, which joins the Des Plaines forming the Illinois River. The next principal tributary is the Fox.

The net effect of all these streams and other minor tributaries coming in above Peoria is indicated on Figure 2, which shows graphically the flow of the Illinois River at Peoria, and the flow of the Chicago Drainage Canal since the latter was opened in 1900. During the past ten years the flow of the Drainage Canal at Lockport has generally ranged between 8,000 and 9,000 second feeet. During the two dryest months in the year the additional flow coming in above Peoria has usually ranged between ten and twenty per cent of the Drainage Canal flow. During the remainder of the typical year this additional inflow has been considerably more, possibly averaging as much as a fifty per cent addition of fresh water. During several months of nearly every year the additional water coming in has been fully equal to the flow of the Drainage Canal. In certain months of heavy flow it has been four to five times as great as the Drainage Canal flow. During the year 1924, which was a year of sustained natural flow in the Illinois river, the tributaries above Peoria brought in a flow of fresh water fully equal to the Drainage Canal flow throughout the year up to and including September.

Sewage Treatment Works.

Realizing the inadequacy of dilution as a permanent solution for the Chicago sewage problem, the Sanitary District some years ago began experimentation and the preparation of plans for sewage disposal works to supplement the dilution project."

* * *

(The report here describes the different treatment projects as shown by testimony and by Master's Report of Nov. 23, 1927.)

Pages 20-21:

"*Industrial Wastes Treatment Projects.*

A very important part of the organic load contained in the Chicago sewage is contributed by certain industries, particularly the packing industries located near the head of the Drainage Canal. Also the Corn Products Company located at Argo on the Drainage Canal and near the western city limits.

The Packing Town wastes and the Corn Products wastes are derived from comparatively small areas respectively. The wastes are highly concentrated and require special treatment. Thorough studies have been made in co-operation with the industries."

* * *

Pages 21-23:

"*Effectiveness of Disposal Operations.*

The diversion of the sewage from Lake Michigan has been followed by a remarkable reduction in typhoid fever in the City of Chicago. A number of other matters have contributed to this improvement, including the chlorination of the water supply which was begun in 1912, the pasteurization of milk begun in 1910, and also no doubt other important causes outside of the Chicago district, which have been instrumental in very greatly reducing the typhoid death rates throughout the United States. Table 3 shows these facts in tabular form.

Condition of the Lake.

Lake Michigan is still badly polluted in the Indiana Calumet region, from the Indiana cities and the periodic discharge of sewage from the southern part of Chicago, a part of which still reaches the Lake. There have also been periodic, but relatively infrequent sewage discharges from the Chicago river due to flow reversals caused by floods. Minor pollution still reaches the lake from the suburban towns north of the Sanitary District. This pollution is comparatively small, and will probably become less with improved conditions in the North Shore Sanitary District, embracing certain suburban towns north of the Cook County line.

Particularly at times of great storms the sanitary condition of the water at the Chicago intakes is very bad. This subject will be discussed hereinafter.

River Conditions.

During recent years the main channel of the Chicago River through the heart of the city, while not seriously objectionable, nearly always contains evidence of floating sewage. Conditions in the north

TABLE 3.

ANNUAL TYPHOID FEVER MORTALITIES IN CHICAGO PER 100,000 POPULATION.

From Report of Engineering Board of Review, and Supplemented.

Years	Typhoid Fever Mortality	Per Cent of Total Mortality	Remarks
1867	73.3	3.45	
1868	79.3	3.34	
1869	65.3	2.82	
1870	87.4	3.66	
1871	61.0	2.92	
1872	142.6	5.16	
1873	71.6	2.85	
1874	53.4	2.63	
1875	51.7	2.62	
1876	41.2	1.96	
1877	37.0	1.98	
1878	33.4	1.97	
1879	42.3	2.41	
1880	34.0	1.63	
1881	105.2	4.03	
1882	82.4	3.49	
1883	62.2	3.12	
1884	56.2	2.84	
1885	74.6	3.98	
1886	68.6	3.53	
1887	50.3	2.48	
1888	46.7	2.38	
1889	48.4	2.67	
1890	91.6	4.61	
1891	173.8	7.20	
1892	124.1	5.68	
1893	53.5	2.47	
1894	37.5	2.06	
1895	37.9	2.14	
1896	52.6	3.23	
1897	29.3	2.00	
1898	40.8	2.79	
1899	27.2	1.73	
1900	19.8	1.35	Opening of Drainage Canal
1901	29.1	2.09	
1902	44.5	3.03	
1903	31.8	2.03	
1904	19.6	1.42	
1905	16.9	1.21	
1906	18.5	1.27	Opening South Side Intercepters
1907	18.2	1.16	Completion South Side Intercepters
1908	15.8	1.09	Opening North Side Intercepters
1909	12.6	0.87	
1910	13.7	0.90	Pasteurization of Milk
1911	10.7	0.74	Completion North Shore Intercepters
1912	7.6	0.51	Chlorination of Water Started
1913	10.6	0.71	
1914	6.9	0.49	
1915	5.3	0.37	
1916	5.1	0.35	
1917	1.6	0.11	Complete Chlorination of Water
1918	1.4	0.08	
1919	1.2	0.09	Completion Evanston Intercepters
1920	1.1	0.09	
1921	1.1	0.09	Completion Calumet Intercepters
1922	1.1	0.10	
1923	1.9	0.16	
1924	1.5	0.13"	

branch of the Chicago River generally range from bad to fair, depending upon the extent of operation of the dilution pumps. The south branch of the river to the head of the Drainage Canal increases in foulness as the additional sewers join the stream. The Drainage Canal throughout its length, as would be expected, always bears evidence of the heavy sewage load carried. Odors on the banks are usually noticeable, but conditions only become very foul during the summer and early fall months.

At Lockport dissolved oxygen is normally exhausted during the warm weather season. A similar condition prevails generally throughout the Illinois River to the head of Peoria lake about ninety-six miles below Lockport. Within this reach of the

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"streams conditions vary, as to the presence or absence of oxygen and the prevalence of putrefactive odors. For ten years or more the natural life of the river, animal and vegetable, has been destroyed. No life is present except sewage organisms. The water is not suitable for bathing and is disagreeable for users of pleasure craft.

During certain seasons objectionable conditions and the destruction of the natural water life has occurred as far south as Peoria. The wet season of 1924 has materially improved the conditions in Peoria Lake.

Conditions in the Des Plaines and Illinois Rivers, below Lockport, have been aggravated by large quantities of sewage sludge which passes down the river during the colder months of the year, comparatively in an undecomposed state, which tends to add materially to the demand on the oxygen contained in the water during the summer months, when decomposition reaches a maximum. This sewage sludge has accumulated to great depths behind dams and in other places where the current is slack during the twenty-five years that the Drainage Canal has been operating. Conditions are becoming worse with the increasing organic load discharged by the Chicago sewage and the Chicago industrial wastes.

Incidentally the river receives additional pollution

although comparatively of small amount from the cities between Joliet and Peoria. At Peoria and Pekin important additional industrial wastes are added to the river. Up to the present time this pollution has been small as compared to the Chicago load.

It has been recognized, by all concerned, that the existing conditions on the Illinois River should not be permanently tolerated. For some time it has been realized that unless corrective measures are applied promptly, these conditions will become materially worse with the further growth of the Chicago region.

The Chicago sewage problem will not be solved until the water supply of the Chicago district is adequately protected, and the streams receiving sewage are restored to a condition of reasonable cleanliness.

Analytical Studies.

The most accurate picture of the sanitary conditions in the Des Plaines and Illinois Rivers, below the outlet of the Chicago Drainage Canal, is furnished by the comprehensive study of the U. S. Public Health Service, covering fourteen months beginning July 1, 1921, and ending August 31, 1922. A complete report of this investigation has not yet been printed. There has been furnished to us, however, a series of tabulations, summarizing the principal results.

It was the purpose of this investigation to determine the extent of pollution, the character of the water at various places within the streams and the factors that particularly affect the decomposition of the organic matters discharged therein. Twenty-seven sampling stations were established between Lockport and the mouth of the Illinois River. Samples were collected daily, or, at certain points triweekly, from mid-depth of the stream. At the stations between Lockport and Shanahan, the latter place just above the mouth of the Kankakee, samples were collected from the center of the stream. At all stations below Shanahan samples were taken at three points from the cross section. Samples were carefully taken, iced and promptly transported to the nearest laboratory. Examination of samples

was made in all cases in less than three hours. The average time was much shorter. The report of the preliminary examination states: 'Due to fluctuations in the sewage strength from night to day at the outlet of the Sanitary canal, and to the variation in flow caused by opening and closing of the gates at the power plant above Joliet, it is probable that the results of analyses recorded in the tables which follow do not represent exactly the average condition throughout the day of the water at the sampling point.'

The tabular data, accompanying the preliminary report, is too bulky to present in full. We summarize the principal features of it on Figures 5 to 8 inclusive. We show upon these diagrams the average dissolved oxygen for each month during the investigation at each of the sampling points. Also the five day bio-chemical oxygen demand for the same places and times. These determinations represent the character of the water from the pollution and nuisance standpoints. The bio-chemical oxygen demand is representative of the amount of organic pollution carried. The dissolved oxygen represents the possibility of local nuisance and the practicability of existence of the natural water life of the stream. Both determinations considered progressively down-stream indicate the degree of improvement in the sanitary character of the water flowing.''

* * *

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''*Future Effect of Water-Way Improvement.*

When the Illinois water-way is built some changes will be brought about in the river conditions, principally between Lockport and LaSalle. In this reach of the Des Plaines and Illinois Rivers it is proposed to improve the same on the basis of slack water navigation. To accomplish this purpose dams will be constructed at Brandon Road, Dresden Island, Marseilles and Starved Rock. The pond created by each of these dams will extend to the foot of the next dam up-stream.

At the present time the water occupies a period of

about thirty-seven hours in its passage from Brandon bridge to LaSalle. Except for the pond created by the present Marseilles dam the current is rapid and conditions are favorable for the absorption of atmospheric oxygen.

After the construction of the water-way based on present plans, contemplating a flow of about 10,000 second feet, the time of travel between Joliet and LaSalle will be increased to about 66 hours. The water surface area in this reach of the stream is about 10.5 square miles at the present time. The dams will increase it to about thirteen square miles.

Below LaSalle the flow of water is much less rapid. Six and one-half days is at present required for it to flow from LaSalle to Peoria. The total time of flow from Joliet to the mouth of the Illinois River is about thirteen days at summer stages with present flows.

With the improved water-way assuming a flow of 10,000 second feet conditions below LaSalle will not be greatly changed. Proposed plans contemplate water surface elevations which differ not greatly from those prevailing at present. With this flow, however, the existing dams will probably be taken out.

Thus the net result of the construction of the water-way will be practically to double the time of travel from Joliet to LaSalle, and to increase the area of water surface about twenty-five per cent. Below LaSalle conditions will remain about as at present.

Conditions with Smaller Diversions.

If the diversion of water from Lake Michigan is very much below 10,000 second feet the plan for the Illinois water-way will probably require the retention of the present dams below LaSalle. Above LaSalle the dams contemplated under a 10,000 second foot flow would probable be unchanged, and the existing areas would not be greatly altered as compared to the larger flow. The time of travel, however, would be increased approximately in an average ratio to the quantity of water flowing.

Rough approximations of the time of travel, as-

suming various quantities flowing in the stream would be as follows:

TIME OF TRAVEL IN DAYS.

	Joliet to LaSalle	LaSalle to mouth of Illinois River
10,000 feet per second.....	2.7	14.5
8,500 " " "	3.2	17
7,500 " " "	3.6	19
4,167 " " "	6.4	35
2,000 " " " 13		73

It is believed that the net effect of the construction of the water-way will be to introduce into the Illinois River a series of four ponds above LaSalle, which may be expected to have a similar effect to that now produced in Lake Peoria. It is believed that the net effect upon the stream under present pollution and diversion conditions would be to throw the 'dead line' now existing near Peoria Lake much further upstream."

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"Part III.

POPULATION AND GROWTH.

Chicago has grown from a frontier trading post to the third city of the world within a period of ninety years. It is the commercial and transportation center of the largest and richest agricultural community on this continent. Its position is such, as regards lines of communication, that it will continue to be the hub of interior America. Its future development must inevitably follow the development of a vast interior region, the limits of growth for which cannot be predicted.

In planning sewage disposal works for this great industrial center, it obviously will be wise to plan for a larger future growth. It is not financially practicable, however, nor is it wise to build very far in advance of immediate requirements. It is practicable, however, to plan for future growth, and to

build upon a unit system so that units may be built a little in advance of need. If the plan is wisely made each unit so built will be permanently useful. It will constitute a link in a future chain of sewage disposal works. Thus each dollar invested will be a permanent investment. If the growth is more rapid than anticipated, units can be added more rapidly, and assessed valuations will be available to meet the necessary charges. If growth is less rapid than is anticipated, works constructed from year to year will be useful for a longer time.

Population—Sanitary District:

The Sanitary District of Chicago includes fifty-two towns and villages lying within Cook County, Illinois. The population by 1920 census was 2,978,635, of which 2,701,705 or ninety-one per cent was resident within the corporate limits of the City of Chicago. Table 5 is a statement of the population within the present boundaries of the Sanitary District in the census 1900 to 1920 inclusive. Within this period the population of the district increased sixty-seven per cent. The outlying towns and villages practically trebled in population during the two decades.

Greater Chicago Region:

Since 1900 municipal growth has extended beyond the Illinois border line into Northern Indiana, in which a great industrial region is developing, served by numerous main lines of railroad and new lake harbors, which have been built at Gary and East Chicago. Improved labor conditions in the outlying localities, adjacent to Chicago, have favored the location of certain industries, on the borders of the city limits, and in certain cities outside of Cook County. The greater Chicago region, as defined by U. S. census, includes Cook, Kane, DuPage, Lake and Will Counties in Illinois and Lake County in Indiana. The total population of this region was 3,521,789 in 1920. It had increased seventy-five per cent in two decades following 1900. Table 6 shows the population within this region for each county for the last three census years. As will be noted the Sanitary District of Chicago includes approximately eighty-five per cent of the total population of the greater Chicago region.

TABLE 5.

POPULATION OF CITIES AND VILLAGES IN THE SANITARY DISTRICT OF CHICAGO.

Name	Population 1900	1910	1920
Bellwood (village)	....	943	1,881
Berwyn (city)	....	5,841	14,150
Blue Island (city)	6,114	8,042	11,424
Broadview (village)	....	....	430
Brookfield (village)	1,111	2,186	3,589
Burnham (village)	....	328	795
Burr Oak (village)	....	....	1,237
Chicago (city)	1,698,575	2,185,283	2,701,705
Cicero (town)	16,310	14,557	44,995
DesPlaines (village)	1,666	2,348	3,451
Dolton (village)	1,229	1,869	2,076
Elmwood Park (village)	....	....	1,380
Evanston (city)	18,721	25,668	37,234
Evergreen Park (village)	445	424	705
Forest Park (village)	4,085	6,594	10,768
Franklin Park (village)	483	683	914
Glencoe (village)	1,020	1,899	3,381
Glenview (village)	....	652	760
Harvey (city)	5,395	7,227	9,216
Cook County	....	....	127
Hinsdale (village) (DuPage County)	2,578	2,451	3,975
Kenilworth (village)	336	881	1,188
LaGrange (village)	3,969	5,282	6,526
LaGrange Park (village)	730	1,131	1,684
Lyons (village)	951	1,483	2,564
Maywood (village)	4,532	8,033	12,072
Melrose Park (village)	2,592	4,806	7,147
Morton Grove (village)	564	836	1,079
Mount Greenwood (village)	190	276	1,441
Niles (village)	514	569	1,258
Niles Center (village)	529	568	763
Northbrook (Schermerville) (village)	..	..	554
North Riverside (village)	..	..	..
Norwood Park (township)	3,447	5,251	6,897
Oak Park (village)	..	19,444	39,858
Park Ridge (city)	1,340	2,009	3,383
Phoenix (village)	..	679	1,933
Posen (village)	..	343	947
Riverdale (village)	558	917	1,166
River Forest (village)	1,539	2,456	4,358
River Grove (village)	333	418	484
Riverside (inc. N. Riverside) (village)	1,551	1,702	2,532
Riverview (village)	406	312	334
Robbins (village)	..	..	431
Schiller Park (village)	..	..	390
South Holland (portion village)	766	1,065	1,247
Stickney (village)	..	..	550
Summit (village)	547	949	4,019
Tessville (village	..	359	355
Western Springs (village)	662	905	1,258
West Hammond (Calumet City) (city)	2,935	4,948	7,492
Wilmette (village)	2,300	4,943	7,814
Winnetka (village)	1,833	3,168	6,694
Total population	1,788,278	2,338,278	2,978,635
Total population, excluding Chicago	89,703	152,995	276,930

TABLE 6.

POPULATION OF THE CHICAGO METROPOLITAN DISTRICT.

County	1900 Census	1910 Census	1920 Census
Cook	1,838,735	2,405,233	3,053,017
Kane	78,792	91,862	99,499
DuPage	28,196	33,432	42,120
Lake	34,504	55,058	74,285
Will	74,764	84,371	92,911
Lake (Ind.)	37,892	82,864	159,957
Total	2,092,883	2,752,820	3,521,789"

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"Part IV.

AMOUNT AND QUALITY OF SEWAGE.

In a study of the sewage problem of any community, a knowledge of the volume and quality of the sewage is of primary importance.

With respect to quality, sewages are often classified as domestic and industrial, and the use of these terms is generally intended to convey the idea that domestic sewage is that resulting from strictly domestic or household operations, while industrial sewage is that resulting from manufacturing or industrial operations.

A strictly domestic sewage consists of the waterborne wastes resulting from household operations in the laundry, kitchen, bathroom, and toilet and the qualitative character of such wastes is substantially the same in any community where the habits of life of the people do not differ materially. Sewage of a strictly domestic character is rarely encountered in large cities, as most, if not all, of our large cities have more or less varied industries, which produce waterborne wastes differing in quality from strictly domestic sewage. The character and extent of industrial operations consequently are largely responsible for any wide differences in quality which may be found in the sewages of various cities.

Measurement of Load:

Various analytical determinations are made today to give expression to the quality or composition of

sewage, such as total nitrogen, free ammonia, suspended solids, settleable solids, oxygen absorbed from permanganate, stability value, biochemical oxygen demand, etc., and in the discussion of the quality of sewage, the only analytical value which will be used for the present will be that secured by the biochemical oxygen demand test.

The biochemical exygen demand test consists of incubating a known volume of sewage with known volumes of pure water containing a known supply of oxygen in solution, and observing the rate at which the oxygen is exhausted, also, the total amount of oxygen required to effect a complete combustion of the putrescible matter in the sewage. The incubation is carried out at a constant temperature, usually twenty degrees C., and for a sufficient number of days to accomplish a practically complete destruction of the readily oxidizable material in the sewage. This test attempts to show what happens in the way of oxygen depletion in a stream of pure water when it is polluted with sewage.

It has long been known that streams are able to affect a destruction of putrescible matter and after doing so to recover their original purity. When sewage is discharged into a stream of water there begins a drama with three actors, namely putrescible matter, bacteria and oxygen. Bacteria and oxygen combine to destroy putrescible matter, and if the bacteria have an ample supply of oxygen, putrescible matter is destroyed in a quiet and orderly manner, but if the supply of oxygen is inadequate, the drama may develop into a tragedy, and although the bacteria will eventually triumph, the stream will suffer considerably from the experience.

The problem then is one of oxygen supply, if sewage destruction is to be accomplished without offense, and there are a number of factors which govern the supply of and demand for oxygen in a polluted stream of water. One second foot of pure water at a temperature of 32° F. is saturated when it carries 79 pounds of oxygen in solution in a twenty-four hour period, whereas at a temperature of 86° F., it is saturated when it carries 41 pounds of oxygen in solution. On the other hand, the activity of the bacteria which destroy the putrescible matter, is almost

"TABLE 12.
SHOWING ESTIMATED DAILY OXYGEN LOAD OF SEWAGE OF SANITARY DISTRICT OF CHICAGO

Year	Polluting Element	Daily Polluting Units	Pounds of Oxygen Required Per Day Per Polluting Unit on Basis of Oxygen Demand Value for			Pounds of Oxygen Required Per Day for Polluting Element on Basis of Oxygen Demand Value for		
			5 Days	10 Days	20 Days	5 Days	10 Days	20 Days
1925	Human Population*	3,355,000	0.182	0.240	0.267	611,000	805,000	896,000
	Stock Yards Waste	33.5 M.G.	5650	7500	8330	189,000	251,000	279,000
	Corn Products Waste	15.0 M.G.	3750	5000	5670	56,000	75,000	85,000
	Totals					856,000	1,131,000	1,260,000
* 1930	Human Population*	3,710,000	0.182	0.240	0.267	675,000	890,000	990,000
	Stock Yards Waste	35 M.G.	5650	7500	8330	198,000	262,000	292,000
*	Corn Products Waste	16 M.G.	3750	5000	5670	60,000	80,000	91,000
	Totals					933,000	1,232,000	1,373,000
* 1935	Human Population*	4,070,000	0.182	0.240	0.267	741,000	977,000	1,087,000
	Stock Yards Waste	36.5 M.G.	5650	7500	8330	206,000	274,000	354,000
	Corn Products Waste	17.5 M.G.	3750	5000	5670	66,000	87,000	99,000
	Totals					1,013,000	1,338,000	1,540,000
1940	Human Population*	4,425,000	0.182	0.240	0.267	805,000	1,062,000	1,181,000
	Stock Yards Waste	38.2 M.G.	5650	7500	8330	216,000	286,000	318,000
	Corn Products Waste	18.2 M.G.	3750	5000	5670	68,000	91,000	103,000
	Totals					1,089,000	1,439,000	1,602,000
1945	Human Population*	4,785,000	0.182	0.240	0.267	871,000	1,148,000	1,278,000
	Stock Yards Waste	40 M.G.	5650	7500	8330	226,000	300,000	333,000
	Corn Products Waste	19 M.G.	3750	5000	5670	71,000	95,000	108,000
	Totals					1,168,000	1,543,000	1,719,000

*Includes Minor Industrial Wastes."

nil at 32 degrees F., whereas at 86 degrees F., they are exceedingly active. It is thus apparent that in cold weather there is a large oxygen content in the water and a low rate of demand, whereas in warm weather there is a low oxygen content in the water and a high rate of demand."

* * *

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"In view of such evidence as has been available and on the basis of the observed behavior of mixtures of sewage and clean water which have been shown to have reasonably definite general average rates of demand for oxygen, it is considered that a supply of dilution water having an initial oxygen content equal to the total 5-day oxygen demand load of the Sanitary District will be sufficient and satisfactory.

For the above reasons, and for the reasons more fully stated in Part V and Part VI, we conclude that the 5-day biochemical oxygen demand of the sewage, and purification plant effluents, will furnish the most useful criterion of organic load."

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"Part V.

STANDARD OF MAXIMUM POLLUTION.

It is desirable that a standard should be fixed to measure the effectiveness of means to be taken to prevent excessive pollution of the rivers below Joliet. This standard should be applicable whether the protective measures consist of dilution from Lake Michigan, sewage treatment works, or both. It will be most desirably and conveniently applied at the foot of the Drainage Canal. A test must cover a period sufficiently long to represent conditions which might create a nuisance, to eliminate unavoidable errors in sampling, and to average up ordinary variations that might be caused by excessive discharge from the storm sewers.

It is regarded as essential that the standard should exclude settleable suspended matters of an organic character; otherwise deposits in the stream below Lockport, in the colder weather, will tend to rob the

stream of oxygen in summer, thus producing undesirable conditions, the magnitude of which is not subject to prediction.

Subject to the above requirement, it is believed to be practicable to prescribe an oxygen content and an organic load, which, aided by reaeration and added dilution from streams below Lockport, will permit of satisfactory stream conditions at all places on the Illinois and Des Plaines Rivers, including freedom from nuisance, conditions tolerable for fishes in the Des Plaines and Upper Illinois, and such as to permit a thriving fish life in the lower Illinois.

Limitations of Standard:

In fixing a standard to be used as a governing basis for the pollution of the Illinois River, both now and hereafter, there are two considerations that should be set forth clearly in the beginning:

1st. It is economically impractical to expect that the Illinois River should be returned to a condition such as exists in streams which receive no pollution at all; *i. e.,* to a condition of pristine purity.

2nd. The existence of any appreciable amount of settleable putrescible material in the drainage course is apt to upset all efforts which are aimed at the maintenance of proper stream conditions through sewage treatment and regulated diversion."

* * *

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Reaeration:

"It is our belief that there will be enough reaeration to prevent a serious depletion of oxygen in the Drainage Canal if the recommended standard of pollution is adhered to.

When the mixed lake water and sewage reaches Lockport, in summer, the purifying action of the lake water is finished. The oxygen content of the liquid is practically zero. Nevertheless in its further flow to Chillicothe, the total organic units, passing that point in a given time, are greatly reduced through agencies other than Lake Michigan water. This, notwithstanding the fact that the normal load in the summer season is greatly augmented by river bottom

deposits which have remained in refrigeration during the colder months.

An analysis of the studies of the U. S. P. H. Service for the month of August, 1922, indicate that the purifying agencies acting below Lockport and above Chillicothe, from sources other than Lake Michigan, are more potent in total than the total diluting water from Lake Michigan. These purifying agencies may include sedimentation, putrefaction, and oxidation. In our opinion oxidation is the chief factor. This opinion is reinforced by the fact that between Chillicothe and Peoria (in Peoria Lake) a distance of sixteen miles, the recovery of oxygen units in the water is nearly as great as was obtained in total diversions from Lake Michigan.

In addition to the natural agencies there are artificial agencies that may be called into action if needed to increase reaeration; namely, the fall at Lockport, and the available fall at the several state dams when the Illinois waterway is built. Several studies of the river indicate a marked recovery in oxygen at the Marseilles dam where much of the water is wasted over the dam. At Lockport it nearly all passes through the water wheels of the Sanitary District, with practically no oxygen gain at present.

Thus in our opinion reaeration even of still water is a most important agency of purification.

Dilution in Other Cities:

Attention is further invited to Table 15 which shows the dilution water available for several American cities which discharge untreated sewage into the streams along which they are located. The data contained in this table simply shows what has been allowed to exist as a permissible pollution and probably the conditions created therefrom in the several streams have varied from satisfactory to doubtful.

The recommended standard contained in this report (eliminating for the moment the matter of settleable solids) is that 5.9 cubic feet per second per 1000 human population will be required to properly dispose of the entire untreated sewage of the Sanitary District of Chicago during the warm weather season of the year.

TABLE 15.

DILUTION WATER AVAILABLE FOR SOME AMERICAN CITIES THAT HAVE NO SEWAGE TREATMENT.

	City	Name of River	Population Tributary 1920	Drainage Area Sq. Miles	Estimated Dry Weat Flow in C.F.S. Total	Per Sq. Mi. Drainage Area	100 Tri
1	Cincinnati	Ohio	681,000	76,320	6,490	0.085	
2	Grand Rapids	Grand	171,000	4,900	1,433	0.292	
3	Iowa City	Iowa	17,000	3,140	128	0.041	
4	Lansing	Grand	57,000		265		
5	Washington	Potomac	541,000	12,555	2,300	0.182	
6	Minneapolis & St. Paul	Mississippi	680,000	35,700	1,600	0.045	
7	Dayton	Gt. Miami	210,000	2,598	342	0.131	
8	Pittsburgh	Ohio	1,216,000	19,020	1,670	0.088	
9	Des Moines	Des Moines	126,000		164		
10	Youngstown	Mahoning	287,000	958	167	0.175	
	Sums		3,986,000	154,233	15,150		
	Means					*0.095	
	Mean, No. 10 Omitted						

*Nos. 4 and 9 omitted.

Dilution After Purification:

We show in Table 16 a list of cities in which more or less complete purification has been adopted, together with the amount of diluting water that is available in dry weather to mix with the purified effluent in the stream below the purification works. The dilution is expressed in cubic feet per second per thousand of population based on the 1920 census.

It will be observed that in several instances the stream goes dry.

The numerical average dilution is .58 second feet per thousand people. The weighted average is .42 second feet per thousand people. Attention is called to the fact that as these cities grow the dilution ratio must become less, for in all cases, so far as known, there is no practicable means by which the dry weather flow of the stream will be increased.

As compared to the above figures the standard recommended in this report and the recommended purification works contemplate dilutions as follows: These dilutions are expressed in second feet of diluting water per thousand people as of the year 1935,

TABLE 16.

DILUTION OF TREATED SEWAGE IN VARIOUS CITIES OF THE UNITED STATES.

	City	Population 1920	Stream	Drainage Area sq. mi.	Estimated dry Weather Flow C.F.S.	C.F.S. Per 1000 Pop.	Method of Treatment
1.	Akron, Ohio	208,435	Little Cuyahoga	..	76	0.36	Imhoff Tanks and Sprinkling Filters.
2.	Calvert, Texas	2,099	Tidwell Creek	..	0	0.0	Separation Tanks, Sprinkling, Final Settling.
3.	Fitchburg, Mass.	41,029	N. Br. Nashua	62	25	0.61	Imhoff Tanks, Sprinkling Filters, Secondary Tanks.
4.	Lincoln, Neb.	54,948	Salt Creek	..	64	1.16	Separate Sludge Digestion, Sprinking Filters.
5.	Madison, Wis.	38,378	Yahara	235	35	0.92	Separate Sludge Digestion Sprinkling Filters.
6.	Sherman, Texas	15,031	Town, Br.	..	0	0	Activated Sludge.
7.	Champaign & Urbana	33,780	Salt Fork	75	0-2.6	0-.08	Imhoff Tanks and Sprinkling Filters.
8.	Columbus, Ohio	260,338 *	Scioto	1,666	30-50	0.12-0.19	Imhoff Taks and Trickling Filters.
9.	Decatur, Ill.	43,818	Sangamon	862	0	0	Imhoff Tanks, Sprinkling Filters, Secondary Settling Tanks.
10.	Oklahoma City	91,295	N. Canadian	..	0	0	Tanks and Trickling Filters.
11.	Dallas, Texas	184,515 *	Trinity	5,950	130	0.71	Imhoff Tanks.
12.	Austin, Texas	34,876	Colorado	37,000	130	3.72	Imhoff Tanks.
13.	Ashland, Ohio	9,249	Jerome Fork	..	3	0.33	Tanks and Sand Filters.
14.	Delaware, Ohio	8,756	Olentangy	..	4	0.46	Tanks and Contact Filters.
15.	Fostoria, Ohio	9,987	Portage Creek	35	3	0.30	Screens, Storage Reservoirs, Sand Filters.
16.	London, Ohio	4,080	Oak Run	..	3	0.73	Tanks, Contact Filters.
17.	Mansfield, Ohio	27,824	Rocky Fork	32	5	0.18	Tanks, Contact Filters.
18.	Plain City, Ohio	1,330	Big Darby Creek	268	3	2.28	Tanks, Contact Filters.
19.	Shelby, Ohio	5,578	Black Fork Creek	40	2	0.36	Tanks, Intermittant Filters.
20.	Westerville, Ohio	2,480	Alum Creek	150	2	0.81	Tanks, Contact Filters.
21.	Crystal Lake, Ill.	2,249	(Creek)	4	0	0.0	Tanks and Sand Filters.
22.	Lexington, Ky.	41,524	Town Br.	..	1.5	0.037	Imhoff Tanks, Trickling Filter.
23.	Houston, Texas	138,276	Brays Bayou	155	5	0.036	Activated Sludge.
Numerical Ave.		....	.....	..	..	0.58	
Weighted Ave.		....	.....	..	..	0.423	

*Population of City and adjoining territory U. S. Census of 1920.

when recommended sewage works have been completed, and ten years thereafter.

With total diversion including dilution water and sewage of	In Year 1935	In Year 1945
4,167 second feet	.65	.5
6,000 second feet	1.1	.9
7,500 second feet	1.5	1.2
8,500 second feet	1.7	1.4
10,000 second feet	2.1	1.7

These figures when compared with the data shown in Table 16 tend to indicate that a liberal amount of dilution is provided by the recommended standard for pollution and the recommended works for purification. It would appear that if this dilution is not sufficient, then the satisfactory disposal of sewage in many of our inland cities is impossible.

Pollution and Fishes:

It is evidently desirable that our streams insofar as possible should be sufficiently pure to permit the continuance of the natural water life thereof, including the fishes. This matter is particularly important in Illinois River which has been the best fish stream in the Middle West. For many years it has supported a commercial fishery with a catch ranging from ten million to twenty-three million pounds per year. About seventy-five per cent of the catch has been the so-called coarser fishes such as Carp and Buffalo. The so-called game fishes have been present in large numbers, and the Illinois River has been the playground of the game fisherman, and is so at present in its lower reaches. Of recent years the commercial catch has materially declined due in part to causes other than sewage pollution.

Inorganic Wastes:

In certain parts of the country inorganic wastes are produced by industries that have poisoned the fishes and entirely destroyed them throughout long stretches of streams. Numerous industrial wastes are poisonous to fishes when present in certain amounts.

Upon the Illinois River, so far as we know, the

inorganic pollution has not reached amounts to be seriously detrimental to fishes.

Organic Pollution:

Certain of the coarser fishes may live and possibly thrive in waters more or less heavily sewage polluted. There is, however, a limit to the suspended organic matters present in waters in which fishes may maintain healthy conditions. All the fishes and the attendant train of water life necessary for their existence are killed, if the air supply in the water is reduced to zero for a sufficient period. This exhaustion of air may result from the decomposition of organic matters.

With a reduction in the dissolved oxygen carried by a stream, the more sensitive fishes, and ultimately all the fishes endeavor to get away. If escape is impossible they die. Some of the so-called coarser fishes may tolerate for a time, conditions in which oxygen is practically exhausted from the water, due to their power to take, store, and use a certain amount of atmospheric oxygen. Other fishes do not have this ability.

During the winter of 1924-5, ice conditions on the Illinois River reduced the dissolved oxygen to figures as low as from .4 to 1.8 parts per million. Under conditions such as this all kinds of fish taken from nets under the ice were found to be dead. At another place where the water contained 2.5 parts per million of dissolved oxygen, only Carp, Buffalo, and Gars were taken alive, all in a stupid condition. In another part of the stream where the oxygen content was 5.4 to 5.8, all fish were found in good condition under the ice.

It is believed that the above figures typify minimum conditions under which the fishes may survive. They probably require more favorable conditions than this throughout most of the year, in order to propagate and thrive.

A study of the graphs and tables of pollution on the Des Plaines and Illinois Rivers herein-elsewhere shown, coupled with a knowledge of the places where fishes may now be found, throw some light upon limits of pollution.

Fishing conditions below Peoria in general are good. Above Peoria fishes are practically extinct except as follows: In seasons of low flow from the tributary streams, the dead line has moved downstream to Peoria and unfavorable conditions have been noted as far south as Havana. In seasons of maximum flow from the tributaries, the dead line moved upstream. It is understood that the 1925 season finds fishes in Peoria Lake, from which they have been largely or entirely absent for several years. This is probably due to the heavy summer flows in 1924.

The study of the river seems to indicate that where the dissolved oxygen exceeds the five-day demand of the organic matter in summer, and considerably exceeds it throughout the remainder of the year that fish may thrive providing that the minimum dissolved oxygen at any time is three parts per million of more.

In the works which we have suggested for sewage treatment at Chicago under various rates of dilution, and the standard herein-elsewhere set down for the liquid discharged by the Drainage Canal at Lockport, we believe that satisfactory fish conditions will be maintained throughout the greater part of the Illinois River. We believe that conditions will permit the coarser fishes to live at all places from Joliet to the Mississippi.

Recommended Standard:

After reviewing all the data which has been available relative to the past conditions which have prevailed in the Illinois River below Lockport, in addition to the studies which have been made and which indicate the sanitary quality of the waters of the streams which are tributary to the Illinois; and, with the purpose in view of seeking a reasonable degree of cleanness in the Illinois River below the terminus of the drainage canal; and, in the belief that the maintenance of such condition is not prohibitive in cost or unduly difficult of attainment; the following standards of maximum pollution are proposed:

The liquid discharged by the Drainage Canal, as

evidenced by the average of representative samples taken for any thirty consecutive days shall:

(a) Be practically free from settleable solids deposited in two hours and

(b) Shall contain dissolved oxygen equal to, or exceeding, the biochemical oxygen demand of said liquid for five days when incubated at twenty degrees Centigrade.

(c) Shall contain not less than three parts per million of dissolved oxygen.

In connection with the second standard relating to the oxygen balance, it is expected that there will be times when a condition of extreme refrigeration will exist in the waters of the canal which may result in a five-day oxygen demand value in excess of the dissolved oxygen content, but it is considered that, with an absence of settleable, putrescible solids in the water and the probability of the presence also of an ample supply of dissolved oxygen, a violation of this standard under these conditions will not be detrimental to the maintenance of proper stream conditions in the Illinois River below the terminus of the Drainage Canal.

It is also suggested in connection with the application of these standards of permissible pollution that sewage treatment devices should not be expected to register maximum efficiency at all times, and that occasionally conditions will arise which will temporarily reduce their efficiency until proper corrective measures can be applied. Fallibility is characteristic of all things human, so that these standards are to be considered, as a rule, with occasional justifiable and unavoidable exceptions."

Pages 79-84:

"Part VI.

REQUIRED DEGREE OF PURIFICATION WITH VARIOUS DILUTIONS.

Our instructions require that we should report upon the purification works necessary under each of several diversions from Lake Michigan; namely

2,000, 4,167, 6,000, 7,500, 8,500, and 10,000 cubic feet per second.

We have been instructed to consider these quantities as stated to be total diversions from the lake, including the water contained in the sewage plus the water used for diluting purposes. Thus practically speaking, the total diversions is equivalent to the dry weather flow discharged at the mouth of the Drainage Canal near Lockport.

Water for Dilution:

For the purpose of this study the amount of water available for dilution in the critical period of the year, July and August, is considered to be the total diversion less the liquid volume of sewage of the Sanitary District. In this computation it will be assumed that the sewage liquid is substantially the same as that which was analyzed in determining the total organic load of the Sanitary District as summarized in Part IV of this report.

In the estimates for purification works hereinafter made, the above total diversions from the lake are considered as constant from year to year. The organic load of the city as shown in Table 12 of Part IV must grow from year to year. Experience indicates that during the hot weather months the sewage has been delivered at the sewer outlets in a condition practically devoid of oxygen. Within ordinary variations in the supply of water per capita, this will probably continue to be the fact. Therefore, with a constant total diversion from the lake and an increase in organic load which is delivered at the sewer mouths devoid of oxygen, the available diluting water will progressively decrease with the growth of the city, and the effectiveness of works for purification must progressively increase as time goes on.

Organic Load and Dilution:

The organic content of sewage for practical purposes must be determined at the point of delivery of the sewers. At this point in warm weather more or less oxidation has already taken place. The analysis represents the organic content of that particular sewage which has passed through a certain history as regards amount of dilution and in other

respects. If the water supply per capita has been less, the analysis would have shown a sewage somewhat stronger in organic load per capita, for less oxidation would have taken place enroute to the sewer outlet. If the water supply per capita had been greater, the analysis would have shown less organic matter per capita, or more dissolved oxygen in the sewage, possibly both.

It is believed that when considering such variations in the use of water per capita as may occur in Chicago, it will be immateriel whether the organic wastes of the city are diluted by water taken into the sewers through the faucet or by water mixed with the sewage at the sewer outlet. It is our opinion, therefore, that it will be logical and proper to take the organic load of the District at the time when the analyses were made; to take the liquid volume of the sewage existing at the time when the analyses were made; to assume that all sewage is delivered to the stream devoid of oxygen; to assume that the liquid volume of the sewage will increase in proportion to the increase in the organic load, namely, that the consumption of water per capita remains constant; and that the available diluting water will be the total diversion less the liquid sewage computed upon the basis as above.

The Sanitary District has made a careful estimate of the total liquid load as of the year 1920 at 758 million gallons. This is equivalent to 253 gallons per capita. We have used the round number 250 gallons per capita in computing Table 17, which shows the total net dilution water available between 1925 and 1945 under the various specified total diversions from 2,000 to 10,000 second feet. The table also shows the available oxygen in the dilution water. These figures are used in Parts XIII, XIV, and XV of this report.

Necessary Purification Plant Efficiencies:

In selecting the type of treatment best adapted to supplement various rates of dilution, it is useful to estimate the average rate of purification that would be required to produce a satisfactory effluent. Upon the following pages we describe the method of calculation, and tabulate the principal results.

The degree of purification of the combined wastes of the Sanitary District of Chicago which must be accomplished in order to make certain specified diversions effective in maintaining proper conditions in the rivers which receive the discharge of the Drainage Canal, is determined on the basis of the daily oxygen required by the entire liquid-borne wastes of the District, and the supply of oxygen furnished daily by any given diversion of lake water.

TABLE 17.

ESTIMATED 'NET DILUTION WATER' WITH VARIOUS 'TOTAL DIVERSIONS' AND OXYGEN AVAILABLE FOR DILUTION IN JULY AND AUGUST.

Year	1925	1930	1935	1940	1945
Estimated volume of sewage delivered to stream devoid of oxygen—sec. ft.	1280	1410	1530	1650	1770
With 2000 sec. ft. Constant Diversion					
Net water for dilution sec. ft.	720	590	470	350	230
Available oxygen lbs. per day	31000	25400	20200	15000	9900
With 4167 sec. ft. Constant Diversion					
Net water for dilution sec. ft.	2887	2757	2637	2517	2397
Available oxygen lbs. per day	124000	118400	113200	108000	103000
With 6000 sec. ft. Constant Diversion					
Net water for dilution sec. ft.	4720	4590	4470	4350	4230
Available oxygen lbs. per day	203000	197000	192000	187000	182000
With 7500 sec. ft. Constant Diversion					
Net water for dilution sec. ft.	6220	6090	5970	5850	5730
Available oxygen lbs. per day	268000	262000	257000	252000	246000
With 8500 sec. ft. Constant Diversion					
Net water for dilution sec. ft.	7220	7090	6970	6850	6730
Available oxygen lbs. per day	310000	305000	300000	294500	289000
With 10000 sec. ft. Constant Diversion					
Net water for dilution sec. ft.	8720	8590	8470	8350	8230
Available oxygen lbs. per day	375000	370000	365000	360000	354000

The basic data for the first part of this computation is recorded in Part IV, Table 12, in which is shown the total oxygen required per day, separately and collectively, by the three polluting elements contributing to the load. This same table also shows the total daily oxygen loads of the entire district for the year 1925, and for five-year intervals to 1945.

One second foot of lake water per day during the warm months of the year (July and August) will supply forty-three pounds of oxygen, and the second feet of lake water required per day during July and August wil be as shown in the first portion of Table 18.

TABLE 18.

SHOWING DAILY OXYGEN LOADS AND DILUTION WATER REQUIREMENTS FOR POLLUTING UNITS.

Polluting Element	Polluting Unit	Pounds Oxygen Supplied During July and August Per Sec. Ft. Per Day by Diluting Water	Pounds Oxygen Required Per Day Per Polluting Unit on Basis of Oxygen Demand For			Second Feet Required Per Day During July and August Per Polluting Unit on Basis of Oxygen Demand For		
			5 Days	10 Days	20 Days	5 Days	10 Days	20 Days
Human Population	1000 Pop.	43	182	240	267	4.23	5.58	6.21
Stock Yards Waste	1 Mil. Gals.	43	5650	7500	8330	131	174	194
Corn Products Waste	1 Mil. Gals.	43	3750	5000	5670	87	116	132

TABLE 19.

SHOWING TOTAL DAILY DILUTION REQUIREMENTS AND PURIFICATION REQUIRED FOR SPECIFIED DIVERSIONS.

	Second Feet Required Per Day During July and August on Basis of Oxygen Demand For			Purification Required on Basis of Following Daily Diversions in Second Feet and for Oxygen Demand Values of 5 Days, 10 Days and 20 Days. (Expressed in Per Cent)																	
				5 Days						10 Days						20 Days					
Year	5 Days	10 Days	20 Days	2000	4167	6000	7500	8500	10000	2000	4167	6000	7500	8500	10000	2000	4167	6000	7500	8500	10000
1925	19,900	26,300	29,300	96.4	85.5	76.3	68.7	63.7	56.2	97.3	89.0	82.0	76.3	72.6	66.8	97.5	90.1	83.9	78.8	75.4	70.2
1930	21,700	28,600	31,900	97.3	87.2	78.8	70.5	67.3	60.4	97.9	90.3	83.9	78.7	75.2	70.0	98.1	91.3	85.6	80.9	77.8	73.1
1935	23,600	31,100	35,800	98.0	88.8	76.8	74.7	70.5	74.0	98.5	91.5	85.6	80.8	77.6	72.8	98.7	92.6	87.5	83.3	80.5	76.3
1940	25,300	33,400	37,200	98.6	90.0	83.2	76.9	72.9	67.0	98.9	92.5	87.0	82.5	79.5	75.0	99.1	93.2	88.3	84.3	81.6	77.6
1945	27,100	35,900	40,000	99.1	91.1	84.4	78.9	75.2	69.6	99.6	93.3	88.5	84.0	78.5	77.1	99.4	94.0	89.4	85.7	83.2	79.4

Taking, for instance, the second feet per day required for the year 1925, Table 12 of Part IV shows the total daily oxygen requirement on the five-day demand basis to be 856,000 pounds, consequently, 856,000 pounds divided by forty-three pounds gives 19,900 as the second feet required per day for untreated sewage.

Table 18 shows the daily oxygen loads for the polluting unit of each polluting element; also the second feet of water required per day during July and August for each polluting unit. These months were selected for use because they represent the critical period of the year both as regards oxygen supply and demand.

If it is desired to determine the pounds of oxygen available in one second foot of lake water per day, the result is secured by multiplying as follows:

Parts per million of dissolved oxygen in water $\times$ 0.646 M. G. in one second foot per day $\times$ 8.33 pounds per gallon, or parts per million of dissolved oxygen in water $\times$ 5.4.

The factor 5.4 is the product of 0.646 $\times$ 8.33 and is a constant.

Table 19 shows the second feet required per day during July and August for five-year periods from 1925 to 1945, and for five, ten and twenty-day oxygen demand values. The five-day demand is sixty-eight per cent of the twenty-day demand and the ten-day demand is ninety per cent of the twenty-day value. It is assumed in this computation that the strength of the polluting unit of each polluting element will remain the same during the period of time involved.

The second section of Table 19 shows the purification, expressed in per cent, required for gross diversions of 2,000, 4,167, 7,500 8,500 and 10,000 second feet per day and for oxygen demand values of five, ten and twenty days.

The computation showing the percentage of purification required, is simply one of subtraction and division, and may be illustrated by taking the first value in the table; viz., 96.4 which is arrived at as follows:

19,900 second feet —(2,000 second feet — 1,280 second feet) divided by 19,900 or 96.4%.

The percentage values in this table are carried to the first place beyond the decimal; however, this is not intended to imply that this degree of refinement should be followed in the use of these values as they constitute simply a record of a mathematical computation.

With these data in hand and a knowledge of practicable plant efficiencies, it is possible to select the types of treatment works that would produce required results.

Seasonal Variations:

All the computations hereinabove made refer to the critical season of the year, namely, the warm months of July and August. In the winter time each unit of lake water will carry about double the amount of oxygen available during the critical period. Furthermore, oxidation takes place at a slower rate during the cooler months of the year and the sewage is thus afforded the opportunity to travel further downstream, to be subjected to additional aeration and to be mixed with additional tributary waters.

For all these reasons, it is undoubtedly practicable to regulate the diversion from the lake in accordance with the needs of the situation existing from month to month. All the interests affected by diversion of water from the lake are concerned only with an average diversion. There appears to be no reason why it will not be entirely practicable to materially increase the flow herein estimated for the warm months of the year should occasion arise, and to save the water thus taken during other months of the year, thus staying within a stipulated average diversion.

Factor of Safety:

It must be admitted that it is not practicable to compute exactly the amount of diluting water that necessarily must be added to the sewage in order to obviate nuisance and to permit a thriving fish life. It is desirable that there should be a factor of safety to provide against error. In our opinion, it will be wise to adopt as the average diversion with various degrees of purification the amounts herein set down as required in the months of July and August, and to

use the additional water available in the cooler months of the year as a factor of safety, thus permitting some increase of the dilution in the hot months to cover,

(a) The possibility of less reaeration in the lower river than herein contemplated.

(b) Washings from the sewers in storm that may be necessarily by-passed from the sewage purification plants.

(c) The accidental depletion in the oxygen in the lower river through the sudden death of green plant growths.

(d) Some degree of inferiority in the diluting water entering through the Sag Canal and other minor drafts on the oxygen supply not specifically considered herein.

Additional Oxygen:

No specific consideration has been given to additional oxygen that may be furnished by the effluent from the sprinkling filter plants and the activated sludge plants. This oxygen will be in addition to that obtained from the lake and from the other sources mentioned.

At the present time practically no aeration is obtained at Lockport in dropping the water from the Drainage Canal into the Des Plaines River in passing through the water wheels. It would probably be possible to add from one to two parts per million to the sewage by an overfall especially designed for aeration. This possibility will occur at all of the dams hereinafter constructed for navigation purposes on the Illinois River except where the water may be used for power purposes."

Page 85:

"Part VII.

PROTECTION OF THE WATER SUPPLY.

It must be a part of any scheme for sewage disposal that the water supply should be protected against any possibility of sewage contamination. Un-

less this is accomplished sewage disposal fails in its principal requirement.

This matter is particularly important to municipalities located on the shores of the Great Lakes. In all of these cities the lakes constitute the only practicable means for municipal water supply. In many instances the lakes are the only practicable means for sewage discharge.

In the Chicago region the means has been provided through the drainage canal, by which the great majority of all impurities are diverted from Lake Michigan. As will be pointed out, certain sources of pollution still remain, and will continue to exist, regardless of any improvements in the Sanitary canal. These sources of pollution are sufficiently great to seriously menace the water supply, unless adequate precautions are taken to guard against them.

Lake Shore Line:

The south end of Lake Michigan is relatively shallow. On the Chicago water front the distance outward for twenty-five feet depth varies generally from half a mile to a mile. The four-mile crib at Chicago stands in thirty-six feet of water. The depth of water is five and eight feet less at the other intake cribs, located at lesser distances from shore. Opposite the mouth of the Chicago River a depth of fifty feet is attained only at seven miles from the shore. Opposite the mouth of the Calumet River the same depth is only attained nine miles out. Opposite Gary the lake is deeper; fifty feet is attained at a distance of four miles from shore.

At the shore line there is a fringe of sand generally varying from ten feet more or less, at Chicago, to about fifty feet in the vicinity of Gary. This sand is a superficial deposit upon a bed of blue clay. The sand layer generaly disappears within a mile or two from shore, and the coating is scattering and thin at this distance out."

* * *

Pages 86, 87:

"*Intakes and Pollution Sources*:

The distance of the Chicago Water Works' cribs

from the mouth of the Chicago River, and Calumet River respectively are as follows:

	Miles from Chicago River Mouth	Miles from Calumet River Mouth
Wilson Ave. Crib	5.2	16
Carter Harrison Crib	2.3	12.7
Chicago Ave. Crib	1.3	12.2
Four Mile Crib	3	9.3
Hyde Park & E. F. Dunn Cribs	8	3.7

About six miles southeast of the Calumet River mouth, the Indiana Harbor canal is located, which taps the Grand Calumet River and discharges more or less sewage into the lake. Between these two points lie the Water Works' intakes of Whiting and Hammond, Indiana. The East Chicago intake is close to the shore, and only a short distance from the Indiana Harbor canal. The Gary intake is one and one-half miles from shore, six miles east of the Indiana Harbor canal and twelve miles from the Calumet River, measured in a direct line.

Sources of Pollution:

From the mouth of the Calumet River, north to the Cook County line, the sewers are now diverted from the lake. North of the Cook County line the towns between Highland Park and Waukegan sewer into the lake, except a small population in Highland Park which sewers inland toward the Skokie Marsh. Most of this sewage reaches the lake in a raw state at present. A portion of it is partially purified. These cities are members of the North Shore Sanitary District, intended to prevent excessive pollution of the lake. Conditions in this locality will probably be somewhat improved hereafter.

Indiana Towns:

The Indiana towns from the State line eastward, including Gary, now contain a population of 180,000. These towns are growing very rapidly. They are the sites of some of the largest industries in the Chicago region. Grand Calumet River is the main sewer of this region. Considerable sewage from the shore population in Hammond and Whiting, and

from several industries, discharges directly to the lake. The entire City of Gary, and the greater part of the sewage in East Chicago and Hammond drains inland and only reaches the lake through the outlets of the Calumet.

Calumet River:

Attention is invited to the Grand Calumet and Little Calumet Rivers, and their relation to Lake Calumet, the outlet of the two streams into Lake Michigan, and the location of the Calumet Sag Channel. The Sag Channel is now designed for 2,000 second feet. At certain seasons of the year this is sufficient to take the sewage of the Chicago Sanitary District reaching it and the entire flows of the Grand and Little Calumet Rivers. In seasons of flood the Sag Channel is very insufficient to take the flow of these streams."

* * *

Page 87:

"A large flood on these streams will undoubtedly wash great quantities of filth into Lake Michigan. The Calumet cities are beginning to study the question of sewage purification. Conditions in the future will no doubt be improved. No practicable means for sewage purfication will place these streams in condition where their waters may be periodically flushed into the water supply of the region even occasionally, with safety to the water supplies."

* * *

Pages 89-92:

"*Water Level Changes*:

Thus the Calumet Rivers and Lake are constantly 'breathing' in and out, toward and from Lake Michigan, depending principally upon the direction and velocity of the winds. In severe storms there are also very important barometric changes causing lake level fluctuations of several feet, bringing out heavy discharges for periods of many hours.

No doubt a similar condition exists where the Indiana Harbor canal taps the Grand Calumet River. This is a wide and deep harbor; only a small differ-

ence in head, an inch or less, is required for the interchange of water between the river and Lake Michigan. The sewage of Gary is supplmented by a large amount of condensing water from the steel mills. A rapid flow is produced in the upper Grand Calumet. The final disposition of this sewage laden water depends upon the stream cross-sections, and the relative elevations of the moment as between the Calumet Rivers and Lake Michigan.

Chance Pollution from Chicago River:

Prior to the construction of the drainage canal, conditions at the mouth of the Chicago River were somewhat similar to those previously described as prevailing in the Calumet region. The floods of the Chicago River have not been accurately measured. It has been estimated that the discharge capacity of the storm water sewers in Chicago makes it possible to produce a flood of about 11,000 second feet. Possibly it may be questioned whether this is so at the present time. If it is not true today it probably will be true as the city becomes improved to a greater extent than at present. With the drainage canal in operation at the rates of flow, which have prevailed during the past ten years, there is little danger of a material amount of flood water reaching Lake Michigan. There have been a few occasions, however, for a short time when a lakeward flow has been noticed following great rain storms. With lesser flows in the drainage canal these occasions would become more frequent and of longer duration.

At the present time lakeward flows of water would be very detrimental to the Chicago water supply. With the general adoption of sewage purification works, and the consequent cleaning up of the Chicago River, the dangers resulting from a lakeward flow of water would be diminished but there would still be a potential danger to the water supply. The purification of the sewage would not be a determining factor in the matter further than to diminish the quantity of filth that might be washed into the lake by flow reversal.

Travel of Pollution in the Lake:

The question as to the travel of pollution in the waters of Lake Michigan has been studied very

thoroughly upon several occasions covering the Chicago water front, the water front opposite the Chicago north shore suburban towns and further north along the lake at Racine and Milwaukee. The results of these studies indicate similar conditions wherever sewage contamination reaches the lake and variable winds and waves are available for dispersion. The net results from these studies are well summed up by Major W. V. Judson in his paper on current in Lake Michigan, (first report Lake Michigan Water Commission, page 67).

> 'In my opinion the currents of Lake Michigan are so irregular in character that nothing would be gained worth the cost if attempt were made to obtain classified further data of a general nature. If it is a question of protecting the water supply of any particular locality, in any event, special study would have to be made inasmuch as the lake currents, available as they are, are much influenced by local conditions.
>
> We do know, and perhaps it is enough for the purposes of this commission, that occasional currents of considerable velocity, say several miles per hour, may be expected to arrive from almost any direction at any point reasonably near either shore of the lake. It is, therefore, apparent that in a general case if the waters of the lake are polluted by the discharge into it of large quantities of sewage, then, practical localities in the lake, even twenty or thirty miles distant from the point of entrance to the sewage, are not safe places in which to derive water for domestic use.'

Numerous special investigations of lake water condition, and the practical experience in the operation of the water works intakes, all indicate that in any particular place reasonably adjacent to the lake shore the quality of the water varies between extremely wide limits, including water almost sterile for considerable periods of time, the usual prevalence of moderately heavy pollution, depending upon the locality, with occasional gross pollutions, regardless of locality within practicable reach of a water works inlet.

Turbidity:

In drawing a continuous supply for the water works, it is necessary to locate the intake not closer than two or three thousand feet from the shore, in order to prevent ingress of sand and stoppages from anchor ice. A large supply must necessarily be taken further from the shore. The Chicago intakes are located from two to four miles outward.

Upon the west shore of Lake Michigan there are long periods of the summer season when the prevailing winds are from the west and southwest. At such times the surface water is blown out into the lake and is replaced by a return current along the lake bottom. At such times as this an exceptionally clear and pure water may be drawn from an intake located at or below mid depth, in twenty-five to forty feet depth.

Severe storms usually occur with an east or northeast wind. The surface water is blown in toward the shore, breakers are formed in the shallow water, the dirty sand and accumulated sludge adjoining the shore are stirred up and the water is returned lakeward as an undertow. The filth is, however, more or less intermixed, from bottom to top of water, in depths under fifty feet. At such times as this no clean or pure water can be obtained; the degree of the turbidity and extent of pollution depends principally upon the severity of the storm and somewhat upon its direction.

Wind conditions varying between the two extremes, which have been mentioned above, produce water conditions varying between the extremes of quality previously mentioned. There are certain conditions in storms when pollution may travel with great rapidity to a Water Works intake. The situation is much like the dissipation of smoke from a tall chimney. In relatively calm weather it may disappear within a short distance from the chimney. Under a current of wind it may stream out in one direction, traveling for miles. Pollution in a lake may travel in similar manner.

Present Condition of the Water Supply:

About two-thirds of the time the water drawn from the Chicago cribs is clear. It is often quite

pure for short periods. However, its sanitary character cannot be depended upon from hour to hour. For a considerable portion of time at all the intake cribs it is distinctly bad. It can only be safely used after heavy doses of liquid chlorine. The required dosage has increased of recent years. Occasionally the Health Department has advocated boiling. The water as delivered to consumers is often decidedly turbid for weeks at a time.

The net result from a sanitary standpoint from the water as chlorinated has been very good, although there have been times when it has been suspected of producing typhoid fever in local instances, apparently due to chance pollution. To a large number of people the taste imparted to the water through the chlorine dosage is extremely objectionable. The demand is becoming stronger from year to year for a water free from the chlorine taste."

* * *

Page 96:

"*Filtration*:

All objection to the present water supply can be eliminated by mechanical filtration, which is practical to apply to the Chicago water supply at a comparatively moderate expense. Filtration will give the citizens of Chicago pure clean water all the time, eliminating all possibility of danger from the chance pollutions of the lake. A number of cities upon the Great Lakes have already installed filtration works, including several of the smaller cities in the Chicago region, also including the cities of Detroit, Cleveland, Lorain, Erie and Niagara Falls. In several cases highly polluted waters are rendered entirely satisfactory for domestic consumption.

Polluted Waters Treated:

At several places on the Great Lakes, lake water is safely filtered after receiving the sewage of the city supplied through intakes removed only a comparatively short distance from the sewage outlets. Cleveland is an example of this type. At Cleveland the water is taken within 19,000 feet from sewer inlets receiving only partially purified sewage.

Upon the Ohio River, city after city, from Pittsburgh to Cairo, takes its water supply from the river, returning the sewage again to the stream, the water being again and again used by the cities downstream after filtration. Table 22 shows a list of these cities with approximately distances measured by river, from sewage outlet to water works intake.

Although it has been felt desirable, and is proper in all cases in the water supply of cities, to select as pure a source as possible even when filtration is resorted to, it has been necessary in some cases to filter more or less grossly polluted water. The results from the sanitary standpoint can safely be said to have exceeded expectations wherever filtration has been resorted to."

* * *

Page 100:

"*Conclusion Regarding Filtration*:

Chicago is entitled to a clean water, safe from a Sanitary standpoint 365 days per year. This standard is generally demanded throughout the United States. It is only a question of time when it will be demanded in Chicago.

In our opinion filtration will insure a pure clean water for Chicago at all times, under any diversion through the drainage canal exceeding 2,000 second feet. It is our belief that no amount of diversion up to the present capacity of the Chicago drainage canal will insure safe water for Chicago without filtration. We believe this is true regardless of any practicable measures that may be taken for sewage purification. We believe it is the only adequate safeguard for the Chicago water supply."

Page 101:

"Part VIII.

SAVINGS EFFECTED BY METERING."

* * *

Pages 112, 113:

"*Effect of Metering Upon Protection of Health*:

Few sanitary engineers will dispute the assertion that $36,000,000 spent for meters and filtration

plants will do more to protect the people of Chicago from water-borne diseases than will an equal or larger amount spent for sewage disposal works.

It has been estimated that with a diversion of but 4167 c. f. s. there would be from seven to eight reversals of flow with discharge of sewage into the lake each year (see memorandum concerning drainage and sewage conditions at Chicago, Sanitary District, December, 1923). It is believed to be a safe assertion that seven or eight reversals with filtration would be much less hazardous than the one to four reversals now occurring.

Filtration is the first line of defense against water-borne disease. Its results are positive, continuous and effectual. It has repeatedly demonstrated its ability to safeguard the public health.

Filtration is only practicable at Chicago if universal metering is adopted. Its cost, together with large additional savings, can be recovered by metering. Metering is, therefore urgent to:

(*a*) Protect health against water-borne disease.

(*b*) Enable the water plant to furnish adequate service and pressure.

(*c*) Prevent wasteful expenditures for the water-works.

(*d*) Prevent wasteful expenditures for intercepting sewers and sewage disposal works."

* * *

Page 114:

"Part IX.

VOLUME OF SEWAGE.

The volume of sewage liquid to be treated is dependent upon:

1st. Tributary population.

2nd. The total water use, and

3rd. Infiltration.

So far as the sewage contributed by the domestic population of the Chicago Sanitary District is concerned, practically the entire amount will be collected in the five major sewage disposal plants; viz. The Des Plaines, Calumet, North Side, West Side

and Southwest Side. The distribution of the population for the present and for each five year period up to 1945, is shown on Table 27.

It will be noted that the total population tributary to these five major plants is somewhat less than the total population of the district as estimated in Part III, and as shown in this table. It is estimated that approximately 105,000 people residing in the district are not tributary to any one of these five plants at the present time, and that it is probable, due to the rapid expansion of the suburban area, that this number will gradually increase and reach approximately 300,000 people by 1945. The sewage originating from this population must either be treated by outlying plants or by pumping to one of the major plants."

* * *

Page 119:

"Part X.

FUTURE INTERCEPTING SEWER CONSTRUCTION.

At the present time there are approximately 150 sewer outlets emptying into the Chicago River and the Drainage Canal. The outlets on the North Branch as far south as Fullerton Avenue are all to be intercepted by the North Side intercepting sewers for which contracts have already been let. These intercepters serve the North Side treatment works. The present outlets from Fullerton Ave. South and West along the river and main Drainage Canal as far as the village of Summit, are yet to be intercepted and the dry weather flow carried to the proposed West and Southwest Side disposal plants to be located in the vicinity of Summit.

All but about thirty-five miles of the total length of intercepters required have already been built. Of this thirty-five miles, twenty miles will be required to collect the sewage and carry it to the West Side plant and fifteen miles will be required for the Southwest Side plant.

Basis of Intercepter Design:

A glance at the map, Figure 3, shows the routes of the proposed West and Southwest Side intercepting

sewers. In general they parallel the river and the Drainage Canal, extending along both sides of these channels from Fullerton Ave. on the North Side, southerly to the main channel where they are joined by intercepters laid from the lake westerly, thence through the highly congested central district and along the Drainage Canal to the vicinity of Summit.

In most of this length the congestion is such as to almost preclude open cut methods of construction. The Sanitary District has accordingly adopted tunnel methods of construction, for which the heavy clay soil of this district is admirably adapted. The tunnels are in general at shallow depths below the street surface.

Other cities such as Milwaukee, Detroit and Cleveland are using tunnel rather than open cut methods quite largely. On paved streets in Milwaukee it has been found economical to use tunnels in constructing pipe sewers as small as ten inches or twelve inches in diameter.

With the conditions prevailing in Chicago, the adoption of tunneling rather than open cut methods will probably be economical, and will greatly reduce inconvenience to the public."

* * *

Pages 128-133:

"Part XI.

METHODS OF SEWAGE DISPOSAL AND PRACTICABLE EFFICIENCIES.

Why Sewage is Treated:

The water-borne wastes of a city are given the general designation of sewage; however, in recent years the tendency has been to restrict the meaning of the word sewage to those wastes produced by household activities and to designate other water-borne impurities as industrial wastes. In this discussion the word sewage will be used as inclusive of both domestic and industrial water-borne wastes.

Sewage is composed of more than ninety-nine per cent of water and less than one per cent of soluble, colloidal, and solid constituents. These latter constituents, in turn, are partly inert or stable and

partly organic or unstable. The unstable constituents of sewage are those which create sight and smell nuisances in overtaxed watercourses, and these unstable constituents may be rendered partially or wholly innocuous or inert by subjecting them to proper processes of treatment.

The destruction of the unstable constituents of sewage is a bacterial function which may be carried out in a watercourse or in treatment works in which satisfactory conditions are provided for bacterial activity. The processes by which unstable sewage constituents are destroyed in a stream are the same as those which result in their destruction in treatment works.

An important condition governing the bacterial destruction of sewage is that of oxygen supply, and in general, it may be said that in the presence of an ample supply of oxygen the process of destruction will proceed to completion in an inoffensive manner, and that in the absence of an ample supply of oxygen, the process of destruction will result in the production of offensive odors. In other words, aerobic conditions favor inoffensive destruction, whereas anaerobic conditions favor offensive destruction.

A somewhat analogous comparison is that of the operation of a steam boiler plant. When the furnace is properly operated, no smoke comes from the stack, but when the air supply is not properly adjusted, large volumes of smoke or unburned carbon come from the stack. A proper adjustment of the opera- of the furnace eliminates the smoke nuisance, whereas an ample supply of oxygen will go far toward eliminating the smell nuisance in the bacterial destruction of sewage.

How Sewage is Treated:

The various agencies involved in the treatment of sewage may in a general way be classified as physical, chemical, bacteriological, and biological, none of which alone would suffice. The physical agencies are those of screening, sedimentation, aeration, diffusion, filtration, evaporation, etc. The chemical agencies are those involved in coagulation, sterilization, and in the mineralization of certain nitrified products. The bacteriological agencies are those in

which the various species of bacteria are the active agents in putrefaction, fermentation, nitrification, and denitrification. The biological agencies are those in which low forms of animal and vegetable life destroy certain constituents of the sewage.

In the various methods of sewage treatment in use today practically all of the above agencies are involved to a greater or less degree. Sewage treatment methods in use today may be classified, in a general way, as follows: screening, sedimentation, sludge treatment, oxidation, filtration and sterilization.

Screening:

As practiced in the United States today, the screening of sewage may be classified on the basis of coarse and fine separation. Coarse screens (two to four inch clear opening) have a negligible value as a purifying process and serve simple to remove coarse solids which might obstruct passageways of pumps or be unsightly in treatment tanks or in a stream. Screens of this character usually remain in a stationary inclined position in the pathway of the incoming sewage and may be cleaned in position or lifted for cleaning.

Fine screens ordinarily have a clear opening of one eighth of an inch or less and usually rotate through the sewage stream. Most of them are power-driven and are provided with self-cleaning mechanism. The work accomplished by the fine screen is intermediate between that accomplished by coarse screening and very rapid sedimentation. The fine screen probably accomplishes less in proportion to its first cost and operating cost than do other methods of sewage treatment, except under certain conditions where fine screens are particularly adaptable.

Sedimentation:

The treatment of sewage by sedimentation has for its object the reduction of the strength of the sewage by the removal of the settleable solids. This is accomplished by passing the liquor through tanks at a very low velocity, which condition is conducive to a settling out of a portion of the solid constituents.

There are two general types of sedimentation tanks in use today; viz., those with one-story and those with two-stories. The one-story tanks are further divided into three classes, viz., those with large capacity for the sludge deposits which are removed at infrequent intervals, those with small capacity for the sludge deposits which are removed at frequent intervals, and those which are provided with a rotating and scraping mechanism for continuous sludge removal.

In the first type of one-story tank the incoming sewage is constantly in contact with actively decomposing sludge for considerable periods of time, and it becomes infected with the products resulting from the decomposition of the sludge. In this type of tank the sedimentation and sludge digestion functions are not separated.

In the second type of one-story tank, the injurious effect of the non-separation of the two functions is greatly reduced by frequent removal of the deposited sludge, while in the third type of one-story tank the separation of these functions is practically complete due to the continuous removal of the deposited solids.

In the two-story type of tank the separation of the two functions is accomplished by having a lower story for sludge reception and digestion and an upper story for sedimentation. The upper and lower stories are so constructed that by an arrangement of sloping bottoms, communicating slots, baffles, and gas vents, the deposited solids enter the lower compartment automatically and the digestion process may proceed without interfering with the sedimentation process and without infecting the incoming sewage. The two processes thus proceed harmoniously, but sludge withdrawals must be made at proper intervals. In many of the installations of this type, more or less serious trouble from foaming at the gas vents has been experienced and corrective measures to date have only been partially successful.

Sludge Treatment:

Solids removed from sewage by the sedimentation process are usually designated as sludge, which, in composition, consists of from ninety to ninety-eight

per cent water, and from two to ten per cent of dry solids.

The treatment and final disposal of sludge is one of the most troublesome problems of sewage disposal. As sludge increases in moisture content, the volume produced per million gallons of sewage treated increases very rapidly. If the volume of sludge produced per million gallons of sewage be taken at 1.0 when the moisture content is eighty-five per cent, the approximate volumes for higher moisture content would be as follows: For ninety per cent sludge 1.5, for ninety-five per cent sludge, 3.0, and for ninety-eight per cent sludge 7.5; consequently those processes of sewage treatment which produce sludge of high moisture content, impose the burden of a treatment of large bulk per unit of dry solid content.

There are four general methods of sludge treatment in use today, viz., 1st, lagooning on land, 2nd, pumping into scows and disposing of it by discharging it into deep water at sea, 3rd, partially dewatering it on specially constructed sand filters, after which it may be used to fill waste places or spread on farm land and plowed in, 4th, partial or complete dewatering by pressing, centrifuging, or drying, after which it may be used as a fertilizer, or for filling in waste places.

The disposal of sludge at sea is obviously a method of limited availability. A high degree of dewatering of sewage sludge through the use of presses, centrifuges, and driers, with the intention of producing a marketable fertilizer, has as yet to be demonstrated as a feasible undertaking. The city of Milwaukee, after a thorough and painstaking study of sludge dewatering processes and the fertilizing value of sludge produced by the activated sludge method of sewage treatment, definitely committed itself to the production of fertilizer sludge and now has a very complete dewatering plant well under construction.

The treatment of sludge by methods Nos. 1 and 3 has been practiced most extensively in the United States with varying degrees of success. The chief difficulty which has attended the use of these methods

of sludge treatment has arisen by reason of the fact that inadequate disposal areas have been provided.

Oxidation:

There are four methods of sewage treatment which might be termed 'finishing processes,' and which result in varying degrees of stabilization of the soluble, colloidal and solid constituents of the sewage. In each of the four methods of treatment, the several constitutents of the sewage are changed from an unstable to a stable condition largely by bacterial activities.

The four methods of securing a finishing treatment of sewage are the sand fileter, the contact bed, the tricking filter, and activated sludge. These four methods of treatment vary widely in capacity per unit of area, and taking the capacity of the sand filter per acre of area as 1.0, the relative capacities of the other methods of treatment per acre of area are approximately as follows: Contact beds, 7.0, trickling filters, 20.0, and activated sludge, 150.0.

The sand filter when properly designed, constructed, and operated produces an effluent which is clear and sparkling, practically free of suspended matter, very low in bacterial content, highly nitrified, and with an oxygen demand which is so low as to obviate any dilution requirements in a stream. Treatment of the sewage of the Sanitary District of Chicago by sand filters preceded by clarification in settling tanks would require at the present time not less than 8,000 acres.

The contact bed is an oxidizing device and consists of a square or rectangular tank filled with coarse broken stone or other suitable material of varying depth and operated ordinarily on a fill-and-draw plan. The effiuent from which the contact bed is ordinarily not clear or well nitrified, has a comparatively high bacterial count, and an oxygen demand which requires some dilution for stability. Not less than 1,200 acres would be required to treat the sewage of the Sanitary District of Chicago for the year 1925, in addition to clarification in settling tanks.

The trickling filter is an oxidizing device similar to the contact bed in general construction but differ-

ing in the method of dosing. The tricking filter is dosed by a system of distribution pipes operated under a head and terminating with open spray nozzles properly located and spaced to give uniform distribution over the entire surface. The sewage is sprayed into the air and falls on the broken stone or other filtering medium through which it trickles to the underdrains which carry it away. The cycle of operation consists of a short dosing period, followed by a short resting period. Trickling filters which are properly designed, constructed and operated will produce effluents having a substantial total bacterial count, a varying suspended matter content, a marked reduction in oxygen demand, and often with a balanced oxygen relation if the applied sewage is not particularly strong. Not less than 400 acres of sprinkling filters would be required to treat the sewage of the Sanitary District of Chicago for the year 1925, in addition to a previous clarification in settling tanks.

The activated sludge process is a comparatively recent modification of older processes, and might be termed an accelerated bacterial treatment in water. The only sizable plants of this character in operation in the U. S. today are the two municipal plants at Houston, Texas. The literature describing the results of the experimental studies which have been made of this process is quite voluminous. Experimental plants of this character, which have been operated on both large and small scales, have given very promising results, and enough confidence in the process has arisen to justify its adoption for several very large installations.

The principal operations in this method of treatment are coarse screening, grit removal, fine screening, aeration in tanks, sedimentation, sludge aeration, return of a portion of the activated sludge to the aeration tanks, and treatment and disposal of the excess sludge.

The final effluents from this method of treatment as produced experimentally and by a small number of municipally operated plants have resembled sand filter effluents with the exception that they have or-

dinarily not been so completely nitrified. The production of an effluent which will not need dilution falls within the scope of the possibilities of this method of treatment. The degree to which sewage may be rendered stable by this method of treatment is capable of some adjustment. This method of treatment is one in which careful and experienced supervision is especially desirable.

Sterilization:

It is possible to effect a removal of from ninety to ninety-five per cent of the total number of bacteria in sewage by treatment with a sterlizing agent. The efficacy of sterilization will be governed by the size of dose, the comminution of the solids of the sewage, the distribution of the sterilizing agent, and the thoroughness and sufficiency of the contact of the sterilizing agent with the sewage.

Experience with the sterilization of sewage to date seems to indicate beyond doubt that it can be relied upon only to provide a lessening of the burden of water purification where a contact exists.

Sterilization destroys bacteria but effects no marked reduction in the organic load, consequently the sterilization of sewage has no marked effect on stream dilution requirements."

* * *

Pages 137-144:

"*Sedimentation and Sand Filtration:*

The treatment of sewage by sedimentation and sand filtration in the United States today is, with one exception, limited to small municipalities and institutions. Numerous small plants of this character are in service today but definite information relative to rates of treatment and operating results is very scarce.

The largest sewage sand filter plant in the U. S. today is the municipal plant at Worcester, Mass., where, during the year 1923, 64.7 acres of sand filters were operated at an average daily yield of 55,000 gallons. A portion of the sewage of Worcester

is treated by sand filtration by reason of the fact that natural sand areas are available.

The average results secured at Worcester, during 1923, by the sand filtration treatment were as follows:

Reduction in total albuminoid ammonia,	89%.
Reduction in total suspended solids,	100%.
Reduction in total oxygen consumed,	90%.

These average results represent a very high degree of treatment, with probably a negative dilution requirement.

Sedimentation and Sprinkling Filters:

The sprinkling filter, almost without exception, is dosed with clarified sewage and the effluent from the filter is often given a final clarification before being discharged into a watercourse. The improvement effected by tanks and sprinkling filters with and without final sedimentation is shown in Table 32.

An inspection of this table will show that of the total amount of suspended solids removed by tanks and sprinkling filters, eighty-five per cent is removed by the tanks and fifteen per cent by the filters. In the reduction of the oxygen demand by tanks and filters, the results in Table 32 show that of the total reduction, forty-five per cent comes from the tank treatment and fifty-five per cent from the sprinkling filter treatment. If the two Atlanta and the Baltimore results are eliminated, the ratio is for tanks forty per cent and for sprinkling filters sixty per cent.

A further inspection of this table will show that the reduction in oxygen demand in parts per million by tanks, with Baltimore results excluded, will vary, on the basis of average results, from thirty to sixty parts and that the reduction in oxygen demand by sprinkling filters, with the Atlanta results excluded, will vary, on the basis of average results, from seventy to ninety parts. The reduction by combined treatment in tanks, sprinkling filters, and final settling basins, with the Atlanta results excluded, will vary, on the basis of average results, from ninety to 135 parts. From a study of the best results obtain-

able, and as recorded in Table 32, a reasonable expectancy from tanks, sprinkling filters and final settling basins is as follows:

Removal of total suspended solids, 75% average result.

Reduction in oxygen demand, 85% average result.

Reduction in oxygen demand in p.p.m., 130 average result.

Data relative to the reduction in the number of bacteria by this method of treatment is limited to the total counts which have been made at the Baltimore sewage works for a number of years. Average values for a period of nine years from 1912 to 1920, inclusive, at the Baltimore sewage works are as follows:

Reduction in the total count on plain agar, 67%
Reduction in acid forming bacteria, 90%

TABLE 32.

SHOWING IMPROVEMENTS EFFECTED BY TANKS AND SPRINKLING FILTERS WITH AND WITHOUT FINAL SEDIMENTATION.

	Location	By Tanks	By Sprinklers	By Basins	By All
Total Suspended Solids Removal in % of Total	Atlanta.....(B)	37	23	..	60
	Atlanta.....(B)	70	13	..	83
	Columbus.....(B)	55	10	..	65
	Fitchburg.....(A)	79	4	3	86
	Lexington.....(A)	60	16	5	71
	Baltimore.....(A)	56	6	16	78
Oxygen Demand Reduction in % of Total	Atlanta.....(B)	63	31	..	94
	Atlanta.....(B)	62	31	..	93
	Columbus.....(B)	25	55	..	80
	Fitchburg.....(A)	38	49	..	87
	Lexington.....(A)	40	49		89
	Baltimore.....(A)	3	67	10	80
Reduction in Oxygen Demand in p. p. m.	Atlanta.....(B)	32	16	..	48
	Atlanta.....(B)	39	19	..	58
	Baltimore.....(A)	4	76	11	91
	Columbus.....(B)	39	87	..	126
	Lexington.....(A)	57	71		128
	Fitchburg.....(A)	59	75	inc.	133

(A) Tanks, sprinkling filters and final settling basins.
(B) Tanks, and sprinkling filters.

Sedimentation and Contact Beds:

Accurate operating results for tanks and contact beds are very limited; however, in Table 33 are shown the analytical data secured by the U. S. Public Health Service from a ten to twelve days' study of the Alliance, Ohio and Canton, Ohio, sewage works which employ this method of treatment. The average results from these two plants show that the improvement effected by this method of treatment was as follows:

Reduction in total suspended solids,	85%.
Reduction in oxygen consumed,	71%.
Reduction in oxygen demand,	80%.

The contact beds of these two plants treat between 600,000 and 700,000 gallons per acre per day, which is about one-third of the volume that can be treated satisfactorily by a sprinkling filter per acre per day.

Activated Sludge:

It is difficult to set a standard of practical efficiency for the activated sludge treatment of sewage without relying considerably on results secured by numerous experimental installations. Little doubt exists today as to the soundness of the principles involved, but some doubt does exist relative to the methods and appliances proposed for carrying out these principles. Machinery plays a greater part in this method of sewage treatment than in any other method in common use; also a very extensive air distribution system must be used, which comprises valves, pipes of many sizes, and in all cases final air outlets which are extremely small. The coefficient of dependability of some features of this process may be said to be somewhat uncertain; however, the several features of this process have been very carefully investigated by so many competent chemists and engineers and their conclusions have been so well founded that its adoption as a practical method of sewage treatment seems to be based on sound judgment.

In Table 33 will be found analytical data secured from a ten to twelve-day study of the north side and south side plants at Houston, Texas, analytical

TABLE 33.

SHOWING IMPROVEMENT IN SEWAGE EFFECTED BY SEVERAL PROCESSES.

Method of Treatment	Location of Works	Year	Period Covered	Total Suspended Solids P. P. M.			Settleable Solids Cu. Cm. Per Litre			Oxygen Consumed 30 Minute Boil			Biochemical Oxygen Demand Parts Per Million				
				Influent	Effluent	% Removed	Influent	Effluent	% Removed	Influent	Effluent	% Removed	Influent	Effluent	% Removed	Temp. Inc. Degrees C.	Days Incubated
Activated Sludge	Houston, North Side	1922 1923	2 Years	310	32	90	.....	.....	.....	.....	.....	.....	140	10	93	.....	5
	South Side	1922 1923	2 Years	166	8	95	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	5
	Houston, North Side	1920	12 Days	200	17	93	2.5	.....	.....	45	10	78	115	11	90	20+	5
	South Side	1920	10 Days	226	7	97	2.1	.....	.....	38	6	84	112	7	94	20+	5
	San Marcos, Texas	1920	10 Days	110	3	97	2.2	.....	.....	29	85	71	67	16	76	20+	5
	Sherman, Texas	1920	11 Days	264	76	71	5.0	3.4	32	64	32	50	202	40	80	20+	5
	Des Plaines**	1922 1924	23 Mos.	160	38	77	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Tanks-Sprinkling Filters	Atlanta, Int. Cr.	1920	11 Days	106	42	60	2.4	Tr.	100—	35	10	71	62	4	93	20+	5
	Atlanta, Peach. Cr.	1915 1920	1 Year 11 Days	140 226	44 38	68 83	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	Baltimore	1913 1915 1920	2½ Years 12 Days	125 159	58 41	54 74	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	Columbus	1912 1920 1920	9 Years 11 Days	177 206	39 81	78 55	.....	.....	.....	.....	.....	.....	114 190	23 49	80 74	37 20+	1 5
	Fitchburg	1909 1924 1920	16 Years 11 Days	229 297	80 42	65 86	.....	.....	.....	.....	.....	.....	205 154	37 21	82 85	37 20+	1 5
	Lexington	1919 1923 1920	5 Years 9 Days	222 166	25 48	89 71	.....	.....	.....	139 32	52 10	63 69	.....	.....	.....	.....	.....
	Lincoln	1924	1 Year	299	131	56	3.3	1.1	67	.....	.....	.....	.....	.....	.....	.....	.....
	Reading	1920	10 Days	145	31	78	2.0	Tr.	100—	45	14	69	118	15	87	20+	5
Tanks Contact Beds	Alliance, O.	1920	12 Days	152	17	89	2.0	Tr.	100—	38	11	71	92	20	78	20+	5
	Canton, O.	1920	10 Days	261	41	81	5.3	Tr.	100—	61	8	71	213	37	82	20+	5

**Sanitary District of Chicago.

results secured from a two years' operation of the same plants, analytical results of a ten to eleven-day study of the plants at San Marcos, and Sherman, Texas; also results of twenty-three months of operation of the Des Plaines River plant of the Sanitary District of Chicago. The Des Plaines plant has been operated on a combined routine and experimental basis, consequently the results are probably not such as might be secured if it had been operated with a single purpose in view.

Omitting from consideration the results from the Des Plaines and Sherman, Texas, plants, the results recorded in Table 33 indicate an improvement from this method of treatment as follows:

Removal of suspended solids, 94%
Reduction in oxygen consumed, 81%
Reduction in oxygen demand, 92%

The north side and south side plants at Houston, Texas, treat approximately six million and one and one-half million gallons per day, respectively. The San Marcos, Texas, plant treats approximately 200,000 gallons of sewage per day.

The use of the activated sludge process for the treatment of packing and stockyards sewage has been tested experimentally by the Sanitary District of Chicago, and the improvement effected, as based on data recorded on pages 47 and 134 of the Report on Industrial Wastes from the Stockyards and Packingtown in Chicago, Vol. 2, 1921, San. Dist. of Chicago, is as follows:

Removal of total suspended solids, 91%.
Reduction of oxygen demand, 96%.
Reduction of organic nitrogen, 83%.

Warm Weather Efficiencies:

In view of the fact that during warm weather there is an acceleration of bacterial activities both in polluted streams and in bacterial processes of sewage treatment, it is evident that dilution requirements in a stream during warm weather are at the maximum, and, for the same reason, it would seem that the efficiency of sewage treatment would be higher wherever bacterial processes are involved.

TABLE 33—Continued.

SHOWING IMPROVEMENT IN SEWAGE EFFECTED BY SEVERAL PROCESSES.

	Location of Works	Year	Period Covered	Organic Nitrogen Parts per Million			Dissolved Oxygen Parts Per Million		Nitrogen As $NO_2 + NO_3$ P. P. M.		Chlorine, P. P. M.	Ether Soluble Matter P. P. M.	Alkalinity, P. P. M.	Contributing Population	Average Daily Vol. Treated in M. G.
				Influent	Effluent	% Remove	Influent	Effluent	Influent	Effluent					
Activated Sludge	Houston, North Side	1922 1923	2 Years	.....	.....	.....	0.0	4.1	0.0	3.5	.....	.....	.....	.....	5.16
	South Side	1922 1923	2 Years	.....	.....	.....	.....	.....	0.0	10.6	.....	.....	.....	.....	1.58
	Houston, North Side	1920	12 Days	.....	.....	.....	0.2	5.2	.....	4.6	136	39	270	80,000	6.00+
	South Side	1920	10 Days	.....	.....	.....	0.8	7.4	.....	6.0	101	36	304	20,000	1.50+
	San Marcos, Texas	1920	10 Days	.....	.....	.....	2.8	7.6	.....	8.8	83	18	306	2,500	0.20+
	Sherman, Texas	1920 1922	11 Days	.....	.....	.....	2.5	6.2	.....	1.2	129	69	415	.....	0.33+
	Des Plaines**	1924	23 Mos.	8.05	2.22	72	.....	.....	.....	8.5	.....	.....	.....	.....	.....
Tanks-Sprinkling Filters	Atlanta, Int. Cr.	1920	11 Days	.....	.....	.....	0.0	5.4	.....	3.1	93	104	77	.....	.....
		1915	1 Year	.....	3.6	.....	.....	.....	.....	5.6	.....	.....	.....	50,000	.....
	Atlanta, Peach. Cr.	1920	11 Days	.....	.....	.....	0.0	5.7	.....	2.1	86	83	68	.....	.....
		1913 1915	2½ Years	.....	2.9	.....	.....	.....	.....	6.3	.....	.....	.....	80,000	.....
	Baltimore	1920	12 Days	.....	.....	.....	0.2	5.2	.....	4.2	86	40	136	.....	.....
		1912 1920	9 Years	.....	.....	.....	.....	.....	.....	6.8	.....	.....	.....	.....	.....
	Columbus	1920	11 Days	.....	.....	.....	1.7	4.8	.....	0.6	113	100	211	.....	.....
		1909 1924	16 Years	.....	.....	.....	.....	.....	.....	4.0	.....	.....	.....	.....	.....
	Fitchburg	1920	11 Days	.....	.....	.....	0.3	7.9	.....	6.1	70	63	97	.....	.....
		1919 1923	5 Years	*4.75	1.49	69	.....	.....	0.9	8.5	61	.....	.....	.....	.....
	Lexington	1920	9 Days	.....	.....	.....	0.1	5.2	.....	.....	89	58	196	.....	.....
	Lincoln	1924	1 Year	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	Reading	1920	10 Days	.....	.....	.....	.....	3.7	.....	5.1	105	25	164	.....	.....
Tanks Contact Beds	Alliance, O.	1920	12 Days	.....	.....	.....	3.0	5.7	.....	2.8	47	37	184	.....	.....
	Canton, O.	1920	10 Days	.....	.....	.....	0.5	0.7	.....	0.3	79	62	342	.....	.....

*Albuminoid Ammonia.
**Sanitary District of Chicago.

A study of the average monthly efficiencies at the Baltimore works for a period of nine years, the sand filtration treatment at Worcester, Mass., for 1923, and the Columbus works for the year 1913, indicate that the average efficiency for June, July, August and September is above the average efficiency for the year in the following amounts:

Baltimore, four per cent; Worcester, three per cent; Columbus, three per cent.

An average efficiency for the warm weather months of the year, of three per cent above the average annual efficiency is a reasonable assumption for sand filter, contact bed, sprinkling filter and activated sludge treatment.

Conclusion on Efficiency:

In consideration of treatment works for the largest sewage disposal plant in the world, we believe we are warranted in expecting the best of operating results. We conclude that it will be practicable to secure the following net efficiencies in the proposed Sanitary District plants, in the warm or critical season of the year, expressed in percentage of the biochemical oxygen demand removed from the sewage compared to sewage as delivered before treatment.

Tankage,	35%
Tanks and Sprinkling Filters,	88%.
Activated sludge on Domestic Sewage,	92%.
Activated sludge on Stock Yards waste,	95%.

Applicability of Other Means of Sewage Disposal:

The subject of sewage disposal for Chicago would not be complete without consideration of certain means for sewage disposal that have been extensively used abroad but which are not considered to be adapted to the local situation at Chicago, particularly when taking into consideration the expenditures that the Sanitary District has already made. We believe it will be useful, briefly to outline these methods of disposal and to show why it would not be practicable or economical to adopt them.

Broad Irrigation:

The oldest method of sewage purification is the

disposal of the sewage upon farm or garden land, commonly called Broad Irrigation. The sewages of Berlin and Paris are thus treated, and the method has been extensively used in Germany, France and England.

Inapplicable to Chicago Conditions:

If Broad Irrigation should be adopted for Chicago, about 60,000 acres or ninety-three square miles, would be required under the average rate of application to land as practiced in England, where, in general, available land contains more or less clay.

If sandy lands could be found, similar to that available for sewage disposal at Berlin, about 25,000 acres or thirty-nine square miles, would be required. It is believed that no such large areas are available, without carrying the sewage a long distance from Chicago.

No surface soils of a sandy nature are available nearer to Chicago than the east line of Gary, which is approximately forty miles distant from the Chicago loop district. A sufficient area could probably be found east of Gary, but the land is very rough and large expenditures in grading, or in pumping, would be required to make it useful.

A sewer about twenty-five feet in diameter would be required to accommodate the present total sewage of the Sanitary District. This sewer would cost about $1,500,000 per mile. Approximate estimates indicate that the initial investment in an outlet sewer and pumping works alone would exceed the cost of the intercepting sewers and the more modern methods of sewage disposal, for which we have previously estimated the costs. In addition it would be necessary to purchase the lands and put them into condition to receive sewage.

Site Below Joliet:

Before the drainage canal was built the suggestion was made to carry the Chicago sewage through a tunnel and dispose of it by gravity upon lands adjacent to the Des Plaines River below Joliet. This might have been possible with the quantities of sewage produced by Chicago thirty or forty years ago.

At the present time it would not be possible to find an acreage sufficiently large to treat the sewage by Broad Irrigation, delivering the sewage by gravity flow. Lands might be found to which the sewage could be pumped.

The land at this location is of a sandy and gravelly nature. It would probably be well adapted to sewage farming. Rough estimates indicate that the cost of development, including tunnel and pumping, would not be less than the figures previously given covering sewage farming on the lands east of Gary. Therefore the costs would materially exceed the costs of works, herein elsewhere estimated.

Broad Irrigation Not Practicable:

There are other and more important reasons why broad irrigation would not be applicable.

(a) Sewage farming is viewed with disfavor by American health authorities, as dangerous to public health.

(b) Climatic conditions are much less favorable in this region than in Western Europe by reason of the severe winters.

(c) The American public is less tolerant of local nuisances than the European public, and is less inclined to properly maintain its sewage works. A sewage farm would be an intolerable nuisance unless well operated.

Other Disposal Methods:

We have herein elsewhere mentioned contact beds and sand filters as means for secondary purification, which have been more or less extensively used by small cities and large public institutions. Either of these methods, by reason of the large areas required, would necessitate large expenditures for intercepting sewers to carry the sewage to more or less distant and remote locations. We believe that the relative areas required, as stated elsewhere in this report, are sufficient to indicate their higher cost as compared to the methods of sewage purification upon which we have prepared detailed estimates."

* * *

Page 174:

"Part XIV.

REQUIRED WORKS WITH 4167 CUBIC FEET PER SECOND FLOW.

With 4167 cubic feet per second total flow in the Drainage Canal there would be available during the summer months of July and August approximately 113,200 pounds per day of oxygen in 1935 and 103,000 pounds per day in 1945. Of this total it has been shown in Part XIII that approximately 33,415 pounds in 1935 and 39,790 pounds in 1945 would be required to care for the effluent of the Des Plaines, Calumet, North Side, Argo and Stockyards plants. There would therefore be available from the flow of 4167 c. f. s. approximately 79,785 pounds of oxygen per day in 1935 and 63,210 pounds in 1945 to care for the effluents from the West and Southwest Side treatment plants.

The total oxygen requirement of the sewage reaching these plants in 1935 and 1945 is estimated as follows:

	1935	1945
West Side Plant.....	326,000#	349,000#
Southwest Side Plant....	206,500	241,000
Totals.....	532,500	590,000

These totals are seven to nine times the oxygen available from the 4167 c. f. s. flow after the other plant effluent requirements have been satisfied.

The type of treatment adopted therefore must be such that it will reduce the bio-chemical oxygen demand in 1935 by approximately eighty-five per cent and in 1945 by approximately eighty-nine and one-half per cent. The two most practicable methods of accomplishing this reduction are by tank-sprinkling filter plants and by activated sludge treatment."

* * *

Page 180:

"Part XV.

REQUIRED WORKS WITH MISCELLANEOUS FLOWS.

In addition to the channel flows of 10,000 c. f. s.

and 4,167 c. f. s. discussed in detail in Parts XIII and XIV, respectively, we have made studies of the requirements and the costs of sewage disposal with flows of 2,000, 6,000, 7,500, and 8,500 c. f. s.

Required Works with 2,000 *C. F. S. Flow:*

With 2,000 c. f. s. flow there would be available during the months of July and August approximately 20,200 pounds of oxygen per day in 1935, and 10,000 pounds per day in 1945. As hereinbefore shown, the oxygen requirements for the effluent of the Des Plaines, Calumet, North Side, Corn Products and Stockyards plants are 33,415 pounds of oxygen in 1935 and 39,790 in 1945.

Inasmuch as the effluents from the above plants require more oxygen even at the present time than is available in the 2,000 c. f. s. total flow in the channel, it is obvious that there is no practicable means of meeting the requirements of the pollution standard hereinbefore outlined with so small a flow in the channel.

Many cities are so located that standards less adequate are necessarily adopted; however, a pollution standard which provides for a thriving fish life in Illinois River cannot practicably be complied with when the total flow in the Drainage Canal is as low as 2,000 c. f. s."

* * *

Pages 193-195:

"*Summarization of the Construction Period Reasonably Required:*

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.

TABLE 50.

CONSTRUCTION PROGRAM ON LARGE PUBLIC WORKS.

Description	Approximate Cost	Start of Work or Date of Contract	Date of Completion	Period or Construction	Approximate Length	Ave. Exp. per Year in Period
Sanitary District Work:						
Main channel*	$29,700,000	1892	1900	7 yrs.		4,200,000
Calumet-Sag Channel	14,000,000	1911	1922	11 yrs.		1,300,000
North Shore Channel	4,100,000	1907	1910	3 yrs.		1,400,000
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
Calumet Pumping Station	1,500,000	1918	1921	3 yrs.		500,000
Calumet Power Plant	1,165,000	1919	1922	3 yrs.		600,000
Evanston Pumping Station	512,000	1918	1921	3 yrs.		170,000
North Shore Sewer (1)	690,000	1913	1916	3 yrs.	7 mi.	230,000
Evanston Sewer	1,252,000	1916	1919	3 yrs.		400,000
North Side Intercepting Sewers						
Section 1	1,998,000	1921	1922	1 yr.	4 mi.	1,998,000
Section 3	2,625,000	1924	1926**	2 yrs.	1.8 mi.	1,300,000
Section 4	2,111,000	1924	1926**	2 yrs.	1.6 mi.	1,000,000
Section 5	1,498,000	1924	1926**	2 yrs.	1.5 mi.	750,000
Section 6	874,000	1924	1926**	2 yrs.	1.1 mi.	440,000
Chicago Produce Market	17,000,000	1925	1925	6 mo.		34,000,000
Union Station (Chicago) (2)	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
Milwaukee Intercepting Sewer	5,622,000	1915	1923	8 yrs.	33 mi.	700,000
Tulsa Water Supply	6,800,000	1922	1924	2 yrs.		3,400,000
Detroit Filtration Plant (3)	5,480,000	1920	1923	3 yrs.		1,800,000

*Includes cost of Main Channel and Des Plaines River Improvement but not main channel extension.
**Date of completion in contract.
(1) Sewers Built in Tunnel.
(2) Cost of Station only. Does not include cost of terminal arrangements. Total $95,000,000.
(3) Does not include cost of Pump Stations."

EXTRACTS FROM COMPLAINANTS' EXHIBIT NUMBER 18—HOUSE DOCUMENT NUMBER 4, 69TH CONGRESS, 1ST SESSION.

COMPLAINANTS' EXHIBIT 18.

Pages 1-2:

"LETTER
From the
CHIEF OF ENGINEERS, UNITED STATES ARMY
Transmitting
Report of the Board of Engineers for Rivers and Harbors on Illinois River, Ill.

WAR DEPARTMENT,
OFFICE OF THE CHIEF OF ENGINEERS,
Washington, March 29, 1926.

HON. S. WALLACE DEMPSEY,
Chairman Committee on
Rivers and Harbors,
House of Representatives.

MY DEAR MR. DEMPSEY: 1. Referring to letter of the chairman of the Committee on Rivers and Harbors of the House of Representatives, dated April 17, 1924, inclosing a copy of a resolution of the committee dated April 14, 1924, requesting the Board of Engineers for Rivers and Harbors to review the reports submitted in House Document No. 1374, Sixty-first Congress, third session, and No. 50, Sixty-first Congress, first session, and in Rivers and Harbors Committee Document No. 2, Sixty-seventh Congress, first session, and No. 7, Sixty-seventh Congress, second session, with a view to ascertaining and reporting the costs of constructing channels, each 200 feet wide and of 7, 8, and 9 feet in depth, respectively, in the Illinois River, Ill., between Utica and the mouth, including separate estimates for each of the aforesaid channels upon the basis of assumed diversions of water from Lake Michigan through the Illinois River of 2,000, 4,167, 7,500, 8,500, and 10,000 second-feet, respectively; also with a view to recommending such depth and

width and channel in said river which would be most suitable for navigation purposes, the quantity of diversion from Lake Michigan necessary for navigation purposes in said recommended channel; and to report when, assuming all funds for such purpose available, the Sanitary District of Chicago can have in operation sewage treatment plants capable of treating the sewage with the amount of water recommended as necessary for navigation in such recommended channel, I enclose herewith the report of the board, dated March 23, 1926."

* * *

Pages 2-3:

"Question 1. What is the estimated cost of channels each 200 feet wide and of depth of 7, 8, and 9 feet, from Utica to the mouth of the Illinois River, on the basis of assumed diversions of water from Lake Michigan of 2,000, 4,167, 7,500, 8,500 and 10,000 second-feet?

4. The board, in paragraph 7 of its report, discusses in some detail the definition of diversion, its essential characteristics, and the effect of its amount, control, and fluctuations on a navigation plan. These points must be carefully studied to make the problem clear.

5. For any of the three depths referred to in the resolution, the river can be improved by two or more of at least four different methods, viz.: (1) complete canalization, using five locks and dams; (2) partial canalization, using the four existing locks and dams; (3) partial canalization, using the two existing Federal locks and dams and partially removing the two State dams; and (4) open-channel improvement, involving partial removal of all four dams. The district engineer submits estimates on all the cases involved. The division engineer and the board concur in his estimates, subject to the qualifications contained in paragraph 7(e) of the board's report. The following condensed table shows costs for a 9-foot channel:

Method of improvement	Instantaneous maximum diversion Lockport, cubic feet per second	Annual average diversion Lockport, cubic feet per second	Cost, thousands of dollars[1] First cost	Maintenance and operation	Annual charge (maintenance and operation plus 4 per cent first cost)
Complete canalization[2]	1,650	1,000	2,666	226	[2] 333
Partial canalization (State dams out)			5,133	210	415
Complete canalization[2]			2,619	216	[2] 321
Partial canalization (State dams out)	3,300	2,000	5,108	171	375
Open channel			6,050	105	347
Partial canalization (present dams retained[2]			1,914	191	[2] 268
Partial canalization (State dams out)	4,580	3,000	3,697	147	295
Open channel			4,482	97	277
* Partial canalization (present dams retained)			1,383	180	235
* Partial canalization (State dams out)[2]	6,050	4,167	2,262	133	[2] 224
Open channel			3,465	89	277
* Partial canalization (present dams retained)			1,264	178	229
* Partial canalization (State dams out)	7,050	5,000	1,789	130	202
Open channel[2]			2,365	87	[2] 182
Partial canalization (present dams retained)			1,141	168	214
Partial canalization (State dams out)	8,250	6,000	1,349	126	180
Open channel[2]			1,925	80	[2] 157
Partial canalization (State dams out)	10,050	7,500	942	122	160
Open channel[2]			1,540	76	[2] 138
Partial canalization (State dams out)[2]	11,250	8,500	171	114	[2] 121
Open channel			1,320	70	123
Partial canalization (State dams out)	13,050	10,000	171	105	112
Open channel[2]			990	63	[2] 102

[1] On the assumption that the flow is regulated primarily in the interests of navigation.
[2] Indicates method which, considering, first, maintenance and operation costs, is cheapest, in terms of Federal money expended, for the given diversion."

Page 4:

"9. The board points out that the question turns essentially on an arbitrary definition of the degree of purity which is to be required in the waters into which the sewage effluent discharges and the point on the drainage canal or the Illinois River where this degree of purity is to be required. The arbitrary assumption made by the department for the purpose of this report was such that there should be no appreciable nuisance in the Illinois or Des Plaines Rivers due to Chicago Sewage."

* * *

Page 7:

"WAR DEPARTMENT,
BOARD OF ENGINEERS FOR RIVERS AND HARBORS,
Washington, D. C., March 23, 1926.

Subject: Illinois River, Ill.

To: The Chief of Engineers, United States Army.

1. This report is submitted in response to the following resolution, dated April 14, 1924:

Resolved by the Committee on Rivers and Harbors of the House of Representatives: That the Board of Engineers for Rivers and Harbors created under section 3 of the river and harbor act approved June 13, 1902, be, and it hereby is, requested to review the reports submitted in House Documents Numbered 1374, sixty-first Congress, third session, and 50, Sixty-first Congress, first session, and in Rivers and Harbors Committee Documents Numbered 2, Sixty-seventh Congress, first session, and 7, Sixty-seventh Congress, second session, with a view to ascertaining and reporting the costs of constructing channels, each 200 feet wide, and of 7, 8, and 9 feet in depth, respectively, in the Illinois River, Ill., between Utica and the mouth, including separate estimates for each of the aforesaid channels upon the basis of assumed diversions of water from Lake Michigan through the Illinois River of 2,000, 4,167, 7,500, 8,500, and 10,000 second-feet, respectively; also with a view to recommending such depth and width of channel in said river which would be most suitable for navigation

purposes, the quantity of diversion from Lake Michigan necessary for navigation purposes in said recommended channel; and to report when, assuming all funds for such purpose available, the Sanitary District of Chicago can have in operation sewage-treatment plants capable of treating the sewage with the amount of water recommended as necessary for navigation in such recommended channel."

* * *

Pages 12-13:

"Question 4. How much time would be required by the Sanitary District of Chicago to have in operation sewage treatment plants capable of treating sewage with the amount of water recommended as necessary for navigation in such recommended channel?

13. The question turns essentially on the phrase 'capable of treating the sewage.' The question is, what degree of treatment is to be considered satisfactory? The discharge from any form of sewage-disposal works capable of application to a great city like Chicago is an undesirable addition to a river; that is, it will decrease the purity of the river water. Depending on both the form of treatment adopted and the flow of the river, the effect may in the general case be anything from a very slight tainting of the water, quickly disappearing, to a gross and even dangerous nuisance. It is wholly a matter of degree.

14. To give any specific answer, therefore, the department was forced to assume some arbitrary standard. That followed was one which would assure that there should be no appreciable nuisance in the Illinois or Des Plaines River due to Chicago sewage. Based on this assumption, a report was obtained from a firm of expert sanitary engineers, which estimates certain sewage treatment works necessary with certain diversions to produce the required result; these figures, and some additional ones, are submitted by the district engineer. If the works should be made somewhat less efficient or the diversion decreased, or both, some nuisance would presumably develop. How much nuisance,

defined as above, the authorities are prepared to tolerate is a matter beyond the knowledge or purview of the board. It is also to be noted that, even with Chicago's sewage satisfactorily handled, there would still be a material nuisance in the river due to other sources of pollution.

15. It appears that treatment for a 1945 population to give the desired degree of purity can be handled by a suitable combination of the activated sludge method, Imhoff tanks, and trickling filters for diversions as great as or greater than 4,167 second-feet (annual average). For a diversion somewhat less than 4,167 second-feet (the exact figure has not been determined) it would become necessary to have recourse to sand filtration. Treatment can thus be provided for diversions at least as low as 1,000 second-feet. For zero diversion it would be necessary to deliver the effluent into Lake Michigan. The district engineer's report contains cost estimates for the various methods. The cost increases rather slowly as the diversion decreases to the point (somewhere below 4,167 second-feet) where sand filtration becomes necessary, then it increases more rapidly.

16. The question asked is, What time is required to construct the necessary works. The district engineer's estimate is seven years for any method not involving sand filtration or disposal in the lake; *i. e.*, methods practicable for diversions down to about 4,000 cubic feet per second or perhaps somewhat lower; and 10 years for any method involving these. This estimate is based primarily on a reasonable time to make plans and a reasonable rate of expenditure of the sums involved. The division engineer concurs. The board also concurs, and submits this estimate in reply to the fourth question, with the qualification that it is necessarily only an approximation."

* * *

Page 18:

"UNITED STATES ENGINEER OFFICE,
Chicago, Ill., March 3, 1926.

From: The district engineer.

To: The Chief of Engineers, United States Army, Washington."

* * *

Pages 25-27:

"SEWAGE DISPOSAL AT CHICAGO.

30. The last question raised by the resolution is: 'Assuming all funds for such purpose available, when can the Sanitary District of Chicago have in operation sewage-treatment plants capable of treating the sewage with the amount of water recommended as necessary for navigation in such recommended channel?' reference being made to the previous request for a determination of the amount of water necessary for navigation purposes in what was considered to be the most suitable channel in the Illinois River.

31. If the duration of a construction period for an undertaking as large as providing sewage treatment for most of the sewage from the Sanitary District of Chicago is to be estimated with any accuracy, fairly reliable information is necessary as to the best methods to follow, the extent and character of the major operations involved, and the difficulties likely to be encountered which might delay construction. This really is equivalent to an engineering study with a view to preparing a complete sewage-treatment program, including costs of construction and operation of the major facilities to be provided.

32. As a study of this character involved specialized engineering knowledge not immediately available to this office, authority was obtained to employ consulting engineers, and the firm of Alvord, Burdick & Howson, of Chicago, was retained for the purpose. The complete report of this firm is included in this report as Appendix D.

33. The consulting engineers were requested to report on the following:

(*a*) Determination of a pollution standard for the effluent from the Chicago Drainage Canal; this standard to be the lowest that will prevent the occurrence of nuisance in the Des Plaines and Illinois Rivers and will permit a thriving fish life therein.

(*b*) Determination of the extent to which purification measures must be taken by the Sanitary District of Chicago for each of the following average flows in the Chicago Drainage Canal: 2,000, 4,167, 6,000, 7,500, 8,500, and 10,000 cubic feet per second.

(*c*) Determination of the most feasible method of treating the surplus pollution, and, for each flow specified, the cost of the necessary works and the operating costs thereof.

(*d*) Determination of the time that reasonably would be required to build the necessary works for each of the flows specified.

34. It is evident that any program of sewage treatment should look to restoration of better conditions in the Des Plaines and upper Illinois Rivers. Almost universally, public sentiment is rapidly forming against further pollution of streams and is going to require the removal of most of it as soon as practicable. For this reason, in planning the necessary works for the Sanitary District of Chicago, it was felt wise to assume that a material improvement of conditions in these streams would be one of the objects to be attained, and accordingly an investigation was directed along the lines of determining a reasonable pollution standard.

35. The consulting engineers are of the opinion that no appreciable nuisance will result if the following standard is maintained:

The liquid discharged by the drainage canal, as evidenced by the average of representative samples taken for any 30 consecutive days, shall (*a*) be practically free from solids deposited in two hours; (*b*) shall contain not less than three parts per million of

oxygen and enough to equal to exceed the biochemical oxygen demand for said liquid for five days when incubated at 20° C.

Whether adherence to this standard will produce exactly the results desired or not is unknown, but in view of the present extremely unsatisfactory conditions prevailing with upward of 4,000 cubic yards of settleable solids being dumped into the Illinois each day, and with periods of several months each year with no oxygen whatever present in the effluent, there is no question but what conditions will be improved materially. It should be understood that other sources of pollution are contributory to the Illinois River, and that with no contamination whatever from the Sanitary District of Chicago conditions in the Illinois will not be satisfactory until the rest of the communities now discharging their sewage into the system carry out satisfactory sewage treatment programs of their own. It so happens that the adoption of a standard that no appreciable nuisance will result carries with it the restoration of conditions which will permit fish life to thrive.

37. The next questions asked the consulting engineers have to do with the determination of the methods, extent, and costs of sewage treatment applicable for each of the flows in the canal. The following summarizes their findings as regards construction costs for 1935 capacities:

	Cubic feet per second			
Annual average flow at Lockport	4,167	6,000	7,500	8,500 and 10,000
Cost of construction of sewage-treatment works	$69,213,520	$68,726,620	$61,477,920	$57,415,240

38. The consulting engineers are of the opinion that no methods of sewage treatment known to be practicable will maintain the pollution standard unimpaired if the gross average flow at Lockport is as low as 2,000 cubic feet per second. The combined oxygen demand of the effluents from plants providing the most complete practicable treatment

known is considerably in excess of the supply available in 2,000 cubic feet per second. For small-scale operations, sand filtration has been known to provide practically 100 per cent treatment, but the consulting engineers doubt the efficacy of this method on as extensive a basis as would be required for Chicago's sewage, particularly with practically no diluting water available as a factor of safety.

39. For very low diversions it would be possible to conduct the effluents from the sewage-treatment plants through tunnels to an outfall located far out into the lake, remote from the water supply intakes. The advisability of such a procedure is doubtful, in view of the large population involved at Chicago, and the costs would be excessive."

* * *

Page 28:

"EFFECT OF PROPOSED DIVERSION ON CONSERVATION OF NATIONAL RESOURCES.

44. The improvement recommended in the previous paragraphs calls for an appropriation by Congress not only of funds from the National Treasury to defray the costs of construction, maintenance, and operation of the project but also of water from Lake Michigan, a national resource of limited extent, which is of immediate value to navigation on the Great Lakes and of potential value to water-power interests. It is a comparatively simple matter to judge whether the expenditure of funds is justified; it is more difficult to decide how far to go in the utilization of a limited natural resource which has economic values from several points of view.

45. To assist in the decision of this more difficult problem, this report includes as Appendix E a study of the economics of the diversion of water from Lake Michigan. The effect of each of eight different programs of water diversion is evaluated up to the year 1950, taking into consideration the more important economic factors involved, such as navigation, water power, sanitation, and riparian damages.

46. The results of this study are decidedly contrary to a continued diversion of 10,000 cubic feet

per second. On the other hand, they do not favor programs of reduction which result in final diversions as low as 3,000 cubic feet per second or lower (annual averages). The conclusions drawn indicate that the resources of the Nation, capital, fuel, and labor, will be conserved to the best advantage by reducing the gross annual average diversion to 4,167 cubic feet per second, or thereabouts, by the year 1935, and maintaining it at that point thereafter.

47. Apparently the appropriation of water recommended for the improvement of the Illinois River will not be adverse to the interests of conservation of national resources."

* * *

Pages 242-244:

"119. For average diversions below 4,167 cubic feet per second or thereabouts, a very serious damage, to an interest which might be classed as 'riparian,' comes as the result of the reduction in amount of water available for condensing purposes for the large central electric power stations operated by the Commonwealth Edison Co., and its affiliates. The Fisk-Quarry Street group of stations on the Chicago River now utilizes 1,250 cubic feet per second for that purpose; the Crawford Avenue Station now under construction on the main drainage canal, and partly in operation, will require 2,000 cubic feet per second; so that it can be seen that if the flow is reduced materially the requirements of these plants may equal or exceed the entire flow available.

120. To preclude any interference with navigation on the river and canal by this use of water for condensing purposes, the amount used should not exceed one-half of the total flow available; hence, if the flow is materially reduced, the capacity of the stations will be limited and the number of stations and the unit cost of each will be increased.

121. To determine the approximate effect of this condition, in the way of limiting the capacity of existing stations and the size of those proposed, it is first desirable to indicate roughly the distribution of the total flow as it passes through the various intakes

from Lake Michigan, as this distribution will have considerable effect on the availability of water for condensing purposes, at any particular power plant location. A tentative arrangement is indicated in Table 29 which follows:

TABLE 29.

APPROXIMATE DISTRIBUTION OF FLOW FOR LOW DIVERSIONS.

(Flow in cubic feet per second.)

Gross flow at Lockport	Sag Channel	North Branch Chicago River	South Branch Chicago River	Main drainage canal to Summit	DesPlaines River at Joliet
1,000	0	300	300	300	1,500
2,000	0	700	1,100	1,100	2,500
3,000	500	700	1,400	1,600	3,500
4,167	800	700	1,900	2,467	4,667

122. Based on the foregoing distribution of flow through the various intakes and upon information from the power companies as to present and future requirements, the effects of limiting the gross flow at Lockport to 3,000, 2,000, and 1,000 cubic feet per second have been computed in Table 30:

TABLE 30.

DAMAGE TO CHICAGO POWER INTERESTS BY REDUCTION IN FLOW THROUGH DRAINAGE CANAL.

Gross flow at Lockport (cubic feet per second)	Station	Flow at station (cubic feet per second)	Flow available for condensing (cubic feet per second)	Capacity in kilowatts					
				Present	Future	As limited by flow	Amounts affected		
							Present	Future	Total
1,000	Northwest	300	150	165,000	205,000	45,000	120,000	40,000	160,000
	Fisk-Quarry	300	150	314,000	444,000	45,000	269,000	130,000	399,000
	Crawford	300	150	235,000	800,000	60,000	175,000	565,000	740,000
	Calumet	200	100	187,000	210,000	30,000	157,000	23,000	180,000
	Ridgeland	300	150	0	1,000,000	60,000	0	940,000	940,000
	Joliet	1,500	750	50,000	1,000,000	300,000	0	700,000	700,000
	Total effect	..	..	..	..	..	721,000	2,398,000	3,119,000
2,000	Northwest	700	350	165,000	205,000	105,000	60,000	40,000	100,000
	Fisk-Quarry	1,100	550	314,000	444,000	165,000	149,000	130,000	279,000
	Crawford	1,100	550	235,000	800,000	220,000	15,000	565,000	580,000
	Calumet	200	100	187,000	210,000	30,000	157,000	23,000	180,000
	Ridgeland	1,100	550	0	1,000,000	220,000	0	780,000	780,000
	Joliet	2,500	1,250	50,000	1,000,000	500,000	0	500,000	500,000
	Total effect	..	..	..	..	..	381,000	2,038,000	2,419,000
3,000	Northwest	700	350	165,000	205,000	105,000	60,000	40,000	100,000
	Fisk-Quarry	1,900	950	314,000	444,000	285,000	29,000	130,000	159,000
	Crawford	1,900	950	235,000	800,000	380,000	0	420,000	420,000
	Calumet	600	300	187,000	210,000	90,000	97,000	23,000	120,000
	Ridgeland	1,900	950	0	1,000,000	380,000	0	620,000	620,000
	Joliet	3,500	1,750	50,000	1,000,000	700,000	0	300,000	300,000
	Total effect	..	..	..	..	..	186,000	1,533,000	1,719,000

123. None of the programs for reductions in flow through the main drainage canal under consideration in this study contemplate a limit as low as an annual average of 3,000 cubic feet per second before the year 1940. Hence, the effects of such a reduction should be applied to conditions as they are likely to exist then. As the program for expansion of the local power system contemplates the completion of all of the stations listed in Table ....., before 1950, the full amount of the loss will be in evidence by that time. By 1940 this will equal the losses due to limiting the capacity of existing installations plus those due to the restrictions placed upon new construction up to that time. Based upon the expansion program of the utility companies, the total kilowatt capacity affected adversely by reductions in flow in 1940, 1945, and 1950, will be taken as follows:

Cubic feet per second	1940 Kilowatts	1945 Kilowatts	1950 Kilowatts
1,000	2,000,000	2,500,000	3,119,000
2,000	1,500,000	1,950,000	2,419,000
3,000	1,000,000	1,350,000	1,719,000

124. It is rather difficult to evaluate the effects resulting from these reductions in water available for condensing purposes. If the reductions took place at once, the loss would amount to the full cost of replacing the capacity destroyed by new installations elsewhere, but as they probably will not occur for some time, it is possible that depreciation and obsolescence will operate to reduce the amount of this loss and put it on a par with the effect on new construction.

125. If the flow is limited to 1,000 cubic feet per second for instance, the capacity at any one power plant site may not be greater than 200,000 kilowatts, below the point of discharge of the west and southwest side sewage treatment plants, and not greater than 45,000 kilowatts east of this point. As a result the required total capacity of 3,659,000 kilowatts, would have to be obtained by adding a comparatively large number of small generating stations whose in-

dividual requirements for condensing water were within the prescribed limits. A marked increase in first cost would result, plus another increase in operating costs. Unquestionably the combined effect would be a capitalized increase in cost of between $30 and $50 per kilowatt capacity affected depending upon the extent of the decrease in flow. The results, on this basis, would be as indicated below:

TABLE 31.

EVALUATION OF CHICAGO POWER LOSSES.

Gross flow at Lockport (cubic feet per second)	Increased cost per kilowatt	1940	1945	1950
1,000	$50	$100,000,000	$125,000,000	$155,950,000
2,000	40	60,000,000	78,000,000	96,760,000
3,000	30	30,000,000	40,500,000	51,570,000

126. As in the case of computing costs of sewage treatment systems for the lower diversions, the values thus computed for the power losses should not be taken as anything more than educated guesses of what the results might be. These values are merely indicative of the seriousness of the situation from the particular point of view involved."

* * *

Geo. B. Gascoigne, recalled on re-reference for Complainants. Sanitary Engineering expert, testified in prior 1927 hearing.

Direct Examination by Mr. Jackson.

Since the previous hearing I have visited the North Side and West Side sewage treatment works of the Sanitary District. I have kept in touch with this problem and the developments there; and, since about the first or middle of March of this year, have given detailed consideration to this problem. From my study and consid-

eration of the Chicago problem I have reached a conclusion as to what would be a practical, workable program for the disposal of the sewage of the Sanitary District of Chicago by means other than lake diversion without
10682 detriment to the water supply. This program consists of completely treating the sewage of the Chicago Sanitary District and filtering the water supply.

The sewage portion of the program consists of completing the North Side Works by installation of the pumping station which is necessary to make tributary to this plant the population which it can serve. It includes the completion of the pumping station, skimming tank, grit chambers, the two batteries of Imhoff tanks, and the sludge beds at the West Side Plant and the extension of the treatment at that plant by the activated sludge process with the necessary appurtenant pumping stations, power buildings, sludge beds, and the like.

At the South West Side site there should be installed an Imhoff tank activated sludge type of works. At the Calumet site there should be installed additional Imhoff tanks and either trickling filters or activation to provide oxidation or secondary treatment. The program also includes all intercepting sewers that are necessary to discharge sewage at each of these sites.

10683 With respect to the water supply the program calls for filtration of the entire water supply of the District in modern and efficiently operated filtration plants.

This program does not contemplate any flow at Lockport after its completion. The completion of this program with no flow at Lockport will provide a practical method for the disposal of the sewage of the Sanitary District of Chicago by means other than diversion without detriment to the Chicago water supply, and without producing conditions which will interfere with or cause a nuisance to navigation in the Chicago River.

Some modifications of or additions to this program would be practical, such as chlorination of the effluent from the sewage plants, extending the existing water intakes, or providing a new source of water supply for Chicago at some point opposite the northerly portion of
10690 the District in the vicinity of Wilmette. None of these modifications would be necessary to prevent detriment to the water supply.

It is practical to obtain a reduction of practically 100 per cent in bacteria by chlorination of the effluent of sewage disposal plants.

I have made estimates of the reductions in the diversion which would be practicable from time to time during the course of construction of this program. By December 31, 1929, the diversion can be reduced to 6,500 cubic feet per second in addition to the pumpage or used water
10691 supply. By December 31, 1935, no flow at Lockport is necessary if this program is carried out and completed.
10692 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. The basis of these reductions in diversion is in accordance with the reduction in the organic load placed
10693 upon the Chicago River and its branches. The estimates of reduction in the diversion are based upon maintaining conditions as they are, or improving them. My conclusions as to the reductions which would be practical,

take into consideration both the public health and navigation in the Chicago River as part of the Great Lakes-St. Lawrence system. The completion of this program will produce a satisfactory condition from both viewpoints.

Assuming the completion of the program outlined by me and no flow at Lockport, there will not be any visible supended particles recognizable as of sewage origin in
10694 the Chicago River coming from the sewage treatment plants. The conditions in the Chicago River in that respect will be improved with the completion of this program.

Assuming the completion of the program outlined by me and no flow at Lockport, there will not be any odors arising from the waters of the Chicago River due to putrefaction of the organic matter contained in the sewage effluents.

Assuming the completion of the program outlined by me and no flow at Lockport, there will not be any grease, oil, color or suspended matter on the surface of the Chicago River due to the flow from the sewage treatment plants. In that respect the conditions in the Chicago River after the completion of this program will be better than the conditions which now obtain.

Assuming the completion of the program outlined by me and no flow at Lockport, the waters of the Chicago River will not be offensive or injurious to the health
10695 of passengers or persons employed on vessels or persons employed on docks.

Assuming the completion of the program outlined by me and no flow at Lockport, the condition of the water of the Chicago River River will not be such as to result in an extensive growth of water plants.

A standard for water which requires conditions that will maintain a thriving fish life and a standard for water

which requires absence of nuisance are not the same. The standard requiring a thriving fish life is higher.

The standard for thriving fish life is satisfactory for navigation but might not necessarily be satisfactory for health purposes. I have in mind that it might require a higher standard, or additional requirements beyond sim-
10696 ply dissolved oxygen, for health purposes, speaking from the standpoint of drinking water. It is different, considered from the standpoint of nuisance in the stream. The thriving fish-life standard is higher than either the standard required for no nuisance or for navigation. By the nuisance standard I mean as far as health is concerned; not for drinking water purposes, but for the purpose of living along and navigating over the waters.

Assuming the completion of the program outlined by me and no flow at Lockport there is a practical method of providing circulating water in the Chicago River if it were desired. That is the same method of pumpage described by the witness Howson.

It would be practical, but not necessary, to construct
10697 a sewer to discharge the effluents of the South and Southwest Side Plants into the South Branch of the Chicago River between the 39th Street Pumping Station and the mouth of the River. It is practical to pump circulating water through the Calumet-Sag Canal.

The effluent of a modern activated sludge plant discharged into an open channel is stable, odorless and clear. The effluent of a modern activated sludge plant discharged into an open tank will remain stable indefinitely.

There is a method whereby the effluents from the sewage disposal plants can be removed from the Chicago River and its branches. That method is by constructing
10698 sewers out to the Lake, as was described by the witness Howson. If there were any necessity to do so for the protection of navigation that would be practical. In my opinion it is not necessary.

Assuming the completion of the program outlined by me and the installation and operation of controlling works so as to divert all storm water overflow, but with no diversion or flow other than at times of storm, this program would practically provide for disposal of the sewage of the City of Chicago without detriment to the water supply or to navigation on the Chicago River as a part of the Great Lakes-St. Lawrence system.

Assuming the completion of the sewage disposal program outlined by the Sanitary District engineers, which contemplates diversion of effluents of such sewage disposal plants, and the diversion of storm water overflows into the Des Plaines and Illinois Rivers, it would not be necessary to add any quantity of dilution water from the
10699 Lake to protect public health or to prevent a nuisance to navigation in the Chicago River as part of the Great Lakes-St. Lawrence system.

Assuming the completion of the program proposed by the Sanitary District Engineers, except that there would be no diversion of dilution water from the Lake, nuisance conditions would not result in the Drainage Canal or the lower river from the sewage effluent and excess storm water, if that program should be modified so that it would take large amounts of storm water as suggested in my program.

Assuming that there would be a mean annual diversion of 1,000 second feet at Lockport for navigation purposes, that would not modify or affect the program outlined by
10700 me other than to prevent an absolute cessation of diversion on its completion. Such a flow for navigation purposes would not modify my estimate of time of construction or the effectiveness of the program in protecting public health and navigation on the Chicago River, nor would the effectiveness of the program or the time required for construction be modified if lockage water not in excess of 1,000 second feet were taken.

Each tank of a unit of aeration or Imhoff tanks does not require a separate detailed design. When one of a group or unit of Imhoff tanks for a particular plant has been designed it is largely a matter of multiplication of units because the design remains the same.

Cross-Examination by Mr. Adcock.

I testified on direct examination that certain treatment
11262 could be made 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 at time of storm. I further stated that this could be done without any enlargement whatever and with the present facilities at the North Side Plant or at the West Side Plant after the completion of the program. Assuming that the channels, gates and weirs and meters in the West Side Plant have been designed and are built to carry a maximum flow equal to 1½ times the average sewage flow, and that the flow through the plant is by gravity, I do not know whether it would require enlarging of all these structures if the flow to be passed through the plant is to be made equal to two or three times the average flow. If it were necessary to enlarge those structures my answer made to the question on direct examination would be incorrect.
11263 I did not make any investigations of the hyraulic loads and elevations in that plant to determine whether certain treatments could be given to two or three times the average flow at storm times. I do not know through what conduit at the North Side Treatment Works the excess flow from the preliminary settling tanks would be passed in order to discharge it into the North Shore Channel, assuming that two or three times the average sewage flow were put through that plant at storm times. As to the possibility of doing so, if there is no conduit

through which to discharge such excess, if it could not be done, it can not be done.

If storm water flows into the River, it would exert an oxygen demand. The heavier organic matter would settle
11264 out into the canal and river system if it were discharged into the river at storm times.

I stated a little while ago that there would be organic matter discharged, if it was so. If this organic matter should be discharged in the winter and should stay there in the summer, it might exert an oxygen demand on the overlying liquid. I do not know whether there would be putrefaction.

Under Complainant's Exhibit 238, I understand that if controlling works were installed, both the effluents from the plants and storm overflows would be discharged down
11264-11266 the Des Plaines River during periods of storm.

If flushing water were provided in the Cuyahoga River at Cleveland at dry weather times, so that the water would be pumped into the River and flow toward the Lake, it would have the effect of carrying the pollution in the Cuy-
11266-11267 ahoga River more quickly to the Lake. With flushing there would be more bacteria carried out into
11267-11268 the Lake with the sewage.

Darwin W. Townsend, for Complainants, on Re-reference. Sanitary Engineering Expert.

Direct Examination by Mr. Jackson.

In addition to the contact through the preliminary report on the North Side sludge disposal plant at Chicago, I am generally familiar with the sewage disposal and water supply at Chicago. Since being retained as a consultant in this case, I have given detailed study to the Chicago problem and have arrived at a conclusion as to

what would be a practical program for the disposal of the sewage of the Sanitary District of Chicago by means other than Lake diversion and without detriment to the
10709 Chicago water supply. Such a program consists in completely purifying the sewage of the City of Chicago in the most efficient manner and the filtration of the entire water supply. This program includes the completion of the North Branch sewage pumping station which will permit the utilization of the North Side sewage plant to its full capacity; the completion of the West Side plant now under construction; the design, construction and placing in operation of the proposed Southwest Side plant and such additions to the existing Calumet plant as may be necessary to completely purify the sewage from the Calumet District. This program contemplates complete treatment which should be accomplished by following the West Side tanks now proposed and under construction with activated sludge tanks, aeration and sedimentation; the construction of a complete activated sludge plant at the Southwest side and the completion of the Calumet plant as an Imhoff tanks trickling filter plant.
10710 This program involves the filtration of the entire water supply by appliances of the most efficient type with no extension of the present water intakes.

This program does not contemplate any flow at Lockport after its completion and would provide a practical method for the disposal of the sewage of the Sanitary District of Chicago with no flow at Lockport and without detriment to the Chicago water supply.

It would be practical from time to time, during the course of construction of the program outlined by me,
10716 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. I have not made any estimate of reduction in c. f. s. at any time prior to the completion of the program. My opinion as to the practicability of reduction is based upon a standard of maintaining the *status quo* at least. My opinion that reduction would be practical takes into consideration the effect on the public health and navigation of the Chicago River as part of the Great Lakes-St. Lawrence
10717 system. The completion of this program, with no flow at Lockport, would provide satisfactory conditions from both standpoints.

Assuming the completion of the program outlined by me which contemplated no flow at Lockport, there would not be any visible suspended particles recognizable as of sewage origin in the Chicago River coming from the sewage treatment plants. The conditions in that respect would be superior to the conditions which now obtain in the Chicago River.

Assuming the completion of the program outlined by
10718 me which contemplates no flow at Lockport, there would not be any odors arising from the waters of the Chicago River due to putrefaction of the organic matter contained in the sewage effluent.

Assuming the completion of the program outlined by me which contemplates no flow at Lockport, there would not be any grease, oil or floating material on the surface of the Chicago River due to the flow from the sewage treatment plants. In that respect conditions would be improved over the conditions now obtaining in the Chicago River.

Assuming the completion of the program outlined by me, which contemplates no flow at Lockport, the waters of the Chicago River would not be offensive or injurious to the health of passengers or persons employed on vessels or persons employed on docks.

Assuming completion of the program outlined by me
10719 the condition of the waters of the Chicago River would not be such as to result in excessive growth of water plants.

A standard for water which requires the maintenance of a thriving fish life is not the same as the standard which requires the absence of nuisance. The standard for water which requires the maintenance of a thriving fish life is not one which is ordinarily adopted and accepted to satisfy public health requirements from the standpoint of nuisance or to prevent interference to navigation.

10720 Assuming completion of the program outlined by me, which contemplates no flow at Lockport, it is practicable to provide circulating water for the Chicago River, if so desired. Circulating water if so desired could be pumped into the canals and river through the existing station at the north end of the North Shore Channel, where equipment is now installed to the capacity of 1,000 c. f. s., and by providing pumping equipment at the Calumet for pumping circulating water through the Sag Channel into the Drainage Canal.

The effluent of an activated sludge plant is stable, odorless, clear and sparkling. The effluent of an activated sludge plant discharged into an open tank will remain
10721 stable indefinitely. This program could be varied so as to entirely remove the effluent from the Chicago River and its branches by diverting the effluent from all of the four plants directly through underground tunnels in an easterly direction into the Lake. If that were necessary

to protect navigation in the Chicago River and its branches, it is practicable. I consider it unnecessary.

When I stated that upon the completion of the last of the sewage plants in 1935, all flow at Lockport could be terminated, I assumed that then the water filtration plants would be completed. If they were not completed, it would be necessary to have controlling works after the completion of the sewage treatment program to prevent reversals in the Chicago River.

Assuming the completion of the program outlined by me, and the installation and operation of controlling gates so as to divert all storm water overflow, but with no diversion or flow other than at times of storm, this program would practically provide for the disposal of the sewage of the Sanitary District of Chicago without detriment to the water supply or to navigation on the Chicago River as part of the Great Lakes-St. Lawrence system from a nuisance standpoint.

Assuming the completion of the sewage disposal program outlined by the Sanitary District engineers at the
10723 March hearings, that is, complete treatment plants (activated sludge except at Calumet where there would be sprinkling filters), and diversion of the effluent and storm water run-off, it would not be necessary to add any quantity of diluting water from the lake in order to protect the public health or to prevent a nuisance to navigation in the Chicago River as part of the Great Lakes-St. Lawrence system.

There is always oxygen available in the effluent of a properly operated activated sludge plant.

Assuming the completion of the program outlined by the Sanitary District Engineers of Chicago but with no diversion of diluting water from the lake, conditions of nuisance would not develop on the Drainage Canal or in

the lower rivers from the sewage effluent and storm water.

Assuming that there should be a mean annual diversion of 1,000 c. f. s. at Lockport for navigation purposes, that would not affect or require any modification of the
10726 program proposed by me. It would not affect my estimate of time of construction or the efficiency of the program in protecting the public health and preventing nuisance to navigation.

The Milwaukee Sewage Disposal plant was designed to and is serving a population of 640,000. The Milwau-
10940 kee plant also has an industrial load equivalent to a population of approximately 200,000. Measuring the size of the Milwaukee plant on the same basis as was suggested at Chicago, it is a plant for a population of 840,-000. That method of measuring the size of a sewage disposal plant has not been followed in Milwaukee.

Cross Examination by Mr. Adcock.

From 1914 until 1917 I was employed in the capacity of chief draftsman and chief designer for the Milwaukee Sewerage Commission. Designs and plans were prepared by me, or under my direction for the
10964 sewage testing or experimental station for the city of Milwaukee. At that time the testing station was considered necessary from the standpoint of determining the character of sewage disposal to be used by the city. That plant consisted of the sewage treatment units recognized at that particular time, Imhoff tanks, trickling filters, chemical precipitation tanks, sludge tank and all the sewage handling accessories consisting of pumps, screens, etc. These experiments in Milwaukee were carried on to determine just which of the processes enumerated might be best adapted to the sanitary conditions

existing at Milwaukee. The Imhoff tank, sprinkling filters and secondary sedimentation process, the activated
10965 sludge process and the electrolitic process were tested out. A sewage experimental station was maintained until 1922 or late in 1921. A sewage testing or demonstration plant is still maintained at Milwaukee entirely separate from the practical plant but on a scale that is comparable with the original testing plant in size. The experimental work carried on from 1914 to 1917 was for
10966 the purpose of determining how best to treat sewage.

The character of the sewage at Milwaukee and its various constituents were determined as part of the routine. Analyses of the sewage were made; the amount of industrial waste was determined at that time. That was necessary in order to determine the design of the plant. The demonstration station is maintained at Milwaukee now for the purpose of determining, in units of size which are easy to handle and manipulate, how the efficiency of a
10967 large plant can be further improved. If other processes of a different character were introduced in the art, it
10968 would be tested out there, if it had not been tested previously elsewhere, for the purpose of learning how it would operate at Milwaukee.

10969 Experiments were commenced in Milwaukee in 1914 and the operation of the experimental plant continued until 1917. The last year of its existence the original testing station, as it was ultimately revamped from time to time, was operated for the purpose of determining how best to dewater the sewage sludge. A testing station was maintained after 1917 and is still maintained. Mr. Hatton reported to the sewerage commission with reference to the result of these tests. The sewerage commission obtained reports from consulting engineers. Mr. Eddy was engaged by the commission to review the experimental work which had been carried on in connection

10970 with the activated sludge process up to that time. I do not recall when Mr. Harrison P. Eddy was employed but his report was made around about 1917. I do not recall any other consulting engineers having been engaged with Mr. Eddy. My recollection is that Mr. Eddy was retained as consulting engineer until designs for the aeration and sedimentation tanks were completed late in 1921.

I designed the plant at Milwaukee and was responsible to Mr. Hatton as Chief Engineer for the designs of the project. My work in designing the plant was done under the direction of Mr. Hatton. Mr. Eddy was consulted with reference to the design of parts of the plant.

10974 Mr. Eddy reviewed and studied the work which had been conducted in the sewage testing station, prepared a report and recommended that further tests be conducted to enable him to form his conclusion as to the adaptability of the process to the work to be done. Mr. Eddy recommended that comparative aeration tests be continued in tanks running parallel 10 or 15 feet in depth. Mr. Eddy reviewed plans of the aeration and sedimentation tanks. His suggestions were pursued and he approved the plans as finally adopted. Mr. Eddy and I were in agreement at the time the plans were completed. I was in responsible charge of the design of the activated sludge plant at Milwaukee.

I have followed in a general way the work which Chicago has done in so far as the design and placing in

10977 operation of the disposal plants are concerned, having previously been interested in the original report on the North Side plant.

10978 I knew that the Sanitary District was carrying on experimental work and made two visits to the old 39th Street station when it was in operation in 1914 and 1915 during the time that Milwaukee was interested in sewage experi-

mental stations. I understood that the experimental work was being carried on for the same purpose as the experimental work at Milwaukee.

I am familiar with the design of the North Side sewage disposal plant at Chicago and the functions that it is expected to perform. I visited the North Side plant once
10979 since it has been in operation which was about a week ago. I visited the West Side plant on the same day. On this inspection trip I started from downtown Chicago about 1:30 P. M. and first visited the West Side plant in company with Messrs. Allen Hazen, of New York,
10980 J. W. Ellms, a witness here, and Mr. L. R. Howson. I spent about half or three-quarters of an hour at the West Side plant. I did not walk over the Imhoff tank construction but saw the construction work in progress from the roof of the pumping station. I did not go over the portion of the Imhoff tanks which is practically completed, nor to the grit chamber, the meter house or sludge drying beds. I inspected the pump house and went up on the roof of that building and thereafter left the plant.

10981 My familiarity with the Chicago harbor is very general having never made any investigations of any part of it for any particular purpose or ridden upon it. I have never been on the Chicago River or any of its branches, on the North Shore channel or on the Drainage Canal. I
10982 observed the controlling works at Lockport from the outside in 1924. I was driving from Ottawa to Chicago
10983 but am unable to recall whether I was on the main road at the time. Construction work was in progress in the vicinity of Lockport and I had dinner in the construction camp with the superintendent whom I knew. That was the only time I had seen the Lockport controlling works. I do not know anything about the Calumet harbor. I have observed the

Milwaukee harbor very frequently, especially in the vicinity of the sewage plant outlet. The outfall of the Milwaukee sewage plant is right alongside of the outlet of
10984 the three rivers making up the Milwaukee harbor.

I made no investigation of the size of the Southwest Side sewage plant of the Sanitary District, but understand that it is to be designed for a daily capacity of 300 million gallons daily and is to be of the activated sludge type.

10985 I understood that the size of the different units in this plant had already been determined or figured out by the Sanitary District. I obtained these figures in conference with Messrs. Howson, Gascoigne, Ellms and Hazen during the last week. I started to arrange some data which I thought might be wanted with reference to the Chicago situation about 2 weeks ago and have been active in it since a week ago to-day. I was employed
10986 about 2 weeks ago.

I had a number of conferences with the gentlemen mentioned at Cleveland beginning last Friday morning, April 12th. Mr. Hazen was there. I conferred with these gentlemen Friday, Saturday and Sunday when I started for Washington. Further conferences were had on the
10987 train. Mr. Howson was present. Mr. Howson, Mr. Hazen and I reached Cleveland on Friday morning.

At the Milwaukee plant the normal flow is about 82 million gallons per day. During times of storm the flow through the coarse screens, grit chambers and fine screens is at the rate of approximately 250 million gallons per day. Through the aeration and sedimentation tanks the flow during the storms is confined to 30 million gallons per day,—that is during storms and thaw run-off.
11022 That is a little better than 25 per cent of the ordinary capacity of the aeration part of the plant.

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.

If the Chicago River and its branches were flushed by
11026 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.

Redirect Examination.

When work was started on the sewage problem at Milwaukee, the activated sludge process was in its infancy. The problem of designing and constructing an activated sludge plant to-day would not be comparable to the problem that was presented to a sanitary engineer in 1914.

Assuming that the large sanitary organization of the Sanitary District of Chicago commenced to study the methods of the disposal of the sewage of the Sanitary District by artificial processes in 1911, it would be possible to have a reasonably adequate amount of data on the problem by 1929.

11028 Assuming that the Sanitary District organization started special tests and experiments to determine the best methods of treating packing house wastes in 1912 or 1913 and continued to make those tests for 3 years, that should afford reasonably adequate data as to the nature of the treatment required. It is not likely that the waste from the slaughter of hogs at the present time would be substantially different from the waste that obtained from 1912 to 1915.

Recross Examination by Mr. Adcock.

I think that the character of the waste at Packingtown is the same as in 1917 when the investigation was made. I do not know whether any changes in process have been made in the manufactnre of the products at Packing-
11033 town. Possibly there may have been changes made. The volume of the waste might be different. I assumed that the Sanitary District in deciding to build the Southwest Side plant had settled the matter of whether the character of the waste is the same now as in 1917. I understood that the Southwest Side plant was a proposed plant that the Sanitary District proposed to build. Assuming that
11034 the Sanitary District has no reliable information upon which to base the design of that plant, the plant should not be designed until that information is obtained.

By reducing the normal capacity of the Milwaukee treatment plant from 85 million gallons daily to only 30 million gallons daily in time of storm overflow, the normal efficiency of the plant, considering just the aeration and sedimentation tanks and not the plant as a whole, is reduced to about 35 per cent. The reason for that reduction at Milwaukee is that a standard for the fertilizer material produced has been established. The Milwaukee plant agrees to furnish users with a fertilizer material containing from 6½ to 7 per cent of nitrogen. During the storm flow a good deal of grit and silt and clay is carried in the diluted sewage and finds its way
11035 into the aeration tanks, unites with the sludge being aerated; and in the resulting fertilizer there is an excess
11036 of ash and a decrease of the nitrogen content. This is done in order to make the fertilizer better. A better price is obtained for the fertilizer if people know it has not this mineral matter in it.

By Special Master.

From the standpoint of sewage treatment, there is not any reason why the plant should not run to full efficiency in time of storm.

Further Cross-Examination.

If the plant were to run to full capacity during time of storm, about 85 million gallons daily would be taken through the aeration tanks.

The Milwaukee crib or water supply intake is about 5 miles in a straight line northeast from the mouth of the
11037 Milwaukee River. At times during the spring usually there is a short period when boiling the water is encouraged. The health commissioner issues bulletins with reference to the boiling of the water.

By Special Master.

The Milwaukee water supply is not filtered. It is chlorinated with no filtration.

Further Cross-Examination.

Chlorination is practiced all the time.

Redirect Examination.

The preliminary tanks at Milwaukee are so-called grit chambers. They are not Imhoff tanks but just straight precipitation tanks. The Imhoff tank has a much greater
11038 detention period than the grit chambers. The grit chambers merely precipitate the inorganic matter or grits. The Imhoff tank precipitates suspended solids other than inorganic matter. With Imhoff tanks before the aeration tanks, there is more of the organic matter removed before the sewage gets to the aeration tank

than with the type of tank used at Milwaukee. Packing house wastes are treated at Milwaukee.

By Special Master.

11039 There are no controlling works at Milwaukee.

Recross Examination.

There is no means at Milwaukee by which the sewage effluent or storm water carrying sewage could be removed from the water supply.

Joseph W. Ellms, recalled.

Direct Examination by Mr. Jackson.

Sanitary and Water Purification Expert.

Testified in prior 1927 hearings.

10727 In my previous testimony I stated that my experience was limited to the design and construction of the Cleveland filtration plant and my experience in water supply. Since the previous hearings, I have had charge of the operation of the water filtration plants and sewage disposal plants at Cleveland.

I have given study to the question of water supply on the Great Lakes with particular reference to Chicago. Since the decision of the Supreme Court in January in this case, I have given particular attention to the Chicago problem. The program for the disposal of the

10728 Sanitary District sewage by means other than lake diversion outlined on Exhibit 238 is a practical, workable program.

I specialize in water supply, but I am familiar with modern sewage disposal treatment in its relation to water supply problems. I understand what is involved

in the program on Exhibit 238 with respect to sewage disposal, so far as it is related to the water supply program.

Assuming the completion of this program as outlined in Exhibit 238 and no flow at Lockport, the Chicago water supply will be better than at present.

As to any additions to or modifications of the program shown on Exhibit 238, that would be practical, though
10731 unnecessary, in my opinion. There might be an extension of some of the tunnels which would draw water from farther out in the lake. There might be a substitution of one new intake with tunnels to a single filtration plant in the vicinity of Wilmette, but these are not absolutely necessary for the completion of the program. These additions, such as the extensions of the present intakes, or the substitution of a new intake off the North Shore in the vicinity of Wilmette would constitute an improvement of the present standard or quality of the Chicago water supply. The program appearing on Exhibit 238 will maintain or improve the present standard or quality of Chicago's water supply, but it would be perfectly practicable to build a new intake off the North Shore, if it were desired to use a higher standard for the Chi-
10732 cago water supply. If the city of Chicago decided to construct a new intake off the North Shore in the vicinity of Wilmette, a single filtration plant would be all that would be required.

In my previous testimony I made an estimate of the cost of such a single water filtration plant. There has not been any change in conditions since that time, that would materially affect my estimates. If there has been any change, I think it would be on the side of a decrease in the cost.

Assuming the completion of the sewage treatment program, which is outlined on Exhibit 238, the construction

10733 of the water filtration plants at the present intakes and no extension of the intakes, and assuming no flow at Lockport, the resulting conditions in the Chicago River would not be injurious to or create any nuisance to navigation.

Assuming the completion of the sewage treatment program outlined in Exhibit 238, the installation of water filtration plants at the present intakes without any extension thereof and a mean annual flow of 1,000 c. f. s. at Lockport for navigation purposes, the Chicago water supply would be as good as at present.

Cross-Examination by Mr. Adcock.

I was not present at the Chicago hearings in March.

10766 Subsequently to the opinion that was rendered in this case on January 14, 1929, by the Supreme Court, I started work on this matter in preparation for testifying about a month ago.

10767 I am familiar with the works that have been constructed by the Sanitary District for sewage disposal. I am also familiar with the program which the Sanitary District has submitted here for future construction work and disposal of the sewage of Chicago or artificially treating it. I visited the North Side plant and the West Side plant; and I have seen the site of the Southwest Side plant. 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. Even though that program is completely carried out, there will be some matter of sewage origin at times in the Chicago River and its branches which has not received treatment. This matter or substance would not be visible. I under-

stand that the storm flow will carry more or less sewage, but it will be very much diluted.

10769 Lake Michigan is the present water supply of Chicago.

Assuming the completion of the program as outlined by the Sanitary District Engineers, assuming that the sewage effluent is discharged into the Lake at dry weather times, assuming the diversion of the storm water overflow and sewage effluent at times of storms, and assuming

10770 no water filtration works, the quality of the water

10771 would not be as good as it is now coming through the intakes for chlorination. In other words, the Lake Michigan water would be affected by the sewage effluent. If the sewage effluent passes into the lake without any filtration of the water taken for the water supply, I would con-

10722 sider it harmful. My answer on direct examination is based on water filtration in addition to complete sanitary treatment.

10896 Assuming that the effluent of the sewage treatment plant flowed into the lake in dry weather and that at time of storm the storm flow is diverted by controlling works at Lockport into the Des Plaines River, I have not made any computation on the maximum load of B. Coli that would have to be handled by the water filtration plant.

I have taken into consideration the effect of the operation of controlling works at the North end of the Drainage Canal. I understood that these controlling works were to be operated at storm times so as to cause the discharge of all the sewage effluent and all the storm water into the Des Plaines River from the Sanitary Canal in times of storm. From a sanitary standpoint, having consideration for a water supply and conditions of navigation in the Chicago River, I understood that the storm period when the controlling works would so operate would

10897 be from 4 to 5 hours. It would be necessary to put these

controlling works in operation some hours before the storm commenced. It would be necessary to keep the controlling works in operation as stated during the period
10898 of the storm. I understood the purpose of the operation of these controlling works to be to keep the storm water flow out of the lake, and also any other substance that was in the Chicago River or its branches at that time. That was in order to keep the filth or pollution out of the lake due to the storm and to discharge it to the Des Plaines River. It would be necessary to keep these controlling
10899 works in operation after the storm only for such length of time as the storm flow was in operation,—that is, as long as the flood flow continued, until it was back into a normal flow. That is, not necessarily back to a dry weather flow but to an average flow that would take away the principal portion of the flood water. That is, it would be necessary to keep the controlling works in operation as long as there was any storm water passing from the
10900 sewers directly into the river and that did not go through the sewage purification plants. It would be necessary to keep those controlling works in operation for sometime after that in order to remove from the Chicago River and its branches and from the canal the dirty, polluted water that had accumulated there during the period of the storm and the flow due to the storm.

I approve the program shown on Complainant's Exhibit 238. The carrying out of that program would not
10901 prevent the fact of purified sewage effluents appearing in the river, because the river is to take the discharge of this purified sewage effluent from the treatment works and carry them to the lake.

The storm flow and any other substances that were in the rivers would be carried to the Des Plaines River if it were assumed that the controlling works were operated for that purpose.

I have seen the report issued by the Municipal Research Bureau of Cleveland entitled "The Report upon Correlation of Water Purification and Sewage Disposal in Cleveland," of March, 1926. At Cleveland a portion of the
10908 sewage is treated in Imhoff tanks at one plant, at another plant the floating matter is removed by screenings and grit chambers, and the third plant is an Imhoff tank and trickling filter plant. Cleveland has a combined sewer system the same as Chicago. At Cleveland about 30 million gallons of sewage a day are treated in the Imhoff tank plant, about 90 million gallons a day receive only wire grating and grit chamber treatment and the other plant is treating only a small amount of sewage at the present time. The first two plants mentioned were put in operation in 1923 and the last plant in 1928. There is a total of 120 million gallons of sewage treated at Cleveland per day. That represents 120 million gallons out of 125 million gallons of the measured sewage at these plants at
10909 the present time. Not all of the sewage passes into these plants. At the southerly plant not all of the trunk sewers are connected with the interceptor, and, therefore, not all is collected, nor is the low level district in the valley at the present time sewered and none of that sewage passes into the plant. It goes directly into the river. I estimate the total ordinary flow of sewage at Cleveland at probably 150 or 160 million gallons per day.

I know Mr. Leighton E. Carter, director of the Municipal Research Bureau of Cleveland. I remember the following statement in the foregoing report of March 26, to which I am referred, reading as follows:

> "The report would not be complete without an expression of appreciation to Mr. Wright, Director of Public Utilities, Mr. Ellms, Engineer of Water Purification and Sewage Disposal, and their associates, who have given freely of their time and energy and

who have so constantly demonstrated their earnestness."

10910 I am the Mr. Ellms referred to.

At page 31 of the foregoing report, the following appears:

> "A canvass of those with experience of lake front conditions discloses that deposits of faeces and other objectionable animal and vegetable wastes are common on the beach, especially after storms. Similar matter may usually be observed floating and decomposing on the water and matter with finer suspended material causing unpleasant odors. Oil and grease in sufficient quantities to befoul the beaches also are reported. Observations indicate that discharge of storm water from the interceptor system is most responsible for the coarse matter deposited. It is probably true that treatment of sewage now discharged into the river would not eliminate the oil nuisance, but it would put the city in a much better condition to discover and control the sources of such waste."

That is approximately a correct description of some
10911 of the conditions at Cleveland. I am not familiar with the report of the Municipal Research Bureau of Cleveland, entitled "A Study of the Financial Requirements of the City of Cleveland; Analysis of Operating Costs and Capital Improvements," dated May, 1928. The following statement appears at page 118 of the foregoing report:

> "A canvass of those with experience of lake front conditions discloses that deposits of faeces and other objectionable animal and vegetable wastes are common on the beaches, especially after storms. Such matter may be observed floating and decomposing in the water. Oil and grease in sufficient quantities to befoul the beaches also are reported. Observations indicate that discharge of storm water from the interceptor system is to a considerable extent responsible for the coarse material deposited."

That is substantially a description of conditions on cer-

tain of the beaches and certain portions of the lake front of Cleveland about the time that that report was made. Those conditions still exist.

Oil pollution in navigable waters may come from refineries, from sewage, or from wastes from garages. One source of pollution is the oil-burning boats on the lakes. That is probably a very great source of such pollution.

10913 In a river where there is oil or grease due to any of the causes mentioned, such oil or grease would be carried away with some current in the river. There would be less fire hazard as a result.

10916 I recognize the images which appear on Exhibits 1252, 1253, 1254 and 1255. They are photographs of the mouth of the Cuyahoga River at Cleveland. I see the dark shading and the light shading. The dark shading represents the turbid water of the Cuyahoga River,—that is not always a very dense black. That is the way it is photographed. That color extends out into the white part which is Lake Erie. The dark color gradually disappears

10917 to some extent as it travels. As to that picture representing the travel of the pollution of the Cuyahoga River as it is spilled into the lake at Cleveland, it is a very good picture of what happens as far as a picture can give it.

Counsel for Defendants produces Exhibit 1406 for identification, which purports to be an aerial photograph of the downtown portion of Chicago showing the Chicago

10918 River and the Lake, dated June 12, 1927. I observe the light shade which appears in the Chicago River coming up from the Lakes to the forks. That would appear to be the clear water as compared with the South Branch. The North Branch coming in at the junction shows a dark color. Exhibit 1406 for identification was received in evidence with the understanding that it was taken in June, 1927, prior to any sewage treatment.

10919 I qualified here as an expert chemist so far as it relates to water and purification. I do not know that I qualified with respect to sewage. I do not personally make sewage analyses for the City of Cleveland. They are made under my direction. I made sewage analyses a good many years ago. In a general way I know the constituents of sewage of a large city. I know something about the chemical processes that go on as the sewage congregates and is carried along. I know the processes that go on in the course of the treatment of
10920 sewage. There are all sorts of things that go into the sewage of the city, wastes of all kinds. As to the chemical or biological processes that go forward in the sewage itself, the decomposition of the organic matter, of course, begins almost immediately it becomes water-borne. The oxygen in the water is exhausted, and if no more oxygen exists or oxygen that can be derived from nitrates, putrefaction processes are set up. As to whether there is produced, then, a substance that is distinctive in the shape of sewage that is in the sewer, depends on how far those processes go. They may go to such a point as to produce hydrogen-sulphide, or other odors of like character, due to the breaking down of sulphate; but if the period in which it is deprived of oxygen is not too long, such reduction processes do not take place.
10921 As to the effect on nitrogen compounds and chlorides as the sewage passes through an activated sludge plant, I see no reason for any change in the chlorides. Nitrogen compounds may be reduced somewhat. The oxygen nitrate is oxidized to an ammonium nitrogen if sufficient oxygen is provided. In an activated sludge plant with a lot of oxygen present, it is oxidized and becomes nitrates. That organic nitrogen is left in the activated sludge effluent. The ammonium nitrogen is converted into nitrites, nitrates and nitric acid. Probably

10922 from 3 to 4 or 5 parts per million of nitrite is left in the effluent,—it might be 5 or 10 parts per million, depending on the amount of oxygen and air that is supplied. The ammonium nitrogen is all dissolved. The chlorides are always dissolved and pass through unchanged so far as I know. The mineralized constituents of the original polluted matter that are soluble in water will remain in the effluent as such. There is no way to dissolve the chlorides. The ammonia is converted into nitrous or nitric acid that is left in a dissolved condition
10923 in the effluent. Probably there is a certain amount of organic nitrogen which is not completely mineralized left in the effluent from a plant of that type. The number of parts per million of chlorides that are left in an activated sludge effluent depends on how many the sewage started with. Ordinary sewage varies very greatly. There might be as much as 30 to 50 parts per million. The concentration of chlorides in Lake Erie water is about 15 parts per million where the city of Cleveland draws its water supply. I do not know what it is in Lake Michigan. I presume that I made a determination at Milwaukee; I do not remember just now what the chlorides were. I think there would not be a very great difference
10924 between Lake Michigan and Lake Erie in that respect. There might be somewhat less in Lake Michigan. There is no possible way, other than by dilution, by which the concentration of chlorides in an activated sludge effluent may be reduced to the concentration of chlorides in Lake Michigan water. So long as chlorides dissolve they cannot be reduced except in the dilution of water which does not contain as much chloride. That is also true of the ammonia and nitrates in the activated sludge effluent so far as they are mineralized and become dissolved. That is also true with the chlorides.

10925 The sludge that comes from these plants is material

which contains considerable colloidal organic matter. It is heavier material which settles in tanks. The percentage of moisture in sludge that arises from an activated sludge plant and secondary settling basin, is 98 or 99 per cent. In a city like Chicago the volume of that sludge in a year would be very considerable. That is a waste which must be provided for in any treatment plant. The ef-
10926 fluent is another sort of waste.

Redirect Examination by Mr. Jackson.

Referring to Defendants' Exhibit 1406 purporting to be an aerial picture of downtown Chicago and showing the filthy conditions that have obtained in the North Branch and the South Branch of the Chicago River without any sewage treatment, for many years last past, after complete treatment has been put in effect at Chicago, these waters will be more attractive to navigation than those that are shown in the picture. After complete treatment has been put in there will not be any discoloration of the water as is shown in that picture.

My attention was directed to Defendants' Exhibits 1252 to 1255, inclusive, showing the black discoloration coming out of the Cuyahoga River at Cleveland. That
10927 river is navigated. My duties have frequently taken me to that river for observation. I have not seen any difficulties for navigators there by reason of the discoloration of the river. Both water intakes at Cleveland are in Lake Erie, about four miles directly opposite the mouth of the Cuyahoga River. The Cleveland filtration plants have produced water that has met the Treasury standard.

With the completion of the program that is summarized on Complainants' Exhibit 238, that is, complete treatment and filtration of the water supply at the pres-

10929 ent intakes, no controlling works and no flow at Lockport, the water supply will be as good as now.

In stating that time as necessary to permit a flow with controlling gates, I referred to how they would have to be operated in order to take off all the storm water.

Recross Examination by Mr. Adcock.

10932 Cleveland has two water filtration plants for the filtration of the entire water supply of the City of Cleveland and of the suburbs which buy water from the city. The water is treated with a small amount of chlorine after it is filtered. The water at Cleveland usually reaches the Treasury standard. Sometimes it falls off from it, but the average for the year or even the month.

10933 If it were desired to get a better water supply for Cleveland, there are one or two courses that might be pursued. The water might be pre-chlorinated prior to its passage through the coagulation and settling basins after it is received and before it passes through the filters, as well as chlorination after filtration. That is one simple and easy method by which a more polluted water could be handled. The filter plant would not be changed. The chlorination facility might be increased. It is a very small part of the plant and very small expense. If it were desired to make the supply still better, there is another method by which these present plants might be operated in which an excess of lime is used, which also, under caustic conditions, produces a water inimical to bacterial life. That might be another way to handle a very polluted water supply.

10934 The complete treatment of the sewage with any city on the Lake which is discharging sewage into the Lakes, is a part, one might say, of the program of providing a pure and potable water supply. With complete treatment of the sewage, there would be a certain amount of

storm water pollution which unavoidably would pass into the stream. The foregoing are not all the methods of improving the water supply. There are other methods which include doubling up on coagulation and doubling up on filtration. After all of these things have been done, if it is desired to provide a still better water supply, the only way would be to keep the sewage pollution out of the lake or move the intakes to some other point from where they were located. That is, to remove the intakes
10935 from the pollution passing in at those points.

There was no trouble at the Division Avenue filter plant in October, 1926, that I know of.

There is some trouble at Cleveland with reference to phenol tastes. That has happened at different times. The filter plant does not take that taste out of the water. The phenol taste comes from waste from by-product coke oven plants, located on the Cuyahoga River, some of which finds its way in very small quantities into the Cuyahoga River and out into the Lake. When this phenol comes in contact with the chlorine which is used for chlorinating the water, combination compounds are formed which are exceedingly tasty. That is what is known as a phenol waste taste.

F. H. Waring, recalled for Complainants:

A sanitary engineering expert, testified at prior 1927 hearings.

Direct Examination by Mr. Jackson.

11040 My present position is that of Chief Engineer of the Division of Sanitary Engineering, Ohio State Department of Health. That was my position when I testified before and has been my position at all times since then. In my official capacity, it is my duty to supervise the

water supplies of the State with particular reference to the public health.

I have considered the program for the disposal of the sewage of Chicago by means other than lake diversion
11041 and without flow at Lockport, as outlined in Exhibit 238. It is the same, or similar to one of the programs which I considered in my testimony on the previous hearings.

Assuming the completion of the program as outlined in Exhibit 238, which contemplates no flow at Lockport, but provides complete treatment of the sewage to the highest practical extent and the installation of water purification works of a modern type for the filtration or treatment of the whole of the Chicago water supply, the Chicago water supply will be as safe to drink as at present. I have considered the question of whether there would be any practical additions to that program from the standpoint of water supply. There might be included the chlorination of the effluents of the complete sewage treatment plants; and also there might be extensions of
11042 the present waterworks intakes. Or there might be relocations of these intakes, abandoning one or more and locating these intakes off the North Shore, in the vicinity of Wilmette. If those additions or changes were made, the city water supply would be superior to the present supply.

H. C. Inches for Complainants.

A Lake Captain.

Direct Examination by Mr. Jackson.

10624 Reside at Lakewood, Ohio. Captain of Great Lakes
10625 vessel. Have sailed on Great Lakes about 30 years, serving in the capacities of lookout, quartermaster, sec-

ond mate, first mate and master or captain. Master or captain for last four years. Navigated the Chicago River during 30 years of service on the lakes. Navigated the Chicago River before 1900.

I did not experience any difficulty in navigating the Chicago River prior to 1900 by reason of the presence of sewage in the River. I was aware of the opening of
10626 the Chicago Drainage Canal. Since the Drainage Canal was opened in 1900 and the river reversed, there has been a decided effect on navigation in the River. The current has caused a great deal of trouble in handling ships and additional expense. I was last in the Chicago
10628 River during October, 1928. The current in the River continued to give trouble up to the last time when I was in the Chicago River in 1928.

I have navigated the South Branch of the Chicago River,—the last time in 1925. The difficulties from a navigation standpoint which I experienced in the South
10629 Branch were from the current when coming around the bends putting my boat over against one dock or another and keeping me from making the swings. The sewage in the River did not interfere with the navigation.

I laid my boat up all winter in the North Branch of the Chicago River in the fall of 1927. The condition of the water there did not injure my vessel in any way. I believe it was good for the iron. The grease and oil preserve it.

My experience in navigating the Chicago River and its branches shows that if the diversion were cut off so as to eliminate the current in the River, navigation would
10630 be very much cheaper and safer. With respect to navigation being made cheaper, I refer to the use of tugs. When I go into the Chicago River, I do not dare go into the piers until there are two tugs there waiting,—one tug is for the purpose of taking the tug line on the stern and

pulling the stern all the while we are in the current. It takes the combined efforts of the boat machinery and the tug to keep from going too fast and ramming the docks or other vessels.

In my experience I have never known of a boat being put in dry dock for the purpose of painting on the Lakes. I did not notice any effect of the sewage on the paint on my boat.

Cross-Examination.

10631 I operate the Steamer Saturn, hailing from Fairport, Ohio, and having a length of 442 feet, a beam of 50 feet and a depth of 28 feet. The vessel principally carries ore and coal and plies between all ports of the Great Lakes, such as Cleveland, Milwaukee, Gary and South Chicago.

I have been operating this boat as captain for 4 years.

10632 I did not operate any boat before as captain. I am 46 years old and started working on the lakes about 1896 or 1897, when I was about 15 years old, as watchman or lookout. I first worked on a small lumber steamer. I presume that was some easier to operate than a large steamer. It was a comparatively small steamer about

10633 127 feet long. I was probably in the Chicago River 3 or 4 times prior to 1900. I did not see any boats stuck in the bridge draws prior to 1900 or over tunnels. I do not know what was the depth of the water at that time. I couldn't say that I noticed any difference in the width of the South Branch of the River between the time I navigated the River in 1900 and the present time. I have heard that the channel was deepened from 16 to 26

10634 feet during that period. I did not observe it. My boat has been loaded as deep as 21 feet draft. With respect to the possibility of having gotten into the Chicago River with that vessel prior to 1900, if I didn't have the available draft, I would load to the draft that I had. I could

carry something with a draft limited to 16 feet, perhaps
10635 5,500 tons. Without a cargo, my vessel draws about 12 feet. The depth to which I load depends on the year.

There was a lot of grease and oil on my boat when I wintered it in the North Branch. I believe that is good for the boat. I have not had this boat in dry dock in the four years I have operated it.

One of the boats on which I went into the Chicago River prior to 1900 drew about 9 feet. I could not state the draft of the other boat. The boat on which I went
10636 into the Chicago River in 1896 was the Steamer Wyoming. I was about 15 years old. I am 46 now. I may have been about 13 years old then,—I do not just remember the first year. I was lookout. I was about 17 in 1900. It was about 1896 when I first visited the Chicago River. I cannot tell exactly the year. It was not as
10637 early as 1895. I have nothing to fix the date by exactly. I remember being there prior to 1900.

As to my willingness to navigate waters filled with waste and sewage going into ports, I would go where the boat would handle the easiest. That is my job and I would rather handle a boat in waste and filth than in the current. Sewage and waste in the waters do not make any difference in the handling of the ship.

10638 During the years I have been on the Lakes, the U. S. Government has done a good many things to remove hazards of navigation, such as erecting lighthouses and establishing buoys to make navigation easier, safer, and more convenient for the people employed on the boats for their operation.

My boat is owned by Pickands, Mather & Company. Bridge piers have been removed in the Chicago River
10639 since 1900, although not all of the center pier bridges have been removed. Bascule bridges have been put in place of those center pier bridges which have been

changed. The Company is a member of the Lake Carriers Association. I have not been sailing this year and I do not know what the depth will be. I have not heard a lot about high water doing damage at Detroit and
10640 Chicago. I have been up the South Fork of the South Branch of the Chicago River with this boat to Armour's elevator, B, near 35th Street. I have not been up the South Branch since. That was the only time with this 442 foot boat. Judging from other rivers where I know
10641 the current, I should judge that the current in the river was 2 to 2½ miles per hour, more or less.

Redirect Examination.

I remember when the Chicago River was reversed
10642 and the current started the other way. I regulate the draft or load of the boat according to the waters I intend to navigate. If proper preparations have been made in that respect, the draft does not make any difference so far as ease of navigation is concerned. I do not believe that there are many large vessels navigating the Chicago River now. I do not see them when I am there.

Recross Examination.

I do not know of any large vessels going into the Chi-
10643 cago River. I wintered this boat at Hedstroms Coal dock, called the North Avenue dock.

I remember reading when the Chicago River was reversed.

I load my boats to suit the depth of water. The small
10644 depth produces less earnings. One cannot carry as large a cargo at 16 foot depth as at 20 foot depth.

Redirect Examination.

I cannot say whether the larger lake freighters navigating the Lakes navigate the Chicago River. They can not with safety.

Colonel Curtis McD. Townsend for Complainants:

Direct Examination by Mr. Jackson.

11042 Colonel, Corps of Engineers United States Army,
11043 retired. Educated in the public schools of New York City, and at the College of the City of New York until my appointment as a cadet at West Point. Graduated from West Point; appointed second lieutenant in the Corps of Engineers. Continued in active service as a member of the Corps of Engineers for 40 years. Since my retirement, I have been employed by the Corps of Engineers about 5 years, making a total active service of approximately 45 years.

After my graduation I attended the School for Engi-
11044 neers at Willets Point. After completion of that course I was assigned to supervision of harbors on the Eastern shore of Maryland, the Appomattox River, and the improvement of Kanawha River. I was next assigned to duty as assistant to the Engineer Commissioner of the District of Columbia and had charge of the water and sewer supply of the District for several years.

I was then assigned as quartermaster at the post at Willets Point, Fort Totten, and installed a sewer and water supply system for that post. I then returned to duty at Washington on the construction of the reservoir which is now behind the Soldiers' Home and the tunnel connecting that reservoir with the reservoir in Georgetown. When that work was stopped, I was assigned to duty in Washington in constructing a 48-inch main extending from the Georgetown reservoir through R Street to connect with the reservoir back of the Soldiers' Home, and a 38-inch main on New Jersey Avenue to the Capitol.

On completion of that duty I was assigned as assist-

ant to the Mississippi River Commission in charge of improving the third district, which extends from the mouth of the White River to Vicksburg. After that I was placed in charge of the improvement of harbors on the East
11045 Shore of Lake Michigan. I was then placed in charge of the Upper Mississippi River and its improvement from St. Paul to the mouth of the Missouri.

I was then ordered to the Philippines in commnad of a battalion of engineers, and while there I was relieved from duty as battalion commander and appointed Chief Engineer of the military division, and had charge of the construction of the harbors on the Islands, including the building of a breakwater at Manila and the construction of wharves. On my return from the Philippines I was assigned as a member of the Board of Engineers for Rivers and Harbors. From that duty I went to Cleveland in charge of the improvement of the harbors along Lake Erie and in Ohio. I was then ordered to Detroit in charge of the construction of the works for improving the connecting waters of the Great Lakes, including the construction of the locks at Sault Ste. Marie, and the Livingston Channel below Detroit. For a short time while on this duty, I was Division Engineer in general supervision of the engineering works along the Great Lakes including the work at Chicago and along the Illinois River.

After this duty I was assigned to the Mississippi River Commission and appointed President of that Com-
11046 mission. I served as President of that Commission for about 10 years with the exception of fifteen months when I was on duty with troops in France. I was retired as President of the Mississippi River Commission after 40 years service, and then spent a year and a half in writing a textbook on River and Harbor Hydraulics for the use of the Engineering School at Fort Humphries.

Thence on my return from a six months' trip to Europe, I was assigned for about three years to the improvement of the mouth of the Mississippi River.

I served on numerous Boards in reference to the rivers connecting with the Mississippi. I was on two boards on improvement of the Illinois River; and, as a member of the Board of Engineers for Rivers and Harbors, I had to review the proceedings of a third board. I also had various duties which led me to investigate questions relating to the Chicago River when I was division engineer on the Great Lakes. I was called upon to re-
11047 port on the question of the reduction in levels which would be caused by the flow of 10,000 second feet down the River. I also had to investigate the influence of the flow in the Illinois River on the Upper Mississippi when I was in charge of that district. When I was president of the Mississipi River Commission I had to investigate the effect of the flow of the Illinois River on floods in the Mississippi River.

With respect to the flow from Lake Michigan, or at Lockport, 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
11048 District of Chicago were discontinued; the Chicago River alone has been developed for navigation to such an extent that it is now a mere inlet from the Lakes, and the height of water in the Chicago River is dependent, not on the flow of the Chicago River, but on the rise and fall of the Lakes. There would be no water needed to maintain such a channel or to maintain navigation on it. The only water from the Lakes would be that which comes in as the Lake rises and falls, and the navigation of that channel would be dependent entirely on the height that the Lake attains. Whenever the Lake is high, there will be certain navigation in the channel; as the Lake falls, navi-

gation in that channel will diminish just as much as the height of the Lake diminishes. The only flow that will
11049 affect navigation will be this variation which will result from a rise and fall in the Lake itself.

By the Special Master.

The witness is certainly assuming now that no water flows down from Lockport but that the water is there held. In that way there is absolutely no slope in the River and its connections.

Direct Examination Continued.

I knew of the opening of the Chicago Drainage Canal in
11050 connection with my work. If the flow at Lockport were cut off at the present time, so as to terminate the current that obtains in the Chicago River, the conditions of
11051 navigation on that River would be improved. There would be no current in the River and its impediment to navigation.

In my long experience in river and harbor work the question of whether sewage was discharged into the river or harbor would not be one consideration in planning an improvement.

Cross-Examination by Mr. Adcock.

11163 I retired from the army service in the vicinity of
11164 1920. I am not in active service now. I am on the retired list.

I have had no practical experience in connection with the construction and operation of works for the artificial treatment and disposal of sewage. My answer on direct examination did not have any relation whatever to the sewage question, that is with reference to whether the sewage was treated or untreated when it was discharged

into the Chicago River or the channels of the different canals or branches. I have no practical experience with reference to the extent to which sewage could be treated in the removal of suspended solids or solids that will de-
11165 posit in navigable channels but merely as a general practitioner. I am aware that the solids that will be deposited can be very materially reduced. Solids will be left that may settle in channels, to a slight extent. There would be a greater settlement of such solids than if there is a current. There will be more settlement with a slower current. With respect to there being a large settlement of solids if at times there was a heavy storm carrying a very large amount of settleable solids in the stream and then a subsidence of the storm and consequent slowing up of the stream gradually or perhaps very quickly to a very small current, there would be a large settlement under any possible conditions.

I do not appreciate that grease and oil may get on to
11166 navigable waters from any source and constitute an obstruction or impediment to navigation. I do not think that either grease or oil would impede navigation. My conception of navigation is navigating a river with boats. As to taking into consideration any question as to whether the waters might be unattractive to navigation due to pollution or refuse going into the Rivers, I have taken into no consideration whatever the picturesqueness of the water.

If there were no treatment of the sewage at Chicago and no discharge of any water to the Des Plaines River from the Drainage Canal, the condition of the Chicago River and the channels of the branches of the Chicago River and the Drainage Canal with reference to nuisance and odors coming from putrefaction of sewage would be similar to those which now exist in similar channels at Milwaukee, in the Rouge River at Detroit, at the Cleve-

land inner harbor, in the harbor at Buffalo, in Newton Creek, New York City, or where it formerly existed at Baltimore.

11167 I was last in Milwaukee and saw the Milwaukee River
11168 about 15 or 20 years ago. I was last in Cleveland and saw the Cuyahoga River when I was in charge of the work, probably over 20 years ago. Cleveland was not very small. It was a very large city. It was probably a city of 500,000. As to that being a rather small city, compared with the City of Chicago with some 3,300,000 inhabitants, if one computes it, it would be one-sixth the size. The sewage of Cleveland then was very much less than the sewage of the City of Chicago. The Cuyahoga River was in pretty bad shape then. The condition in
11169 the Chicago River would not necessarily be several times worse than the Cuyahoga River under those conditions. In saying, "not necessarily," I mean that it would be only a comparatively small part of the City of Chicago which drains into the Chicago River. A great part of the City of Chicago does not drain into the Chicago River. It drains off to the North sewers and to the South. South Chicago drains into the Calumet River. That sewage is drained into the Calumet-Sag Channel. The Calumet-Sag Channel connects with the main channel of the Sanitary District at Sag, Illinois.
11170 If there was no discharge into the Des Plaines River from the canal at Lockport, all that sewage would go into the Chicago River, but there would be the area or the volume of the two streams that would be contaminated. That would be the Calumet and the Chicago Rivers. The dry weather flow of the Calumet is rather insignificant. I do not know what it is. I think it is like the Chicago River. It would furnish no practical dilution for the sewage. Dry weather flow for the Chicago River is insignificant, and there would be practically no dilution

11171 there. I do not know the dry weather flow of the Cuyahoga River. I would assume that it was greater than the dry flow of the Chicago River, but I could not personally state.

The deposits from these settleable sewage discharges from the channels of the Chicago River and its branches would impede navigation to a limited extent. The great impediment to navigation in these streams comes not from the sewage proper but from the rainfall washing the area and depositing material through the catch basins, and these catch basins are not usually large enough, and the overflow goes into the River. The great reduction in the navigability of the various inlets arises more from that cause than from the sewage. Sand comes from that source, but it would not come from sewage. Floating trash might come from sewage, but there would not be sand or material which would diminish the depth
11172 of the river. Street wash is a very material question in reducing the flow of those inlets.

I was division engineer at one or two places about the Lakes. I was division engineer in charge of the Lakes. I had to supervise the enforcement of the '99 Rivers and Harbors Act. I am familiar with Section 13 of that Act which provides in substance that no refuse or materials of that character shall be discharged into the navigable waters of the United States.

I started work on my testimony in this case the day before yesterday.

11173 I have heard that General Jadwin has testified in this case. I am not sure that I have read the record of General Jadwin's testimony, but I have familiarized myself with what I believe to be a statement of General Jadwin's testimony which was furnished me. My attention is directed to portions of the statement which was read by General Jadwin at the Chicago hearings in response to

an interrogatory as to what flow, if any, from Lake Michigan 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 for the Sani-
11174-11178 tary District were discontinued.

For me to say that I agree or disagree with a statement so complicated as that, is almost an impossibility. I would have to read carefully the various items that are stated and answer, not categorically, Yes, or No, but what sections of that statement I was in favor of.

11180 I read from and comment upon the statement of General Jadwin as follows:

> (Reading) "The introduction of the deposits of sewage into the Chicago River would, without dilution, render it so foul and putrid as to materially impair its navigable condition."

The question of its being found putrid would, in my judgment, have nothing to do with its navigable condition. Navigation does not depend upon the condition of the water.

> (Reading further) "Through its deterrent effect on the navigators and on those engaged in loading and unloading vessels."

11181 I have never seen any injurious effect on navigators by sewage in water. I have never seen any injurious effects on roustabouts from the effect of sewage in water. In fact, when I was in charge here of the District of Columbia Sewer Department my men, who were working on the sewers, were as healthy as any other men. I have been through miles of sewers in this City, breathed the sewer atmosphere, and I do not know of its having had any effect on me personally from breathing absolute sewage in the sewer, so I do not agree with that statement. I did not like that work at all. It was intensely disagree-

able. In fact, I would have to change my clothes and wash after being sweated with the sewage conditions. But it was essential for me to do it, and I can not say that it has had any effect on my health. I would not have done it, if I had not held it my duty, and a necessity. I would prefer to work in water that did not have such a
11182 polluted surface—water that was clean.

(Reading further) "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 the sanitation of Chicago."

That requires no comment.

(Reading further) "The sanitary conditions essential for working conditions for those engaged in navigation should be substantially the same as for the residents on shore."

That is certainly so, as far as its physical effect is concerned, as I have just stated.

(Reading further) "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 7,250 cubic feet per second, will be requisite to dilute the sewage and carry it away to an extent sufficient to
11183 render the Chicago and Calumet Rivers suitable for navigation."

I do not agree with the Chief of Engineers on that statement.

(Reading further) "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 water tolerable for navigation."

That is covered by my preceding statement. I would agree with the statement of keeping it tolerable for navigation under the provisions that I have just made, defining conditions. I do not agree that that is necessary to keep the condition of the waters tolerable for naviga-

tion, as the Chief of Engineers has stated. 7,250 feet are not necessary at all.

(Reading) "The effluent from sewage treatment plants is not pure water, and the added refuse from ships and streets, together with unavoidable accumulation of oil requires more water for flushing than is available from the natural run-off which the urban
11184 development has, in large part, intercepted and turned into sewers."

With that I agree. The natural run-off would be as detrimental during storms, and even more so, than the sewage, and would be an essential element in the question of the navigation of the Chicago River, as it would be the material which would have to be dredged in the greatest quantity in order to maintain the navigation of the river.

(Reading) "When the ultimate practical 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."

I agree that the flow of clear water from the Lake of 1500 c.f.s., need not be exceeded.

(Reading further) "This would give an average annual flow of about 3200 cubic feet per second at Lockport. This diversion would create a current on the principal river channels of from one-quarter to one-third foot per second, and would be sufficient to
11185 renew the average water content of the main portions of the Chicago River in about two days."

I have not made a computation, but would assume that this is correct.

(Reading) "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, be-

cause 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."

I do not agree that it would be offensive, to a degree detrimental to navigation. I agree with the statements, except as I have commented on them.

I do not recall that I ever had occasion to make a report to my superior officer or otherwise on the effect on navigation of the discharge of sewage or sewage effluents,
11186 or sewage storm waters in the rivers and harbors. The Engineering Corps and the Secretary of War have not had occasion to consider that question with regard to navigation. They have with regard to nuisances,—that is, nuisances in navigable waters. A great deal of time has been spent investigating, at different times, different nuisances, and I presume that I have submitted reports on the flow of oil in waters and things of that kind that have been investigated quite frequently. When I was at New Orleans, I assume that I submitted a report. I do not remember the report, but officers were called upon
11187 to investigate those matters. I do not remember any fire down about New Orleans due to oil on the water. I have always been afraid there would be, but I do not remember having any particular fire from that cause. Fire is liable to result from oil on water. A reasonable circulation of the water would lessen the danger, the length of time the oil was on the water; but, as a matter of fact the danger which I anticipated at New Orleans would be enormously increased by the current in the Mississippi River, because if the oil breaks loose above the docks at New Orleans the fire would be propagated down the river, and would sweep every dock along the front of that City. The oil would not be broken up if it escaped in sufficiently large quantities. Whether the par-

11188 ticles of oil would be separated in the current depends upon the amount of oil that is distributed in the water. The case to which I allude, and on which I had to submit a report, was the case of a vessel hitting a pier and spreading oil over the water, in which case I was very much afraid that if the oil should get on fire, it would set fire to the entire waterfront system of the City of New Orleans.

If there was no water coming from Lake Michigan into the Chicago River, the only discharge would be the natural flow of the River. Under the existing conditions the natural flow of the Chicago River goes down the Sanitary
11189 District Canal and then into the Des Plaines River. In answering the question on direct I did not take that into consideration. In my answer, when I stated that there would be no water flow, I did not understand that there would be a discharge to the Des Plaines River from the Drainage Canal. I assumed there would be no water flow. That is, it was on the assumption that there would be no discharge at all from the Drainage Canal to the Des Plaines River that I said it would require no water. Under those conditions there would be no discharge. The connection of the Drainage Canal for navigation at Lockport and Joliet is by a small state canal; but the works by the City of Chicago have not been completed to such an extent as to enable any navigation down the Des Plaines River. I have been over the waters upon which
11190 a boat would travel from the Chicago River to the Illinois and Mississippi Rivers.

As I understand it vessels would pass through the Drainage Canal from the Chicago River to Lockport, from thence pass through the lock into the upper basin of the Illinois and Michigan Canal at Joliet, from thence through another lock at Joliet, Dam No. 1, of the Illinois and Michigan Canal, and on by different locks, etc., to

the Illinois River at Utica. That is the proposed plan. That is not what exists at the present time. That is what is proposed as a project. At the present time the only connection the witness knows of is a small canal by the State of Illinois, which carries less than 4 feet of water. As to the old Illinois and Michigan Canal having been abandoned and replaced by the Sanitary Ship Canal of the Sanitary District of Chicago from Joliet to Chicago, its connection is by a 4-foot channel from the Sanitary Drainage Canal. That is the understanding of the wit-
11191 ness. The connection is at Joliet. From Joliet to Chicago the navigation is by way of the Sanitary Canal. I understand that a boat, in order to pass from the Chicago River to the Illinois and Mississippi Rivers would have to travel over the waters which have been mentioned. If there were no discharge of any water at any time from the Drainage Canal into the Des Plaines River, a boat could not go through the lock at the end of the Drainage Canal. It would be necessary to have a discharge to pass the lock. There would be no way of doing that with no flow.

As to whether it would be necessary to have some water pass from the Lake to the Chicago River, Drain-
11192 age Canal, and Des Plaines River in order to keep up present navigation on the Chicago River on the assumption that at present boats pass from the Chicago River to the Illinois River through the Drainage Canal and Illinois and Mississippi Canal, and *vice versa;* it would not be necessary to have any water because there is no navigation down there.

I have not visited that territory for some time. Assuming that there is present navigation, it would require the amount of water necessary to lock that existing navigation—that is, in order to keep up navigation in the Chicago River.

Redirect Examination.

Assuming that there is navigation passing from the
11193 Drainage Canal to the Illinois River the amount of water which may be needed for lockage in locking vessels from the Drainage Canal down the Illinois River, or the other way, has nothing to do with the physical navigation of the Chicago River. The passage of boats down the lock would have nothing to do with the passage of boats in the Canal above the lock.

Assuming that there is through navigation from the Drainage Canal down to the Illinois River, the quantity of water which would be necessary for lockage or any
11194 other purpose would be determined by the dimensions of the lock. For the purpose of water power the Sanitary District built a very high lift. There is a very high lift at Lockport and to fill the space at that lock the high lift would require very much more water than would be necessary in what is called a chain of locks. Lockage water which would be necessary there for any through navigation would be somewhere in the vicinity of 1,000 c. f. s. for a heavy navigation.

11195 Assuming that all the sewage of the Sanitary District of Chicago were treated so as to remove 85 per cent of the solids and organic matter; that the balance was in a fine suspended state in the effluent of the sewage plants; that there would be an overflow of the sewers in
11196 time of storm carrying rain water mixed with sewage, the proper method to maintain navigation in the Chicago River under such conditions would be to dredge out deposits in the river itself. The river has already been developed far beyond any dimensions which can be maintained by any currents which can be inaugurated in the river. The depths have now been enlarged. The stream is an insignificant stream for navigation purposes, and

it has been necessary to dredge it to such depths that it is now merely a slip in the land, and if it is to be maintained it is necessary to dredge the material that is deposited from any source. The dredging of harbors is regularly done at various ports just to correct these very conditions. On the assumptions that were made the course of maintenance required at Chicago would be similar to that which would be used at Milwaukee, Cleveland, Buffalo, or Detroit.

Recross Examination.

11197 I believe that for the general status of the city it is beneficial to stop the odors which arise in these various slips, but do not consider that it would be essential to the navigation of those slips. To do so would be more attractive to the City. It would be more attractive to the navigator and to the people on the boats if they do not have to smell this sewage.

If the Chicago River were dammed at its mouth and the Drainage Canal were dammed so there could be no flow from the Drainage Canal to the Des Plaines, and if a system of drainage were built whereby all the sewage could be diverted from the Chicago River and its channels and branches, and the Chicago River and the channels
11198 were filled with water, an excellent condition for navigation in the Chicago River would not obtain. Physically, as far as the Chicago River and its channels are concerned, there would be an excellent condition for navigation in the River inside the dam. The navigation could not go out, and it could not come in.

The defendants then proceeded with the offering of further testimony on re-reference in April, 1929.

Ross A. Woodhull, for Defendants:
A Trustee of Sanitary District.

11483 *Direct Examination by Mr. Beebe.*

11484 Reside at Chicago; am one of the trustees of the Sanitary District; was installed first week in December, 1928; am Chairman of the Finance Committee of the Board of Trustees. It is my duty to preside over the meetings of the Finance Committee and to affix my signature to all payments made by the District, checks and warrants. The warrants bear also the signature of the clerk.

Am not now actively engaged in any private business. I was connected with a subsidiary, the Hydrox Company of Chicago, of the National Dairy Products Company. I had to do with the organization of the latter company as the plants that I operated under the name of Woodhull Ice Cream Company were acquired by the Hydrox Company just prior to the consolidation with the National Dairy Products Company. Since that time I have retired from active business. Prior to the time I was elected Trustee, I was in the City Council of Chicago for six terms, twelve years. I was on the Finance Committee of the City Council for ten and a half years. Was
11486 Chairman of the Finance Committee for four years during the Dever administration, and left the City Council when I was elected Trustee of the Sanitary District. My terms in the City Council were consecutive.

11491 When I became a member of the Board of Trustees of the Sanitary District, the old Board had passed an ordinance authorizing the sale of $27,000,000 of bonds. Under the law the deal had to be consummated, the sale of the bonds and the money had to be in the treasury of the

District before midnight of December 31, 1928, because after that date a referendum attached itself by an act of the Legislature and was necessary before any bonds could be sold by the District. The old board availed itself of the opportunity at the close of 1928 to issue bonds without a referendum. They would have been sold within the requirements of the statutes had it not been for the interference or the objection of a taxpayer in the court. The District was unable to deliver a certificate free from litigation, so the sale of the bonds was not completed. It was necessary for the District to either wait until the coming November of 1929, which would be the first opportunity we would have to get before the electorate of the Sanitary District, there being no machinery by which a special election could be called for the submission of a referendum. Having in mind the contractual obligations standing against the District for the work done in constructing plants, the work that must necessarily go forward as rapidly as possible, we went to the Legislature and asked them, in view of the decision of the Supreme Court and hearings to be held before your Honor, that time ought not to be lost, and asked that they lift the referendum clause, modify the legislation and give us the right to sell without a referendum bonds necessary to produce such money as would be necessary to complete the treatment plants in compliance with the permit under which we are operating. We realized that the disposition of the Trustees was not sufficient, but they had to demonstrate their ability. We felt it our duty to go to the Legislature and tell them the story of what we thought should be done. We introduced a bill known as Senate Bill Number 110, in which we asked to be given the right to issue bonds, such moneys to be used exclusively for such work as might be necessitated in the construction of the treatment of sewage in that program.

11493 Defendants' Exhibit 1414 is Senate Bill Number 110, which is in the form drawn by the Sanitary District and as originally introduced in the Senate. We went before all the civic organizations, such as the Chicago Chamber of Commerce, Association of Commerce, City Club of Chicago, Women's City Club, and explained to them the problem and the necessities, asking them to give us their moral support by endorsing our legislation. The Association of Commerce sent a delegation to Springfield and appeared before the Senate Committees. The disposition of the legislators was that there ought to be some restriction and that they ought not to take off the referendum feature except during the interim when there would be no session of the Legislature. The bill was later amended in the Senate and restricted the Sanitary District in issuing bonds the first year $27,000,000 and not to exceed $15,000,000 each year thereafter, for the carrying on of this work. The bill was later amended, restricting the bonds that might be issued without a referendum to $40,000,000 as and when necessary during the next two and a half years, which is Defendants' Exhibit 1416 and shows Senate Bill Number 110 as amended, which passed the Senate. Senate Bill 110, Defendants'
11495 Exhibit 1414, as originally introduced, is in part as follows:

11496 "After December 31, 1928, no such sanitary district shall issue bonds for any purpose or purposes, except for the purpose or purposes of constructing outlets, intercepting sewers, tunnels and conduits,
11497 treatment and disposal plants, pumping and other appurtenances necessary for the disposal of sewage and its products, and water regulating works and sites necessary for the foregoing, for the purpose or purposes of complying with any direction or directions of the United States Government, or with the conditions and requirements of any permit now in force, or which may hereafter be issued to any sanitary district by the United States Government or the

Secretary of War, or for the purpose or purposes of complying with any decree of any court of the United States, or any laws thereof, or any treaty between the United States Government and any other Government; and for the purpose of paying lawful claims against such sanitary district for damage to land or for damage to or destruction of other property, where such damage or destruction is caused or occasioned by such sanitary district, unless the proposition to issue such bonds shall have been first submitted to the legal voters of such sanitary district at a general election, or at any special election called for such purpose by the corporate authorities of such sanitary district, and shall have been approved by a majority of those voting upon the proposition."

11507 The Sanitary District did not suggest, procure or cause any of the amendments to the original bill. We endeavored to prevail upon the Legislature at every hearing and in every conference, to recognize that the decision of the Supreme Court was a definite and mandatory instruction, and that it was our duty to provide all necessary money to do whatever was necessary to do, and that in view of the fact that we could not at that time determine exactly what in the final analysis we would have to do, we did not want to be restricted and asked that the referendum feature be lifted for that reason. We did everything that we could do.

Edward A. Evers, for Defendants:

Naval Reserve Captain at Chicago.

11510 *Direct Examination by Mr. Behan.*

Fifty years old; reside Wilmette, Illinois; Naval Reserve Officer on active duty in United States Navy, in training Naval Reserve of Great Lakes District; am Captain in Naval Reserve in command of U. S. S. Wilmette;

11511 connected with Naval Reserve since 1897; entered as seaman in United States Navy; served in United States Navy from 1897 until after Spanish American War; after that went into Naval Reserve of Illinois; in that continuously ever since.

11512 Illinois Naval Reserve was organized in 1893; continued as State of Illinois Militia Organization until 1916; in 1916 Congress passed act creating United States Naval Reserve, and members of Illinois Naval Militia were transferred to United States Naval Reserve.

During World War, in command of Camp at Chicago on Lake Front, training men for service on sub-chasers and patrol boats; also had command of officers' material school, training men for duty as officers in Navy; also had charge of remodeling seven vessels taken over for service on salt water; remodeled six ships and they went into regular navy for transport and patrol duty; these activities were entirely work of Navy Department; have been on active duty ever since with Navy Department,

11513 training members of Naval Reserve on Great Lakes.

Naval Reserve at Chicago consists of 800 officers and men; occupies as Shore Headquarters at Chicago, remodeled vessel; at present time are constructing $500,000 new building there; located on filled in land at foot of Randolph Street about 1,200 feet south of mouth of Chicago River on line parallel with end of mouth of River; that approximate location since 1897; during

11514 World War, approximately 7,000 officers and seamen were prepared for service in Navy through our organization.

Members of Reserve required to drill one night each week; required to take 15 day tour each year on training ship; taught to sail, to handle motor boats, to dive in diving suit; we follow out navy program of training exactly.

11515 Members of Naval Reserve are paid by Federal Government for attendance on drills, and also for their 15 day tour each year.

Am in command of U. S. S. Wilmette; property of U. S. Navy; vessel 285 feet long, 40 feet beam, 2,200 ton displacement; 3 boilers, 2 triple expansion engines, 3,000 horsepower, carries average crew of 250 men; Wilmette in service since 1919; have been its Commander ever since that time; it is part of fleet of seven vessels on the Great Lakes.

11517 Navigated Wilmette on Chicago River and branches
11518 in fall of 1926 and spring of 1927, and from five to eight years prior to that; navigated north branch and main river as far as turning basin; docked Wilmette at turning basin at North Avenue; no difficulty of navigation so far as actual movement of vessel is concerned; lot of trouble with sludge in the water; our piping picked this stuff up readily; our condensers got quite a load of it; we had to take heads off and clean them; found it in
11519 our pumps; found it throughout fire mains and generally throughout all piping on ship; in spring of 1927 picked up very heavy coating of grease just above and below water line; after dry-docking we found all paint disappeared from bottom of ship after spending four months in turning basin;

Water supply for vessels of Great Lakes fleet while on cruise taken out of Lake Michigan, out of Lake Huron and out of Lake Superior whenever suitable;

Try to avoid taking water out of Lake Erie; never take any water out of Erie without distilling it; orders
11520 on Great Lakes Fleet not to use Lake Erie water for drinking purposes without distilling it.

In harbor of Cleveland almost every year on cruise; am familiar with water in harbor of Cleveland; there August last; we found the water decidedly dirty.

11521 Water so dirty that men not permitted to swim in it; not much odor noticeable from big ship, but in small boats, close down to water, we found very decided odor; that was in the harbor, right near the mouth of the river; inside the lake, the breakwater.

11522 We were in harbor of Milwaukee several times last year; last visit about August first, 1928; two bathing beaches at Milwaukee; most popular one at north end of harbor; north of Milwaukee River; have observed within last summer condition of water at that beach; we found water at beach was very dirty; Doctor decided that men
11523 had better not go in there; order issued to men of fleet that there was to be no swimming in Milwaukee harbor at that particular time.

Prevailing wind on Lake Michigan in summertime is southwest; southwest wind blows anything in flotation or suspension in the water to the bathing beaches.

Am familiar with use of Lake Michigan on Chicago
11524 front for recreation and bathing and swimming; used very extensively; am familiar with improvements now being made along water front of Chicago by two park boards; am member of Committee of Lake Michigan Yachting Association, which is to confer with park boards relative to improvements being suitable and proper for yachting and of extensive use by the people; use of water of Lake Michigan along Chicago Front has decidedly increased for recreation purposes last few years.

11525 *Cross-Examination by Mr. Ward.*

From my experience, Chicago has better water in front of its beaches than other cities.

Dr. W. A. Evans, recalled for Defendants:
Public Health expert.

Direct Examination by Mr. Lewis.

I testified before. Am still the historical writer on the subject of health and matters similar and cognate, for the Chicago Tribune and papers in its syndicate. Am
11526 now Emeritus Professor of Public Health in Northwestern University Medical School at Chicago. I was health officer of the City of Chicago for a term, and have been giving constant attention from time to time to different conditions and matters of health in that locality. I have information as to the general state of the water of Lake Michigan so far as it relates to seamen and sailors, in the matter of health. I have studied the reports on the prevalence of typhoid fever among the regular seamen, found in the annual reports of the
11527 United States Public Health Service and the annual reports of the Deputy Minister of Health of Canada, and as found in the Office of the Sanitary Engineer of the United States Public Health Service, located in Chicago. In 1908, when Commissioner of Health of Chicago, I organized the Lake Michigan Water Commission, and in the proceedings of that Commission in 1908 and 1909 we had discussions on the prevalence of typhoid fever among seamen inaugurated by papers by the Public Health Surgeons, Young and Cobb, then located in Chicago, and I have been somewhat in touch with the situation since that time. Young and Cobb were in the United States Public Health Service.

11528 The sources of information that I have examined with reference to prevalence of typhoid fever among seamen are in the main the annual reports of the Surgeon Gen-
11530 eral of the United States Public Health Service and

the Deputy Minister of Health of Canada, supplemented by what I found in the Office of the District Engineer located in Chicago. That information shows that the typhoid rate among sailors and seamen on the Great Lakes is about twelve times as high as the typhoid rate among civilians at Chicago, Detroit, Cleveland, Milwaukee and other Great Lakes cities. In 1928 in the Marine Hospital of that district there were cared for sailors with typhoid fever from which we would calculate that the prevailing morbidity rate of typhoid fever among these seamen was about 6.0 per 100,000. That is, as compared with the prevailing rate among civilians in Chicago of about .5. The rate among Canadian seamen was higher than that among American seamen.

It is difficult to control the water supply of vessels on the Great Lakes. In 1921 the United States Public Health Service issued rules and regulations for interstate carriers, supplemented by other rules and regulations for vessels on the Lakes. Those rules provided that the passenger vessels would be required to take water from certified and approved places, unless they were equipped to treat that water in some way or other for the purpose of purification. The rules laid down the requirement that passenger vessels should be equipped with ultra-violet apparatus of approved type; that freight vessels should be equipped with distillation apparatus of approved type. That related to everything except a few vessels which have permission to chlorinate and one or two others with permission to treat the water with ozone. Vessels with crews of less than ten are not covered by these rules.

11532 In order to enforce the rules, the Government has a laboratory service, and a district engineering service. The laboratory service that they make use of is the laboratory service of the various health departments located

around the Lakes. They inspect the vessels, to see that the installation of equipment complies with the rules. They have the water supplies taken from the vessels, to see how those water supplies—whether they comply with the rules for water used by interstate carriers.

They have not found it an easy matter to enforce these rules under the circumstances that prevail. The ships are advised to take water in mid-lake, and away from communities. They have found it difficult to enforce that advice. It is not a requirement; it is a request. The proof that they have found it difficult to enforce this with seamen is of several types. They have greatly improved the typhoid rates; they are considerably lower, the typhoid rates, among seamen, than they were some 21 years ago. But nevertheless, they are considerably higher than the typhoid rates among the civilian populations of the ports touched by these ships. There are a number of samples of water that run below the legal standard. Water as they find it on these vessels is rather higher than the percentage of samples of polluted water that are
11533 obtained in the several communities.

11534 Pages 99 to 102, inclusive, of Annual Report of the United States Public Health Service Treasury Department for year 1928, received in evidence as Defendants' Exhibit 1417.

At the top of page 100 of said exhibit there is a report on the cases of typhoid fever treated in the Marine Hospitals of the United States by years from 1915 to 1927, complete. 1928 is incomplete, but I have a table here making that data complete. The table was obtained from Mr. Frank R. Shaw, local representative of the Public Health Service at Chicago. The table sets forth the
11536 number of cases of typhoid fever in the United States marine hospitals for the years 1921 to 1928, by vessels and other data, and by months. The number of seamen

registered on vessels on the Great Lakes in 1928 was 17,760. On the basis of the number of cases of typhoid fever cared for in these marine hospitals, we have no way of keeping track of the cases that were not cared for in any way—gives us a rate of 6.44 for the year 1928. The number of seamen varies from about 18,000 to about 25,000 on the United States register on the Great Lakes.

11537 A very considerable percentage of typhoid is among the seamen in the engine room on ships. The fact that they take water overboard and drink water that has not been properly protected, is, I think, the largest factor in this undue prevalence of typhoid amongst seamen. The largest factor in producing typhoid is the result of water conditions. In 1928 the typhoid death rate among seamen was about twelve times as high as that of the civilian population of the City of Chicago. It was higher than that of the civilian population of any city located on the Great Lakes of which I have knowledge, and it has been so, so far as my information extends, back as far as 1908.

Pages 104 to 105 of the Public Health Service Report of the United States for the year 1927, Defendants' Exhibit 1418. Pages 106 to 107, inclusive, of the same Public Health Service Report received in evidence as Defendants' Exhibit 1419.

11539 Certain documents or tables obtained by the witness from Major Shaw, District Engineer of the United States Public Health Service at Chicago, received in evidence as Defendants' Exhibit 1420.

11544 Defendants' Exhibits 1421, 1422 and 1423, being pages 27 and 32 of the 1927 report, pages 51 and 53, 62, 64 and 65 of the 1926 report, pages 38, 39, 43 and 44 of the 1925 report of the Department of Health of the Dominion of Canada, respectively.

If Chicago's sewage should be sent into the Lake, it would increase the danger to sailors from typhoid fever.

11545 The Public Health Service is doing almost all that it can do in providing for the protection of the water supply on the vessels by treatement with ultra-violet or by distillation. They could do somewhat better if they had an increased inspection service or police service. If the sewage were kept out of the Lake or anything that is done to prevent the pollution of the Lake, will serve to decrease this danger. The water at the south end of the Lake, from 68th Street, Chicago, to the extreme south end of the lake, is a great deal worse polluted than is the water in any other part of the lake in the vicinity of Chicago,
11546 and wind streams of pollution and wind streams of phenol, tainted water, travel considerable distances to the north and in other directions from the mouth of the Calumet River at times. The more pollution that is put in at the mouth of the Calumet River, or elsewhere in our vicinity, the greater will be the hazard to the people who get their water supplies north thereof.

The most effective thing is to keep the pollution out of the lake by diversion, plus biologic treatment, wherever that is required. That is, sending the sewage down the Canal. In a measure biologic treatment would serve the place of diversion. It has very high merit. They both
11549 co-operate together.

I am acquainted with the bathing beaches at Chicago. I know something of the relation of bathing beaches to the spread of typhoid fever among the people using those beaches.

11552 My opinion is that we do not have so much typhoid fever from bathing in polluted water as there has been asserted in other places, I doubt as much as one per cent, or to exceed one per cent of the typhoid fever in the City of Chicago is from that source. I have here the typhoid cases occurring in Chicago between 1924 and 1928, in which it was thought by the Chicago Department

of Health, and they give it as their opinion, that these cases in the main, except where exception is here to be found, are the result of such bathing. This report of
11553 the Chicago Health Department, covering the years from 1924 to 1928, states the result of the investigations of the Chicago Department of Health as to sources of cases of typhoid fever coming from bathing in polluted water, not all of which is Lake Michigan. The facts are set forth.

Assuming the sewage effluent at dry weather times to flow into the lake, installation of pumps at the easterly terminus of the Calumet Sag Channel, whereby 2,000
11555 second feet would be pumped from the Little Calumet River and the Lake, into and through the Calumet Sag Channel, which water would flow through the Main Channel towards Chicago, West Fork and South Branch, which would be augmented at the junction of the South Fork and South Branch with 2,000 second feet pumped at 39th Street through the conduit there to the South Fork, and that this volume would flow on to the forks or junction of the North and South Branch, where it would be augmented by 1,000 second feet of lake water pumped at Wilmette, and this volume, together with the sewage effluent from the various purification plants, would flow
11556 into the Lake at the mouth of the Chicago River, it is my judgment that there would be a different effect on the navigation and uses of water for recreational purposes. We would come presently to have a condition of water in the lake opposite that district which would be approximately the same as the conditions that now prevail at the foot of Lake Michigan in the vicinity of the mouth of the Calumet River and of the Indiana Harbor Canal. The water in the vicinity of the mouth of the Chicago River would be very heavily polluted, about as heavily polluted as was found in an investigation of the water in

the vicinity of the Calumet River and the Indiana Harbor Canal, as set forth in Public Bulletin No. 170, Treasury Department, 1927, commonly referred to as the Crohurst-Veldee Report. I refer to pages 133 and 134. The particular portion referred to of that report is as follows:

11558 "The existing water intakes in Lake Michigan, north of the Dunne and Sixty-eighth Street cribs, appear to be beyond the zone of pollution from the Calumet district and are receiving water of such quality that it can be satisfactorily purified by artificial processes, excepting the supplies of Waukegan and Lake Forest. Although the pollution of these latter supplies is in no way chargeable to the Calumet district, and its discussion is beyond the scope of this report, the existing pollution in this area of the lake, north of the Sanitary District of Chicago, obviously demands attention and abatement.

If the use of the lake as a source of water supply for the urban population in the southern part of the City of Chicago and the Calumet district is to be continued, as seems inevitable, it is necessary in the interest of public health that the water supply intakes in this locality be protected. To remove the intakes beyond the zone of at least occasional pollution would require their extension very far into the lake, to a

11559 distance which is probably not practicable. Moreover, in the absence of any remedial measures, it is to be anticipated that the present zone of gross pollution would be extended, with the increase in population and development of the adjacent land area, thereby increasing the danger from intermittent contamination of the water from the extended intakes and of the water of other intakes. The obvious remedy for the present extremely unsatisfactory conditions, in the southern end of Lake Michigan, is abatement of the existing pollution from sewage and industrial wastes reaching the lake directly or through the Calumet River and Indiana Harbor Ship Canal. The choice of methods to achieve this end involves engineering and economic problems which it is not within the province of this report to discuss. There is no question, however, that abatement of the existing pollution is possible, notwithstanding the diffi-

culties which it may present, and it is certain that the need is imperative."

The said report, entitled "Report of an Investigation of Pollution of Lake Michigan in the Vicinity of South Chicago and the Calumet and Indiana Harbors," received in evidence as Defendants' Exhibit 1424.

11560 Defendants' Exhibit 1425, being certain tables made up from pages 89 to 92 of the said Crohurst Veldee Report, Defendants' Exhibit 1424, received in evidence.

11564 Defendants' Exhibit 1426, certain charts made up from said tables, Defendants' Exhibit 1425.

On the assumptions with reference to discharge of effluent and storm water and the flushing of water from the lake into the Calumet Sag Channel and the channels of the Chicago River, there would result the discharge of harbor pollution, shore wash, effluent, and 2,000 feet of water diverted from the Calumet into the Lake at the mouth of the Chicago River, and would tend to bring about in the territory in that vicinity from Evanston to the Dunne Crib, the conditions which prevail in the vicinity of the mouth of the Calumet River.

11565 Certain manufacturing interests put phenol bodies into the water. There are several factories of that type located in the South Chicago territory. It has been noted with some degree of frequency that with the wind in the right direction, these phenol bodies are carried to the water intakes supplying the City of Chicago as far away as the Wilson crib, or a distance of at least ten to fifteen miles. That bears on the question of lake currents and the ability of wind currents on the lake to spread pollution from the point at which it is put into the lake to the intakes. There are no definite currents on the Great Lakes except those that result from wind action. When the wind blows steadily in one direction

for a certain length of time, currents of water flow with the direction of the wind.

11568 *Cross-Examination by Mr. Ward.*

Typhoid vaccination, so far as the civilian population is concerned, has not changed the situation with reference to typhoid fever. Immediately after the World War it was thought that a considerable percentage of vaccinated soldiers returning were having influence on typhoid, but it is generally thought that influence no longer exists. Vaccination is practical and useful, particularly with military forces. We found it impossible to get much use of typhoid vaccination with civilian pop-
11569 ulation. I never have heard of typhoid vaccination recommended by Federal or Canadian health authorities for seamen. I attributed the amount of typhoid fever not solely to the drinking water impregnated with germs. It is the principal cause. It has not happened in several years, but there are reports of epidemics of typhoid fever of a considerable number of a ship's company. I have seen the report of the Steamship Rochester of the Cana-
11570 dian Inland lines, carrying about 200 people from Rhode Island to the unveiling of the Perry Monument at Kelly Island in about 1912, when 40 of them came down with typhoid fever after leaving the vessel and within the prescribed time. You will find that in the report I have submitted. I don't know the cause of that epidemic. I would regard an adequate cause that the pumps and hoses which were used to take drinking water from the city mains to the vessel, were also used in drawing polluted water from the harbor for flushing purposes. I don't know that that practice is being used on the lake vessels. It has been discussed as one of the hazards to seamen. I don't know of any vessels that have duplicate pumps for the two different purposes. I have read vari-

ous reports where that has been complained of. If that was the practice, it would be a contributing part of the hazard of being a seaman. The rules governing danger of typhoid to seamen are very definite and prescribe that passenger vessels shall have apparatus for purifying the
11572 water of a type approved by the United States Public Health Service, and that vessels carrying freight shall be equipped with apparatus for distillation of a type approved by them.
11573 In addition, these reports that I have submitted show that they have been able to certify about 75 per cent of the vessels on the Great Lakes, from 75 to 80 per cent; a certain percentage has up to date escaped them. In addition thereto, they check the matter by periodic laboratory examination of the water supplies. They are aware of the fact that it is quite difficult, and the reports in evidence show that they are aware of the fact that it is difficult to enforce these rules, particularly amongst the seamen themselves.

There has been a quite marked diminution in typhoid among seamen in the last ten years.

11575 *Redirect Examination by Mr. Lewis.*

Defendants' Exhibit 1427 is as follows:

"TYPHOID FEVER DEATH RATE PER 100,000 POPULATION. CITIES OF MORE THAN 100,000 POPULATION IN GREAT LAKES REGION.

Cities	1926-1928 Years. 1926	1927	1928	Average
Chicago	0.8	0.7	0.5	0.67
Milwaukee	1.4	0.9	0.7	1.00
Detroit	2.2	1.2	1.0	1.47
Cleveland	1.4	1.0	0.6	1.00
Buffalo	3.1	2.4	2.3	2.60
Rochester	4.0	1.2	0.9	2.03
Hamilton	0.0	0.0	0.0	0.0
Toronto	1.4	1.1	0.9	1.13

To bring up to date the table on P. 137, Report of the Special Master."

11709 *Direct Examination by Mr. Lewis.*

Sailors become infected as other people do in a variety of ways, such as drinking polluted water, infected milk, eating polluted food, contact with carriers.

11711 The method required to protect water upon a ship is to provide those ships with water purification apparatus, which I have described, and to require them to take the water from approved sources. All that applies to vessels with ten or more crew. It does not apply to the others, nor to pleasure craft.

11712 The barriers that should be drawn around a body of water like Lake Michigan are, first—the sewage should not be put into the Lake, it should be diverted at Chicago down the Drainage Canal. The second barrier is purification. The water may be purified by replacement of the intakes, by treating the water with chlorine and by filtering it, or by several of these combined. Much depends upon the distance that the intakes are in the Lake and upon the direction and force of winds and the volume of pollution. The water at the intakes now is frequently moderately polluted even at the four mile intake. It has been necessary for twenty years to chlorinate the water. Sometimes the water has a phenol taste, due to certain industrial processes, coal-tar. At Chicago these wastes get into the Lake more in the Calumet region. The water is less appealing or attractive; otherwise it is harmless.

11714 *Cross-Examination by Mr. Jackson.*

I stated yesterday that the typhoid death rate of seamen was 6.24 or about 6.0. It is about 6. I cannot state how that death rate compares with the typhoid rate for all of the United States. I don't think it is lower than the rate for all the rural communities in the United

States. I am not willing to say that the typhoid of the United States exclusive of large cities is less than 6.0. I don't know.

11715 I don't think that the question is involved at all as to whether it is more healthful to be a sailor on the lakes than it is to live in the rural communities. The death rate varies in the different parts of the United States. In the State of Alabama, for instance, the typhoid rate is 13, and in the extreme southern states it is in that

11716 vicinity. The typhoid rate of Illinois and of the states contiguous is about 3 to 4. The rate of the districts around Lake Michigan is about half that of seamen on the lakes. To get into the far south, the rate is higher than it is amongst seamen.

I have no conclusion about the effect of seamen navigating the waterway from Chicago to the mouth of the Illinois River if sewage were turned into the narrow confines of that river. I don't know how many seamen there are there. I don't think they would drink any water out of that river. The water in Lake Michigan is much more attractive in taste and in appearance than that of the Illionis. I couldn't conceive of a sailor or

11717 anyone else voluntarily drinking water out of the Illinois. They habitually drink water out of the Lake. The rules and regulations of the Public Health Service provide that vessels can only take water from approved sources unless they are equipped with purifying apparatus of the types I mentioned. The report of the Sur-

11718 geon General shows that on the Great Lakes about 75 per cent to 80 per cent of the larger vessels in interstate commerce have been so inspected and so certified. About 20 to 25 per cent have not been.

It might be true that had one less person died of typhoid fever in Milwaukee in the year 1928, the death

rate there would have been lower than that of Chicago for that year.

I didn't say that phenol waste was harmful. I referred to it as an index of the distance to which polluted water would spread and the fact that it would reach certain intakes.

Referring to Exhibit 1425 and 1426, I should say that the B. coli shown for the water at various points, indicates the condition of water along the lake front at those various places, and shows also the relative quality of the water along the lake front at the points at which they were taken. The B. coli readings for water at Hammond, Whiting and East Chicago were taken at the cribs or at the tunnel intakes. It is also true of Gary. The same is true of the Chicago intakes.

11720 Opposite Gary the pollution is less than East Chicago. At East Chicago there are 8,000 B. coli per 100 c.c. At Gary it is less than 1,000. The distance of the Gary intake from the shore line is approximately 8,000 feet. The East Chicago intake is 2400 feet. The

11721 old intake was 600; Whiting 1200; Hammond 5100. Gary shows about the same pollution as is shown at the 68th Street Crib in Chicago. The distance from shore of the intake is a factor of importance which should be taken into consideration in analyzing this chart, Defendants' Exhibit 1426. It would be a factor of error in any direct comparison. As to whether a test made 100 feet off shore in one place and another one four miles off shore in another place, would give any indication of the relative pollution opposite those points in the lake, I would say that it would, but as to whether they are completely comparable, I should say no. I don't think

11723 that if we went four miles off shore at Gary or East Chicago, Whiting or Hammond, we would have practically the same B. coli index that there is at Chicago at

the four mile crib. I could not say how high the pollution would be four miles off shore at Gary, but it would be very high. I think it would be over 100 B. coli per 100 c.c., and I think these charts show that. Some years ago I participated in the survey of the condition of lake water at considerable distances off shore some as far as four miles, and it is my recollection that the water is rather uniformly polluted four miles off shore and becomes quite heavily so with the wind in certain directions.

During the period of the examination shown by the
11725 Crohurst Report—June, July, August and September, 1925,—four miles off shore would put you beyond the contour line of 2 B. coli per 100 c.c. I don't believe there was sewage treatment at Hammond when that report was made. Whiting filters and treats its water. There is no sewage treatment there and none at East Chicago or at Gary. My understanding is that it goes into the Calumet River without treatment at both places. I could
11726 not answer as to what per cent of the time there was reversal of the Calumet River. I do know that there is not infrequent reversal of flow of water in the Calumet River. I assumed that the 2,000 second feet of water that was to be pumped through the Sag under the flushing program, would be Calumet River water. The Calumet River opens into Indiana Harbor at the east end. The Grand Calumet River is more or less of a bayou, opening into the lake at both ends. The Indiana Harbor Canal water is worse than the Calumet River, the B. coli count being considerably higher The Indiana Harbor Canal is continuous with the upper reaches of the canal and a flow down the Calumet River would carry some part of the Indiana Harbor water down into the Calumet River. I didn't have pumping circulating water from the Lake in mind. I had in mind in connection with

the flushing program that the water in the Calumet River of the type which now flows through the Sag Channel, would be carried into the Chicago River and be dis-
11728 charged at the mouth into the Lake. Some part of the Indiana Harbor water would be drawn through the Calumet River. I did contemplate the circulation of the sewage of these Indiana cities untreated through the Calumet and Chicago Rivers. The water as it is in the Calumet River connecting with the Indiana Harbor would go through the Sag Channel under the plan proposed or, as I understood it was proposed, finally reaching the Chicago River, being discharged from the river into the Lake at the mouth of the Chicago River.

11729 *Redirect Examination by Mr. Lewis.*

The chart showing the contours and measurements is a record of an investigation made by the U. S. Public Health Service. They took water for the study whenever it could be done satisfactorily. My experience is that in very bad weather they are not able to take water, and of course that is usually the worst water, the times when the water is worst.

I am uncertain that there are any sailors on the Illinois River, but if there are any, the water supply of the boats is taken from the municipal supplies along the river. The Illinois River water is not used for domestic purposes by any community along the river, and people do not have the habit of drinking water from that river. The re-
11730 duction of typhoid fever among seamen on the lakes is almost altogether due to the result of the stringent regulations enforced by the United States with reference to use of water for domestic drinking purposes. The farther we go into the lake and the farther we go from the
11731 sources of pollution, the safer the water is. The mat-

ter of placing intakes, one, two or four miles out, as a means of protection, we have had a lot of experience with. It is to some degree, and a considerable degree, a protection, but at times as a means of protection it fails.
11732 Much depends upon the direction of wind currents. At times of storm the hazard is increased.

Horace P. Hamey, recalled:

Assistant Chief Engineer of Sanitary District.

11644 *Further Direct Examination by Mr. Beebe.*

I testified at the March hearings; have heard the testimony of the Sanitary District engineers in connection with the program for the artificial treatment of sewage. I heard described the method proposed for the discharge of the effluent and storm water to the Des Plaines River, with the provision that a certain amount of water be withdrawn from Lake Michigan to keep up navigation on the Chicago River.

I have had charge of the operation of the channels
11645 of the Sanitary District for the past 12 years, with special reference to the flow in those channels. I testified also at the hearing in January, 1927.

In August, 1927, I carried on experiments to determine the discharges and the amount of flow at various points of the Drainage Canal and Chicago River under various conditions, in collaboration with the Government engineers. We carried out a very comprehensive series of experiments on flow through the Chicago River and Main Drainage Canal, as well as the Calumet Sag Channel. About a month was consumed for these experiments, and some sixty men were employed.

We made experiments to determine conditions of steady flow, and we determined the slopes that would be

11646 required to produce a steady flow of various quantities, and once during this series of tests we established a steady flow of a small quantity. I have not the data right with me, but I believe it was something like 4,000. Perhaps it was a little higher. Then we suddenly increased the outflow at Lockport to a much higher flow, I believe 14,000, and observed the time that an increase would be produced in the flow at various points upstream, making observations at all points along the channel clear up to Lake Michigan.

The object of that particular test was to determine how long after a change had been made at Lockport the full effect of that change would have been felt in the Chicago River. This was to check certain similar tests that we had made February 22 and 23, 1914, March 8 and 9, 1914, and a test that we had made in November, 1925, for the same purpose.

The tests in February and March, 1914, were made by Sanitary District forces only, but the tests in November, 1925, and in August, 1927, were made in collaboration with the government engineers.

11647 I furnished Professor King, Mr. Howson and Mr. Sabin a series of discharge curves showing the results of these four special tests. I offered to furnish any of the basic data; that is, to let them look at any of the basic data. They accepted my average curves as correct. I should have said that they accepted these discharge curves, which discharge curves are exhibits in this case 1402, 1403, 1404 and 1405. Then I furnished them with certain average curves that I had drawn from these curves. From these discharge curves, certain average

11648 curves were drawn to show the time of change at various stations upstream.

I furnished them with an average curve for the Station Lemont, which was about 9½ miles upstream from

Lockport, where the change in flow had been made; at Lemont, because there were four tests, there were, of course, four curves showing the time that the change had occurred at Lemont. Those four curves were slightly different, and I had drawn an average for the station at Lemont to show the average result of these four tests. I furnished that curve; also an average curve for the next station upstream, which was at Willow Springs; also the curves with the average curve for Station Summit, still farther upstream. Another curve for all the observations we had made in the vicinity of Ashland Avenue. Also the curves and the average curve for all observations that we had made in the vicinity of the junction of the North and South Branches of the river.

11649 I have made studies of gates at Robey Street and at Western Avenue and at Kedzie Avenue. Now, between Robey Street and Kedzie Avenue the channel is divided; that is, the main drainage channel runs southwest from the South Branch of the Chicago River at Robey Street. At Robey Street the west fork of the Chicago River runs directly west for about a mile and a half and then there is a connection between the west fork of the Chicago River and the drainage channel at a point just east of Kedzie Avenue.

If controlling works were installed just west of Robey Street, or at Western Avenue, this west fork would still be open, and water could pass from above the controlling works to a point below the controlling works through this west fork. There is not much room at Western Avenue or at Robey Street; in fact, the State of Illinois is

11650 planning a terminal for the Illinois waterway at Robey Street. So I do not believe it is practicable to build controlling works east of Kedzie Avenue.

The West Fork of the South Branch west of Kedzie Avenue is not navigable, and Congress has so declared.

I have heard the testimony of Professor King. 2,750 cubic feet of water from Lake Michigan, exclusive of any water pumped for domestic use and storm flow, will be required to so operate controlling works at the northern terminus of the Sanitary District Canal so as to prevent the pollution of Lake Michigan waters due to such storm flow. In reaching the above conclusion, I have made the following assumptions:

11651 That sewage purification works outlined to be constructed by the Sanitary District for the complete purification of all sewage arising within the limits of the Sanitary District, which have been approved by complainants, are completed and put in operation; that controlling works are installed at some convenient place at or near the easterly end of the drainage canal, and that such works when operated will permit the discharge at dry weather times of the effluent from the said sewage purification works into Lake Michigan by way of the Chicago River, except as to the effluent from said sewage purification works serving that portion of the population of the Sanitary District in the area south of 87th Street, which will be discharged by the use of the present works into Lake Michigan by way of the Calumet and Little Calumet rivers; that the said controlling works when operated will also permit the discharge of all of that direct storm flow which cannot, or may not, be treated completely by said sewage purification works, to the Des Plaines River; that the purpose of said operation of the controlling works is to discharge to the Des Plaines River all effluent and storm flow reaching the channels of the Chicago River and the channels of the Sanitary

11652 District canals and the greater portion of the storm flow of the Little Calumet River in order to prevent the

pollution of the Lake Michigan waters due to such storm flow.

11653 The facts taken into consideration and the methods used to arrive at the conclusion as to the amount of water necessary to be withdrawn from Lake Michigan to accomplish the above mentioned purpose, are:

I have assumed that if controlling works were installed in the vicinity of Kedzie Avenue, they would need to be operated every time there was a storm on the Chicago River watershed, either actual or threatening; that it would take a certain discharge through these works for a certain length of time to establish a flow in the Chicago River sufficient to carry the storm run-off. I have assumed further that the controlling works would operate during the actual time of rainfall on the Chicago River watershed, and for a certain length of time after rain had ceased to fall, but was continuing to run into the river through the sewers.

Then I have assumed that since the Chicago River would be polluted from this storm run-off, it would be necessary to replace the volume of water in the river

11654 and other channels with an equal volume of clear lake water. There are in Chicago approximately 55 general rains per year of sufficient size to cause storm water overflow.

This has been determined by study of the rainfall records at the various rainfall stations in the Chicago area, and that has been testified to previously at these hearings.

In addition to the 55 general storms per year there are a number of heavy local storms affecting certain portions of the area. These are recorded at the various local rain gauging stations situated all the way from Evanston, Illinois, to Whiting, Indiana. Study of the records for recent years indicate that there are approxi-

mately 50 of these heavy local rains affecting some one or more of the rain gauging stations. To allow for the pollution caused by these local rains I have assumed that the controlling works would need to be operated 25 times per year, or for half those local rains. To allow for threatened rains, or rains too small to produce an overflow from the sewers, I have assumed that the controlling works would be operated ten times per year.

Summing up all these operations makes a total of 90
11655 times per year that the controlling works would be opened to prepare for storm flow conditions in the Chicago River. So far as within reason I have used figures as testified to by Professor King. I have assumed that the operation of the controlling works 90 times per year would require the opening of the gates and maintaining a flow through them for 40 minutes each time at an average rate of 14,000 second feet. The quantity of water discharged through these gates during these times of preparatory flow would average 87 second feet for a year. The same result would be obtained if the gates were opened so as to discharge an average of 9,333 second feet for one hour each time in preparing for a rain.

A study of the records indicates that the average period of rainfall for each rain that produces overflow from the sewers is 5.6 hours. Based on the best available data, I have assumed that the period of run-off for each storm subsequent to the cessation of rain will be three hours. This gives a total of 8.6 hours during which storm flow will pass through the controlling works for each rain. I have assumed that the flow would vary between 10,000 second feet and 6,000 second feet, or be an average of 8,000 second feet during the 80 periods per year of rainfall and subsequent run-off.

The volume of water passing through the controlling

works at Kedzie Avenue during these periods is equivalent to an average of 522 cubic feet per second for one year.

In a similar way I have calculated the flow through the controlling works of the Calumet Sag Channel at Blue Island, except that because of the different character of the territory I have allowed an average time for run-off subsequent to rains of six hours in place of three, that I used in the Chicago River. During the period of flow preparing for rain, and of flow during actual rainfall, and flow during run-off period subsequent to rainfall, there has been required an average of 212 cubic feet per second for one year through the Calumet controlling works.

Then in order to clean up the channels after a rain it would be necessary to draw from the North Shore channel and North Branch all of the polluted water there from the storm; next to draw water from the main branch of the Chicago River and from the South Branch to Kedzie Avenue, the location of the controlling works, and then to draw all the polluted water out of the main channel to the Lockport controlling works, including the polluted water in the Calumet and Little Calumet Rivers and the Calumet Sag Channel. This would be done by pumping in 1,000 second feet into the North Shore Channel at Wilmette, which with the three hundred second feet of effluent from the North Side treatment plant would displace the storm water in the North Shore Channel and North Branch of the Chicago River in 30.7 hours. During this time a flow of 2,500 second feet would be maintained through the main river to insure against back flow into the Lake—and incidentally would replace any storm water that happened to be in the main river.

When the storm water has been displaced throughout the North Branch, the pumping at Wilmette will be

stopped and the flow through the main river into the South Branch would be increased to 6,700 second feet for 6.7 hours, at the end of which time all the storm water in the South Branch down to the controlling works at Kedzie Avenue would have been displaced.

Of course, under this program there will be no way of displacing the storm water which has accumulated in the south fork of the South Branch, the west fork of the South Branch, or any of the various slips.

Then, in order to clean up the upper main channel between the Kedzie Avenue controlling works and the Sag, there would be required an average diversion of 3,090 second feet, plus 1,300 second feet of effluent from the North Side and West Side and Southwest Side treatment works, making a total of 4,390 second feet for a period of 19.7 hours. In that I have assumed that 1,000 second feet of effluent from the West Side and the South-
11658 west Side plants would be introduced into the channel—into the South Branch—east of these Kedzie Avenue controlling works.

In order to displace the storm water which has accumulated in the Calumet River and Sag Channel it would be necessary to draw in from Lake Michigan 1,500 second feet for 41.7 hours; after this 12.4 hours would be required to displace the water in the Calumet Sag Channel, from the Blue Island controlling works, down to Sag, flowing 1,500 second feet from Lake Michigan, 325 second feet from the headwaters of the Little Calumet, and 175 second feet effluent from the Calumet treatment works, making a total of 2,000 second feet, which is the nominal capacity of the Calumet Sag Channel. After this the combined flow through the upper main channel, 4,390 second feet, plus 2,000 second feet through the Calumet Sag Channel, making a total of 6,390 second feet, would displace the volume in the main channel between Sag and Lockport controlling works in 9.7 hours.

The time required to displace the accumulated storm water in all the channels after a rain would therefore be approximately three days. Now, since there will be a certain amount of overlapping of storms, or storms following each other in less than three days, I have assumed, from the best data available, that after 80 storms
11659 the Chicago and Calumet Rivers, and the various canals, would have to be cleansed 60 times per year, and that with 60 times per year the complete operation of displacing all the storm water in the various channels which I have described, and in the manner I have described, will be carried out.

Now, to summarize: For 90 times of preparing for storms, for 80 times of actual rainfall and subsequent run-off, and for 60 times of displacing the volume in the various channels, would require an annual average discharge at Lockport to the Des Plaines River of approximately 4,100 second feet, composed of 2,750 second feet direct diversion from the waters of Lake Michigan, 550 second feet estimated annual average rainwater run-off of the Chicago River drainage area, plus a portion of the rainwater run-off of the Calumet River, and in addition approximately 800 second feet of sewage treatment plant effluent.

There is no way of flushing the slips and a portion of the West Fork of the South Branch. It is possible to flush the South Fork of the South Branch but not the slips.

11660 The slips and the west fork would, of course, contain storm water after a rain, and that storm water would be more or less polluted. Then, if a long dry period succeeded the rain, that water would surge into the channel at times when the South Branch was dropping, due to a drop in the Lake, and would surge back

when the water surface in the South Branch raised. I assume that the pollution would get out of those slips from time to time.

In my calculations above outlined, I have assumed that save at times of flood run-off, the effluent from the sewage purification works would go into Lake Michigan.

To keep all effluents out of Lake Michigan, there would be required in addition to the 4,100 second feet flow at Lockport stated by me, some 500 or 600 second feet,
11661 on the assumption that the Lake would remain still, which would be the balance of the sewage treatment plant effluent not discharged to the Des Plaines River during flood run-off and during the period of flushing the storm flow out of the different channels, as I have above outlined. But I believe there would be required two or three times that much in order to be sure that you could maintain flow from the Lake and keep that effluent moving towards Lockport.

To keep all storm water and sewage effluent at storm times and at all other times from Lake Michigan, substantially and effectively, there would be required at least 5,000 second feet flow at Lockport.

11662 With 5,000 second feet there would be numbers of small reversals when the water that was in the main river would get into Lake Michigan.

The capacity of the Drainage Canal west of the Willow Springs Spillway, that is, the rock section, is considerably greater than the capacity in the earth section upstream or east from Willow Springs. The rock section capacity is about 14,000 second feet. That is its capacity with flow parallel to the bottom and at a certain depth of 24 feet, called the nominal capacity. The nominal capacity of the Canal east of the Spillway in
11663 the earth section is 10,000 second feet to Summit, and from Summit to Robey Street the nominal capacity is 8,000 second feet. That is the designed capacity.

11667-11676 Defendants' Exhibit 1434 is as follows:

"FLOW OVER WILLOW SPRINGS SPILLWAY—REVERSALS OF CHICAGO RIVER—MEAN FLOW AT LOCKPORT—RAINFALL—1926, 1927, 1928, 1929.

Date	Flow Main Channel C. F. S. Mean	Max.	Min.	Flow Over Willow Springs Spillway C. F. S.	Reversal Hours Min.	Rainfall Inches
1926						
Feb 24	7310			00		
25	9570	11955	7415	0	1:40	0.70
Apr 9				265		
10				800		
11				800		
12				745		
13				405		
14				160		
15				5		
Jun 10	8690			0		
11	9975	12080	7795	0	4:00	2.65
12	9700			0		
13	9905	12385	6940	0	4:05	1.96
Sep 14	8357			0		
15	8215	9440	6065	0	0:08	0.99
21	6685			0		
22	6695	8715	5845	0	0:19	0.23
23	8560	12537	6700	0	0:40	0.88
26				135		
27				105		
28				5		
Nov 16				65		
17				330		
18				450		
19				450		
20				405		
21				330		
22				160		
23				5		
1927						
Feb 5				10		
6				90		
7				190		
8				150		
9				70		
10				30		
Apr 15	6730			0		
16	9120	10985	7755	0	1:15	0.78
17	6730			0		
18	8315	11745	6465	0	0:50	0.36
19	9740	11860	8270	15	2:25	0.70
20				225		
21				185		
22				60		
May 8	6675			0		
9	6840	9390	4595	0	1:13	0.58
17	6245			0		
18	7505	8720	6495	0	0:05	0.66
19	6875			0		

Date		Flow Main Channel C. F. S.			Flow Over Willow Springs Spillway C. F. S.	Reversal Hours Min.	Rainfall Inches
		Mean	Max.	Min.			
	20	7175	11210	6415	0	0:54	0.42
	23	8105			0		
	24	11120	12280	5545	0	2:05	1.16
Jun	3	5845			0		
	4	8330	12365	6510	0	2:25	0.40
	19	6640			0		
	20	9295	17055	6720	0	2:45	2.34
	21	7800	10980	6665	0	2:20	1.32
	30	6495			0		
Jul	1	7370	10065	6370	0	0:40	0.28
	14	7640			0		
	15	8143	12055	7500	0	0:36	0.74
Sep	27	10555			0		
	28	11180	12625	10190	0	1:35	1.46
1928							
Apr	6				175		
	7				1010		
	9				1530		
	9				1335		
	10				760		
	11				430		
	12				125		
Jun	18	10070			0		
	19	11380	12215	8595	0	0:11	0.41
	23	10680			0		
	24	10640	14380	8650	0	1:35	1.98
July	1	9645			0		
	2	10410	12410	9850	105	0:30	1.64
	3	11180	15720	9740	175	1:15	1.56
	4	10400	12495	9660	1225	0:12	0.43
Jul	5				1750		
	6				1640		
	7				1240		
	8				520		
	9				95		
	20	9985			0		
	21	9960	10280	9555	0	0:15	0.61
Aug	3	10735			0		
	4	12110	12740	11505	0	0:20	0.79
	22	10185			0		
	23	11515	12675	9560	0	0:34	0.96
	28	10120			0		
	29	10945	12695	10025	0	0:45	1.47
Sep	13	10020			0		
	14	10590	12810	7410	0	0:10	0.98
Nov	18				165		
	19				830		
	20				890		
	21				570		
	22				240		
	23				45		
	24				2		
Dec	15				65		
	16				300		
	17				460		
	18				640		
	19				650		

Date	Flow Main Channel C. F. S. Mean	Max.	Min.	Flow Over Willow Springs Spillway C. F. S.	Reversal Hours Min.	Rainfall Inches
20				465		
21				290		
22				210		
23				35		
1929						
Jan 21	9995			0		
22	11255	12740	9705	0	3:00- 3:55 pm 4:30- 4:40 5:04- 5:25 5:36- 6:05 6:10- 6:39 7:30- 8:05	1.01
Feb 28	10235			90		
Mar 1	10565			490		
2	11150			710		
3	11735			965		
4	11655			1465		
5	11675			1560		
6	11650			1480		
7	11685			1380		
8	11060			870		
9	10210			370		
10	10190			95		
11	10195			20		
12	10225			0		
13	10535			20		0.36
14	10125			210		Trace
15	9615	12520	6880	595	2:10- 2:32 pm 11:45-12 mid	1.41
16	8080	10835	5590	1105	12:00-12:10 am 12:50-12:55 2:00- 2:12 4:30- 4:38 7:18- 8:15 10:20-10:40 11:35-12:15 pm	0.15
17	8320			1465		0
18	7210	8530	6135	1280	3:25- 4:28 pm	0
19	5880			750		Trace
20	5550	5825	5380	335	3:05- 3:10 pm 3:30- 3:35	Trace
Mar 21	5000	5385	4935	35	1:25- 2:20 pm 10:15-10:30 11:32-11:41	.06
22	5435	8965	4925	0	12:04-12:15 am 1:08- 1:17 1:22- 2:01 10:50-11:20 2:30- 2:45 pm	.08
23	4950	5000	4925	0	5:45- 6:05 am 6:30- 6:45 7:45- 8:15 3:45- 4:00 pm 4:05- 4:18 5:15- 5:27 5:35- 5:43	.01

Date	Flow Main Channel C. F. S. Mean	Max.	Min.	Flow Over Willow Springs Spillway C. F. S.	Reversal Hours Min.	Rainfall Inches
					8:05- 8:16	
Mar 24	4965	5000	4925	0	8:25- 9:00 am	0
					5:20- 6:17 pm	
					9:02- 9:30	
25	5525	11415	4925	0	4:07- 4:14 am	.02
					5:02- 5:08	
					6:29- 6:44	
					7:04- 7:29	
					8:40- 9:00	
					9:20- 9:25	
					10:35-10:55	
					12:25-10:45 pm	
					2:10- 2:30	
					3:40- 3:55	
					4:22- 4:38	
					4:50- 5:20	
26	4950	5000	4925	0	10:00-10:50 am	0
					11:20-11:53	
					12:40-12:50	
					1:20- 1:40	
					3:10- 3:30	
					4:35- 4:55	
					5:55- 6:54	
					6:47- 7:20	
					7:45- 8:20	
					9:25-10:05	
					11:39-11:46	
Mar 27	4965	5000	4925	0	1:08- 1:28 am	0
					4:10- 4:25	
					5:50- 6:15	
					7:35- 8:00	
					8:55- 9:50	
					10:15-10:40	
					11:00-11:20	
					11:30-11:40	
					12:15-12:35	
					1:10- 1:30	
					2:15- 2:35	
28	4995	5335	4925	0		0
29	4985	4995	4935	0		Trace
30	4975	5055	4925	0		0
31	8600	17970	4755	0	10:35-11:45 am	3.12"

Sherman M. Woodward, for Defendants:
An Hydraulic Engineer.

11684 *Direct Examination by Mr. Beebe.*

Reside Iowa City, Iowa; Professor of Mechanics and Hydraulics of the University of Iowa; attended Engineering School of Washington University, St. Louis, graduating in 1893 with degree of Master of Science; took their entire course in civil and mechanical engineering; at Harvard University for one year, studying advanced mathematics and advanced theoretical physics; degree of Master of Arts in 1896; since 1896 engaged either in teaching or in the active practice of various aspects of hydraulic engineering; have somewhat combined the two; from 1896 to 1905 was employed in the beginning,
11686 two or three summers, by City of St. Louis and by an electric railway company in various kinds of elemental engineering work; certain research investigations following the big St. Louis cyclone in 1896 to determine the effect of such cyclones on the water towers and other structures; made certain researches in connection with a testing laboratory they were then building; in fall of 1896 was at the University of Arizona, at Tucson, as Professor of Mathematics and Mechanics; there eight years, and in addition to teaching various branches of engineering and mathematics, carried on researches for the Agricultural Experiment Station in connection with irrigation, pumping water therefor and handling of irrigation water in ditches, and measuring devices for such water; assisted local representatives of
11687 the U. S. Geological Survey in making hydraulic measurements; in 1904 became Professor at the University of Iowa in engineering; there only one year; then accepted position with U. S. Government to investigate

irrigation and drainage for agriculture; the investigations were scattered about the country; was assistant to the chief of the branch and acting chief in his absence at Washington; duties largely in visiting, inspecting and supervising field investigations, surveys and experimental studies, handling of water for irrigation work carried on in quite a number of western states such as Washington, Oregon, California, Arizona, New Mexico and Colorado, and some others; reports were made to the department of such investigations; directed the local men; one of my chief duties was to edit the reports for publication in the Washington office; had also something to do with drainage investigations and for that purpose worked in many of the eastern states, such as Virginia, South Carolina, Louisiana, Texas, Mississippi, Arkansas, Illinois, Ohio, Delaware. 1908 returned to the University of Iowa as Professor of Mechanics and Hydraulics, which I have held ever since.

During that time have been employed as consulting Engineer for specially difficult hydraulic work in connection with various engineering projects. From 1913 to 1920 was Consulting Engineer for the Miami Conservancy District, which is the legal name of the corporation that built the flood protection works in the Miami Valley centering around Dayton, Ohio. This is many times the largest of any local flood protection work that has ever been executed in this country. My responsibility was for all the hydraulic calculations. I did not make the construction estimates.

11690 After I left the Government, was employed on occasions as a special consultant to visit certain places by the local authorities in the lower Mississippi Valley; do not recall the names of all the districts; one time the Government asked me to go over into the Illinois Valley to prepare a report on pumping plants for

drainage district. This report which I made was published. I was a member of the Engineering Board of Review of the Sanitary District in 1924-25.

At the University of Iowa we have the largest and best hydraulic laboratory in the country for a certain kind of hydraulic investigation, it being established while I was there and at my urgency. It has been under my control ever since and I have made particular investigation into hydraulic matters there. I carried out investigations in co-operation with the Department of Agriculture. This department has two permanent men stationed there, one there six years. They give all their
11691 time to this work and the Government bears part of the expense and the University furnishes the laboratory and certain help. The investigations are under my general directions, subject to the approval of the department officials at Washington.

11692 Am the author or joint author of the following publications:

"Flow Through Drain Tile" and "Pumpage Plants for Drainage Districts," published by the Department of Agriculture; and "The Hydraulic Jump & Back Water Curves," published by the Miami Conservancy District, being a mathematical treatment of certain hydraulic phenomena. The hydraulic jump, translation of the French name—was invented about a hundred years ago. It is a phenomenon that occurs when water moving swiftly strikes a certain sort of obstruction and is very suddenly changed in depth to a greater depth and it make a foaming and tumbling mass of water where the change takes place; like the boiling surf of the ocean.
11693 If you open a faucet and let it run into a smooth-bottom sink, with the outflow shut off, the jet of water coming down from the faucet strikes the bottom and spreads out in all directions on the bottom in a smooth thin

layer. When it gets over towards the sides of the sink and begin to fill the sink, a circle will be seen on the bottom of the sink around this jet of water, and as the sink fills up that rather conspicuous circle comes in slowly toward the jet and finally will reach the center. That little wave of water is a diminutive hydraulic jump.

In some of the great rivers there is a large hydraulic jump as much as 10 feet high, and it is very destructive to boats. It occurs below dams and is a matter that perhaps never had been thoroughly studied or explained or analyzed, I think, until this pamphlet was published. The Conservancy District published 2,500 copies which were sold. There has been another edition of the work. It is used as a textbook in my classes and has been used at other places. There has been a steady demand for the publication all over the world.

11694 There was also published a larger volume called "The Hydraulics of the Miami Conservancy District." It was prepared by me and published by the District and is sold. It discusses all of the important hydraulic problems in connection with the project. I was co-author of a bulletin published by the State University of Iowa entitled "Flow through Culverts." It is a report on the co-operative work of the United States Government. Am joint author of another work called "The Effect of Agricultural Drainage upon Flood Runoff," published by the American Society of Civil Engineers.

11695 The field covered by me in the twenty-two years as Professor of the University of Iowa, is various aspects of hydraulic engineering. I am a member of the American Society of Civil Engineers, American Society of Mechanical Engineers, American Association for the Advancement of Science, of which latter organization I am

a fellow; also member of the Iowa Engineering Society, and other engineering clubs and societies.

Have been here during the hearings that have been conducted for the last two weeks; was present at the March hearings at Chicago; heard the testimony of Professor King and Horace P. Ramey; made certain mathe-
11696 matical and engineering investigations with reference to the discharges in the Chicago River in connection with run-off from floods, etc. Mr. Ramey and I have been working in collaboration.

I have made a calculation as to the quantity of water necessary to be withdrawn directly from Lake Michigan under the following assumptions: that the sewage purification works outlined to be constructed by the Sanitary District for the complete purification of all sewage arising within the limits of the Sanitary District, which have been approved by complainants, are completed and put in operation; that the controlling works are installed at some convenient place at or near
11697 the easterly end of the drainage canal, and that such works when operated will permit the discharge at dry weather time of the effluent from the said purification works into Lake Michigan by way of the Chicago River, except as to the effluent from sewage purification works serving that portion of the population of the Sanitary District in the area south of 87th Street, which will be discharged by the use of the present works into Lake Michigan by way of the Calumet and Little Calumet Rivers, and that said controlling works when operated will also permit the discharge of all of that part of the storm flow which cannot or may not be treated completely by said purification works to the Des Plaines River; and that the purpose of said operation of the controlling works is to discharge into the Des Plaines River all the effluent and storm flow reaching the chan-

nels of the Chicago River and the channels of the Sanitary District canals, and the greater portion of the storm flow of the Little Calumet River in order to prevent the pollution of the Lake Michigan waters due to such storm flows.

The quantity so calculated under those assumptions is 2739 cubic feet per second.

11699 In making these computations it is necessary, of course, to have particular values to use in the computations, and therefore I have used definite values of a considerable number, each one of which is largely a matter of judgment or opinion, combining various other data, and I have tried to carry out the computations consistently with those figures, carrying the numbers down to a single cubic foot per second, but I don't claim that the final answer is that precise, of course. That is a 11700 matter of convenience and consistency in the computations.

In going through all of the various items I have tried to follow consistently the point of view that I was saving water as much as possible; that is, in choosing average values, or what are called average values, I have tried to keep them in such a way that the result will be to keep the quantity just as low as it seems to me it can possibly be kept.

In computing the amount of water to go through the control gates, I used the number of times the control gates were to be opened as 90 times per year. That is based, to a large extent, upon the weather records at the U. S. Weather Bureau Station in Chicago and surrounding stations.

The 90 is made up of two figures, 80 times when there would be actually enough rain to produce storm overflow from the sewers, and ten times when the gates might be opened in preparation for a rain, and then the rain might

11701 not occur at all, or it might be so slight that there would not be any storm overflow.

I have assumed in general the most skillful operation of the gates that it seems to me it is possible to expect. Of course, these computations are based upon the actual past records, but the people operating the gates would not know in advance just how much rain is going to come or how intense it will be, and that accounts for the assumption of ten times the gates might be opened when the later developments would not indicate that they were needed, that they were necessarily open at those times.

This is all on a yearly basis. Now, the method of computing the discharge at the gates has been to divide it into four parts. The first part is called the preparatory flow, which is a very short time relatively, following the first opening of the gates. The second part is the flow during storms, which is a much longer time and larger quantity. The third part is the estimate of the storm overflow from the sewers after the rain has ceased falling. It is common to use a period of concentration for storm sewers in which it takes time—the time required for them to fill up to reach their maximum flow, and there will be a time after the rain ceases when they will be emptying and continuing to flow, which will be somewhat
11702 the same sort of time. That is the third division of time. The fourth division is the time necessary to wash out the polluted water in the channels so that the channels would be relatively pure, in a quiescent state, after the gates are shut. They would not be absolutely quiet, but the flow would be very small, on the assumption that the sewage effluent only is to go into the Lake.

Assuming 40 minutes for the length of each preparatory flow period and 90 times a year, adds up for the whole year to two and a half days of operation, or two and a half days of being open, totalling it for the year.

And taking the average rate of flow through the gates at Kedzie Avenue at 14,000, that would contain the sewage effluent at the same time, the sanitary sewage effluent, which is taken as 1,300 cubic feet per second for this calculation. That 1,300 is made up of 300 from the North Side plant and 1,000 from the West Side and Southwest Side plants, which is proposed to come into the canal just above the control gates. Of course then when the control gates are open, that effluent would flow through the gates. That leaves 12,700 cubic feet per second of water drawn from the Lake until—and it finally becomes partly the storm flow.

The flow during storms—now, I would like to say,
11703 these storms will be of all kinds, some very small and some heavy. Some will last a long time and some will be brief in duration, and we have averaged the length of time as best we could from the data that could be obtained, and have an average length for each storm of 5.6 hours. It is assumed that the average rate of flow through the control gates for that time would be 8,000 cubic feet per second. That is, on this theory of operating the control gates during the preparatory period, the flow would have decreased from an original amount of 18,000 cubic feet per second down to 10,000 cubic feet per second. For many relatively small storms it would not be necessary to keep it steadily at 10,000 cubic feet per second, but it would be tapered off at varying amounts, depending upon the nature of the storm and the diversion in each case. On that account I have used 8,000 as the average.

Using 80 storms per year gives as the total length of time in a year that the gates would be opened during the rainfall period, 18½ days.

Now, it was assumed that the storm sewers would overflow into the river on the average for three hours

after each storm, and that gives the total period in days for the year of ten days.

These three periods added up to 31 days in a year,
11704 and the total flow during that period averaged over the year, to get an average constant value for the whole year, is 609 cubic feet per second.

Now the time to flush out the channels—well, there was a similar calculation made for the Blue Island controlling works at the entrance to the Sag Channel. The times are exactly the same, except it was assumed in that case that the run-off after the storm would average six hours instead of three hours on the Chicago River. The reason for that is first, the Little Calumet drainage area is much larger; and secondly, it is not built up nearly so intensively, and the records we know, show that after a storm that river runs for a considerably longer time than the Chicago River.

The result obtained at the Blue Island controlling works for those same three periods of calculation is 212 cubic feet per second.

Now, the time to flush out the channels or to displace the polluted water was given somewhat in detail in Mr. Ramey's testimony, and mine is substantially identical. I can go through it again if there would be any use for it, but unless it is wanted I will just give the total.

11705 The total for the fourth period in that calculation is 1665 cubic feet per second. That figure includes the storm flow of the present lake water, because it passes through the gate together, and has not been computed here separately. The similar figure for the Sag Channel 796 cubic feet per second. When all those figures that I have given are totalled, I reach a total value of 3,282 cubic feet per second. That includes the storm runoff for the whole year. Then deducting 543, the amount of the total runoff in those two streams that have been sub-

mitted in evidence here in the exhibit, as I understand, gives the final result of 2,739.

11706 Four thousand eighty-four feet per second is my calculated value of the total flow at Lockport, which contains these figures as stated, with the sanitary sewage effluent from the treatment plant, during the period when those gates were open.

About the slips in the South Branch beyond the Drainage Channel and West Fork. There is no method of flushing that portion of the stream out.

11707 I have an estimate of the amount that will be necessary to keep all sewage effluent from the lake. That is made, as before, by assuming the highest degree of skill in operating gates, and I feel somewhat doubtful whether they can be operated that skillfully or not. But my figures are as follows: 3,716 cubic feet per second of fresh water from the Lake; 1,475 cubic feet per second of sanitary sewage effluent during the year; and 543 cubic feet per second of total run-off from the drainage, making a total after they pass the control works at Lockport of 5,734 cubic feet per second.

11732 *Further Direct Examination by Mr. Beebe.*

In one of the figures I gave in my direct examination I gave the quantity for flushing out the Calumet River and Sag Channel as 1,008 c. f. s. It should have been 796.

11870 *Cross Examination by Mr. Jackson.*

11872 I worked this problem out in collaboration with Mr. Ramey and my assumptions and conclusions are substantially the same. The figures likewise. We were trying to work out the problem in a practical way to accomplish the substantial diversion of the storm water by proper operation of the control gates. When the control

gates should go into operation with respect to the rainfall, would differ a good deal in different kinds of storms. I would say on the average it would begin a few minutes before very evident impending rainfall. I haven't had
11873 any definite figure in mind as to the quantity of rainfall that would be necessary before the control works should go into operation. In some cases they might be opened for a summer thunder-shower just on the appearance of very black clouds before it was known it was raining anywhere in the area. For a very slow winter rain they might not be opened until after the rain had started. The amount the storm water overflow would have to be before it would be necessary to divert it, is based on the assumption that as soon as there is storm water overflow, the gates would have to be opened and the current started in the other direction. The District has made many elaborate calculations for several years as to when there would be storm overflow; that is, as to quantity of rain. For a very sudden rain when .06 of an inch has fallen, storm water overflow begins. If it is a very slow rain, it does not begin until a larger quantity has fallen, because some of it runs off in the mean-
11874 time. An elaborate sliding scale has been used in the computation, and I went over that work very carefully and adopted it for my purposes. The runoff that .06 of an inch of rainfall would produce is 50 per cent or .03 of an inch. I have not calculated how much it would be in cubic feet per second. For the use I made of the figures I did not compute quantity in number of cubic feet. I considered the limiting factor .06 or .07 of an inch rain per hour. The runoff is just one-half. I did not reduce it to seconds feet. In the calculations the District has made they used the capacity of the intercepting sewers. I used the data that had been calculated in the office of
11875 the Sanitary District. I could easily calculate what

the runoff would be in cubic feet per second that would be produced by that rate of rainfall. I did not use the number of cubic feet per second in that particular calculation. I don't of my own knowledge know whether the factor is correct. I haven't in mind the total capacity of the intercepting sewers in the Sanitary District. I can look up the record. I knew those figures, but I did not use them in this calculation. I know at about
11877 what storm runoff the storm sewers begin to overflow. A runoff of .01 of an inch per hour is about the capacity, and any excess over that spills over but it takes a rainfall of about .03 of an inch to fill them up. .03 of an inch is a definite quantity, independent of time.

All these records, which are Weather Bureau records, are based on hourly measurements of the rate of rainfall, and therefore the rain that was assumed to be at a certain rate per hour. We used the .03 of an inch as being constant for an hour. That is, it would be .03 of an inch in depth on the ground. Most of it would be in the sewers. I don't know the area of Chicago above the Kedzie Avenue control works, and I did not use in my investigation what quantity of runoff would be produced in cubic feet per second, assuming that for one hour .03 of an inch of rain fell, and that all the rain that fell ran off. You ask me to assume that the area is 307 square miles, but in this storm runoff only the part inside the sewered part was used, which is about half of that 307 square miles. The upper end of that Chicago River Drainage Area runs away up north, and that has not been used in any important degree in this calculation; but the storm sewers are all down in the
11881 City of Chicago. It was used, however, in one place in getting the total annual runoff, but it did not come into computing with reference to the overflow of storm water. If you deduct 180 square miles, the total in cubic feet

per second would be about 3,456. I calculate that the runoff would be 50 per cent of the actual rain. I used the figure .06 of an inch actual rainfall, or .03 of an inch run-
off. With .03 of an inch rainfall, the runoff would be
11884 about 1,700 second feet. That was not the point at which I concluded the control works would come into operation. It would come in at twice that much. Storm waters would begin to overflow when the rainfall is .06 of an inch in an hour and the runoff half of that. With .06 of an inch an hour rain, the runoff would be a little over 3,000 cubic feet per second. That would happen 50 to 60 times every year, and has happened that way for the last nine years based on the rainfall record at a single station, and it is not quite right to say that it always is .06 of an inch in one hour, because if it does not reach .06 of an inch the first hour, it exceeds .08 of an inch in the first two hours. That is just a sliding scale.
11885 Assuming the sewers are filled up and then begin to fill up, the storm overflow begins to occur if .08 is reached in two hours. You do not have to have 3,000 cubic feet per second before the control works are brought into operation. You could get an overflow with a smaller runoff if you take a two hour period. It is not because I think the capacity of our sewers is less than 3,000 second feet, but if you take a 2-hour interval you could have a smaller rate and fill them in a 2-hour interval. After the overflow begins they could carry only .01 of an inch runoff per hour. If the rain is not big enough to make
11886 that overflow, you would not get any. You do not have 3,000 second feet capacity in your interceptors. You only have about one-third of that. The intercepting sewer capacity in Chicago is much less than 1,300 or 1,400 second feet, probably about 1,000. There are two kinds of capacities, one is a carrying capacity after they are filled. That which we are now referring to is the car-

rying capacity. But they have a cubical content of capacity that has to be filled up before they carry as much as comes in, and it is this first filling up that I thought you were discussing at first where the 3,000 rate would exist for an hour in order to fill them up and get them full. The capacity that I was thinking of was that additional capacity for carrying storm overflow. Their capacity is over 2,000 cubic feet, of which about two-thirds is used for the ordinary dry weather sanitary sewage
11887 flow. Then they have an additional capacity of about 700 cubic feet per second, and it was that I had in mind as carrying this storm water. I was mistaken entirely in giving the other figure as the total capacity.

I have used in my calculations 2,000 as the capacity of the Chicago interceptors. If it was a fact that the capacity was 4,000 c. f. s., then I think my figures should be changed to correspond to 4,000 second feet.

11888 Assuming that treatment plants of Chicago are designed to treat an average flow of 1,716 c. f. s. and an excess capacity of 50 per cent, and that the intercepting sewers are large enough to carry the total capacity, I cannot tell how many overflows of untreated storm water there would be, because I have not made the calculations on that basis. It probably would reduce the number slightly, but it is very hard to tell how much because these rains usually are so large that whether you change that capacity much or not, you would still get overflow. For example, you get a fall of .21 or .25 of an inch in an hour and you would get the overflow whether you changed this or not. A good many rains come that way and everything would have to be examined in detail to count that number. I cannot state what would be the number of storm overflows, if metering of the Chicago water supply should reduce the sewage flow to 1,000 second feet. I did not take that into consideration. It would take quite a lot

of counting up from the records to answer that precisely. I cannot tell the number of times there would be overflow, assuming the capacity of the interceptors to be 4,000 c. f. s. and 1,000 c. f. s. sewage flow, and that three times the quantity of sewage flow passes through preliminary treatment tanks. I think that it would be necessary to have a runoff of about 3,000 cubic feet per second. I have not recently made and do not estimate how often
11889 there would be storm runoff of 3,000 second feet.

Referring to page 57 of Exhibit 1, Major Putnam Report on Diversion of Water from Lake Michigan, (November, 1923), where it is stated:

> "It has been estimated that rates of storm runoff from the drainage area of the Chicago River have the following frequency: 3,000 cubic feet per second ten to twelve times per year,"

if that statement is assumed to be correct, that would make a very material difference in the conclusions I stated yesterday. I did not make any investigation to determine whether that statement is correct. The amount of water would be nearly proportional to the number of overflows which brought controlling works into operation. If you had that small number of overflow, the figures would not be in proportion. For example, we took the time of displacing the polluted water in the river as three-fourths of the number of times a year that there were storm overflows on account of the fact that storms might overlap if they came frequently. If this happened only ten times a year, they would not overlap and you would not have quite a proportional reduction. It would be approxi-
11891 mately in that proportion. I tried to make this computation that would save the most water in the most practical way. I calculated an item for flow through the controlling works for 40 minutes 90 times a year to establish the flow in the Chicago River. The 40 minutes might

represent in each instance and it might not represent approximately the time before the rain started. There was added a 40 minute period before the beginning of each rainfall. The concentration period for rains means the time until you reach the highest rate of storm overflow,
11892 while if you are controlling this storm, the flow might vary where you would try to control it at the time the first part of the storm overflow began, which would be much less than 4½ hours. The overflow would begin pretty quickly in the case of a heavy storm down in the loop district. It could begin in 15 or 20 minutes in some cases. The runoff would be relatively small but it would be desirable to keep that from flowing toward the Lake. I haven't any way of saying definitely how much it would be. I would have to get out the storm sewer map and take a real case to make the calculation. It would be relatively
11893 small as compared with the larger figures. You get the beginning of the storm overflow long before the sewers are full. It would be relatively a small part of the total. I think it would be larger than 10 per cent. That 10 per cent would produce a very slight current, probably .1 of a foot a second, or less than that. It would take several hours for that current to reach the mouth of the Chicago River unless the current was already running that way.
11894 The South Branch under this assumption in this calculation was supposed to be carrying 1,000 cubic feet per second of sewage effluent toward the lake. That would cause a rate of about one-fourth of a foot a second, assuming 1,000 second feet of effluent, and 300 second feet of storm overflow going towards the lake. It would take several hours to move from the junction of the North and South Branch to the Lake; probably five hours; but there are storm sewers that enter into the Main Branch within a few hundred feet of the lake. My calculation was from the junction out to the Lake. After the con-

trolling gates are opened at Robey Street, a flow would be induced immediately away from the Lake at the gates. It would take between half an hour and an hour to get any very appreciable flow between the junction of the South and North Branches and the Lake. It would start probably in forty minutes. It would not start as quickly as the wave of acceleration could run to the Lake; no appreciable flow in that time. How long after the wave of acceleration reached the Lake would be required to start an appreciable flow, depends entirely upon the volume to be removed. I think it would take between a half and an hour for this velocity of a quarter of a foot or half a foot a second to be induced in the main part of the Chicago River after the gates were opened at the controlling works. Some flow would be established before the 10,000 second feet flow was established at the mouth
11897 of the Chicago River. If the operators could know the exact time that the rain begins at whatever place it begins first and know how hard it is raining, I think that the flow could be induced sufficiently to keep the storm water out, if you did not open the gates much before the rain. It would depend then upon how heavy the shower. A very heavy summer rain sometimes starts up very quickly and sometimes it does not. As I tried to say yesterday, my theory was on the basis of human operation, without advance knowledge and trying to play safe. The critical point would be the main part of the Chicago River. You would not get any flow in the main river for about 40 minutes after the gates were opened.
11898 My impression is that to have safe control, which means to try to have no reversals, then I think it would be necessary to begin to operate the controlling works a considerable time, perhaps not 40 minutes, but say 20 or 30 minutes, in some cases 40 minutes, before the rain actually begins.

11899 Assuming that a flow at the mouth of the Chicago River can be induced in 21 minutes from the time the controlling works are opened, and that there would be flow from the sewers in 15 or 20 minutes, I don't think there would be any danger of reversals by waiting until after the rain commenced, to operate the control works.

11901 But the wave of acceleration I regard as a surface phenomenon, like the wind wave on a body of water. I think that wave could travel to the mouth of the river even if the river were flowing in that direction all the time and were flowing after the wave reached there. For example, with a steady, dry weather sewage effluent flow of 1,000 c. f. s., or 1,300, toward the mouth of the river, you could produce this sudden water surface effect at the gate and have wave travel clear to the mouth of the river, and still the river would be flowing that way all the time and flow that way afterwards. So, in this assumption, it is a little doubtful to me, but as I understand the assumption,

11902 my answer is as I think he meant the assumption to be. The whole item as to the annual average amount of water that would be diverted in this 40 minute period is very small. I put it in largely because I was trying to conform to the testimony on the other side. If I had been starting the data I would have made it still a little smaller, but I was trying in the interest of simplicity to conform to what they have stated. I think that that item of 40 minutes could be reduced somewhat if it were compensated for in the next item which is where I would

11903 have done it. The next item provides for an average flow of 8,000 c. f. s., for 8.6 hours, 80 times a year. That total flow includes 1,300 c. f. s. of sewage effluent and 6,700 c. f. s. from the lake. Before the 8.6 hour period I had es-

11904 tablished the flow in the river during the 40 minute period. In some storms the amount would be larger than 8,000 second feet and in others smaller. The 8,000

is the average. I did not assume that the limiting capacity of the upper portion of the Drainage Canal was 8,000 cubic feet per second. However, if you did assume that the limiting capacity of the Drainage Canal was 8,000 second feet in its upper reaches, then it would be impossible to flow more than 8,000 second feet through the control works. Any excess beyond that under that assumption would have to go into the Lake, but I do not admit the assumption to be true at all. In this calculation I have not assumed a certain number of storms of a certain size. Under the assumptions which you have made the maximum capacity of the channel is 8,000 second feet. There would be relatively few storms that would flow 8,000 second feet. The 8,000 second feet, however, includes 1,300 of sewage effluent. There should be deducted 1,300 cubic feet, if you are using the figure as the storm flow diversion. I don't know the number of storms that equal or exceed the 6,700 cubic feet per second.

Referring to the following quotation from Complainants' Exhibit 1:

11906 "3,000 cubic feet per second, ten to twelve times per year; 4,167 cubic feet per second seven to eight times per year; 5,000 cubic feet per second, five to six times per year; 7,500 cubic feet per second, three to four times per year; 9,500 cubic feet per second, two times in three years,"

the amount through the controlling works always ex-
11907 ceeded the storm amounts by an amount that could not be determined because there is no way of measuring it. I am assuming that during that storm, except in rare cases, there would be some lake water being drawn in all the time, in order to be on the safe side. I didn't try to hit those figures at all. But assuming that there are only five or six times a year when the storm runoff in Chicago exceeds 5,000 cubic second feet, I think it fair to calculate 80 times the maximum flow through the con-

trolling works, because there are a lot of small storms which cannot be foretold. The number of storms that produce runoff are very much larger than those, and one can't tell in advance. If it were not necessary to start the gates until after the rain began, the 10 storms that did not materialize where the gates were opened in my calculation would be eliminated. There are a good many rains where there is no storm overflow, and these times when you might have opened your gate and the rain may
11908 have come and still it wouldn't have been necessary, because the rain was so slight it didn't produce an overflow. There are a great many such rains in Chicago every year; I don't know just how many.
11909 I continued to run 8,000 second feet for three hours after the rain ceased for each of the 80 storms. I would expect the runoff to decrease after the rain ceased. There would be a fall from the maximum concentration down to a point where it would be eliminated at the end of the estimated period. The average is three hours. I assumed, also, that there would be a certain quantity of the flow intercepted by the intercepting sewers. In my calculation I did not determine any definite quantity; assumed that a relatively small quantity would be intercepted in the intercepting sewers. I did not use the
11911 quantity, the numerical size of that. In some cases there would be a runoff or overflow for many hours, longer than three hours, after the storm ceased, and in some cases it would be quite short. To average the big storms and the small storms, the three hours was taken as the average length of time. The three hours was for the time of storm overflow. I didn't try to estimate the time of runoff after the rain ceased. There would always be a small flow for quite a while afterwards, of course, if the sewers were carrying more than usual,
11912 from one to three days, perhaps, for the runoff. At

the end of the three-hour period, if I assume that I am taking care of the maximum storm at the height of concentration, the overflow would have fallen considerably below that maximum. The storm overflow would have decreased to the point of what would be carried in the intercepting sewers without overflow at the end of the three hour period. 8,000 cubic feet per second is not the maxium capacity of the channel at all. The flow should be cut down as the storm water overflow tails out, subsequent to the time when the rain ceases. I have given credit to that in this estimate. The 8,000 second feet for three hours is used as an average. It might be a lot higher at the beginning of the three hour period. It might be as high as 10,000 second feet.

I didn't understand that Mr. Ramey testified yesterday that 8,000 second feet was the maximum capacity of the Main Channel in its upper reaches. Mr. Ramey
11916 stated what the nominal capacity was, which is different from actual capacity. With these control gates in and the water level kept many feet below the nominal grade line, the actual capacity is much larger, due to the fact that it has a steeper slope on the surface. From
11917 the point above Robey Street up to the Lake, there was an assumed capacity of 10,000 second feet, but I don't think that it is limited to that, and I am quite sure it can be more, from calculations I have made.

The level of the water in the Chicago River would be
11918 at all times higher than the level of the water in the Drainage Canal below the control gates. Below the control gates there is quite a different slope for these large quantities and down at Lockport the level might be 10 feet lower than it is in the Chicago River. It would be a hydraulic grade line from the Lake to Lockport, nearly uniform. There would be some change at the control gate. The flow after the control gates are opened would

11919 depend on the control gates at Lockport. They can be opened and lowered and make a larger flow. The limiting capacity in the upper part of the channel with control at Lockport is much more than 8,000 second feet. How much more has never been determined. I think it is well over 12,000, probably 14,000 or 15,000 second feet. The ultimate capacity of the canal with the gates at Lockport open wide, is somewhere in the neighborhood of 14,000 or 15,000 second feet. The nominal capacity was the figure used in the design where they would have the canal almost full as a ship canal. It does not mean very much, except as a figure used for comparison.

The capacity of the Main Drainage Canal in 1925 and 1926 was lowered a great deal because of the lowering
11921 of the lake level. When I said the ultimate capacity was much higher, it was on the assumption that you referred to the gate lowered so you could drain all the water and lower the level at Lockport. I did not assume that you were going to take the gates out entirely at Lockport. I did not assume any material difference in the operation of the old control at Lockport. If you
11922 are having storm flow coming in, it comes in lower down the channel. It does not all come from the Lake, and you gain quite an appreciable amount, it being very hard to say exactly how much, when this flow is coming in at various points. You gain something on the amount that can be passed through the head of the canal. If you can raise the water level at the head of the canal by a couple of feet, you would have more than the canal could carry. This established flow spoken of was on the theory that 10,000 second feet was coming in from the Lake and the level at the control gates was to drop down to about 3 feet below the level of Lake Michigan. If you had with the sewage effluent from the West Side Plant quite a lot of storm sewers spilling in sufficient water to

11923 the control gates, they might raise that level to the level of Lake Michigan. You immediately then gain three feet in head, tending to raise the level. I don't think it would pile up three feet, and if it piled up to the level of the Lake, you would not have anything coming in from the Lake. I don't think it is true at all that it would not make any difference whether you had any control gates or not. If you did not have the control gates there and you had this large amount coming in at that point, you
11924 would have it running into the Lake, or if you had not established a flow for a strong current.

I have considered for four or five years what the storm water concentration was in the Chicago River in maximum storm. It is a fair assumption, if you assume a maximum storm of 10,000 second feet runoff, there would be 2,000 coming in from the Calumet Sag Channel, and there would be less than 8,000 above the control works. My estimate is based upon assuming a maximum in the vicinity of these controlling works of around 12,000 cubic
11926 feet per second of storm runoff. On the biggest storm that we had there on Easter Day, the best calculation we could make showed over 12,000. The flow was raised at Lockport very much higher for short periods. The rain-
11927 fall was then over three inches. I don't remember how long prior to that there was over a three inch rainfall. One ought to give weight to the frequency of rainfalls, their intensity and runoff. The average that we took of 8,000 second feet was discussed. Different figures were used. We discussed them and I considered them a long while.
11928 That contains a little margin for diversion from the Lake as well as the largest storm water flow. I tried not to have very much margin—not over perhaps a thousand second feet. Under the assumption from the statement read from Major Putnam's Report Complainants' Exhibit 1—that there are not five or six rain runoffs in

Chicago in a year on an average that equal or exceed 5,000 second feet, the average of 8,000 second feet for eighty storms in each year would be greatly in error.

I figured another amount for initiating the flow through the Calumet River. I don't remember what the capacity of the long intercepting sewer in the Calumet District is.
11929 The storm water that is taken care of from the Calumet River is a very large amount separate from the effluent from the sewage treatment plant. The storm water is to be taken care of in the Calumet River or from the Little Calumet River, and from a certain part of the Grand Calumet. Some of the storm flow would come from Indiana cities.

Referring to the Little Calumet and Grand Calumet and Lake Calumet, the lower ends of these rivers are in Illinois and the upper ends are over in Indiana. There
11931 is a large area of that drainage area in Illinois and within the boundaries of the Sanitary District. I don't know just what the proportion is. I don't carry that in my head. But under your assumption I should think that there is a considerable part in Indiana. In my cal-
11932 culation I have treated it all as if it were Chicago sewage or overflow. I don't know whether the interceptors intercept all of those sewers going over to the Calumet Treatment Plant or not. So I cannot say whether there is storm water discharged from the sewers of the Sanitary District into the Calumet River eastward or lakeward of the controlling works at Blue Island. The upper ends of these rivers, both the Chicago and the Calu-
11933 met River, the runoff from the unsewered country in that region is an objectionable surface runoff. I have not tried to separate that part from the part that comes off from the city streets. I have assumed all of the natural runoff of those rivers was to be diverted. I had a figure to clean out part of these Indiana Rivers after

I had diverted the storm water above the Blue Island Controlling Works. I assumed as fully as possible to take care of any storm water overflow that arose in the Calumet Rivers in Indiana or elsewhere. So far as sewage is concerned, if all of the sewage were diverted westward of the controlling works, that factor would be elim-
11934 inated, but if storm water is objectionable and gets into the Chicago region, it still has a detrimental value, whatever that is. But I am not testifying as to whether it is objectionable or not. I assume that after the subsidance of a storm overflow, it would be necessary to wash out all of these rivers. The North Branch and North Shore
11935 Channel I determined in volume capacity in cubic feet without taking the dimensions of the width and depth. I took that volume from the Sanitary District records. I accepted that from the Sanitary District records and did not calculate it myself. I did not examine the record to find whether it would require a depth of 23 feet. In working that out I worked that out in three separate items. The North Channel is very much smaller than the North Branch which does have a depth of 20 feet. I do not recall how far up that depth extended, but it has been improved for navigation up a considerable distance, and I think it has been dredged up where the North Channel comes into the North Branch. I don't know about navigation on the channel, as I have never been on that channel in a boat. I don't believe that I checked the figure. I have used areas and dimensions more or less, but this
11937 particular figure I don't recall that I checked at all. I think the sewers come in right close to the upper end at the Wilmette Pumping Station. I assumed they came in right at the end, so it had to be flushed. It would not make much difference, as you would have to pump in water anyway. I assumed they came in practically at

the end. It would not be polluted above where the sewage came in except that it might have been stirred up.

I have a figure of 6,700 c. f. s. for a number of hours to clean up the South Branch from the junction to the controlling works. If you had tapered off on your controlling works so as to keep the diversion a minimum,
11938 the river would be pretty largely storm water at the end of that time. I did not assume that the controlling works were discharging 8,000 second feet up to the end of the three hour period, but at the end of the three hour period would have been reduced down approximately perhaps to the amount of the flushing streams. At the
11939 start of the three hour period, it might be 10,000 second feet. Wouldn't do that in small storms, but it might be that much. It would average up to 8,000 second feet for the three hour period. I have taken figures for draining the canal between the controlling works and Lockport, which is not necessary, in so far as keeping storm water out of Lake Michigan is concerned. I took another figure for draining the Calumet Sag Channel from Blue Island down to the Main Canal. It is not so large as the other and it takes the same time as the other, which would not be essential so far as keeping storm water out of Lake Michigan is concerned. I don't think the South Branch would be in pretty good shape in the course of the flushing of the North Shore Channel, because the North Branch would be pretty badly polluted at time of storm, and of course this calculation regards the whole mass of water as though it were a solid slug that could be pushed ahead, and if that were all pushed
11940 down into the South Branch, that would all be in the South Branch, what had not already gone past the controlling works.

The flushing that I have outlined would not remove all the storm water, but I think reasonably so. I think

it is reasonably as close as one could calculate. I be-
11941 lieve my assumptions are fairly average minimum assumptions.

The records at the Chicago Weather Bureau Station
11942 show that at that single point 55 times a year there is enough rainfall to produce overflow of the sewers, at that point. That does not mean that all of those 55 at that point cover the whole city. The additional 25 is due to the fact that at the time when the Weather Bureau at a single point shows rain enough to produce overflow, we know also from the records of the surrounding weather bureau stations that they are having rainfall heavy enough to produce overflow at pretty nearly double, or pretty nearly an equal number of additional times. Fifty times is what we got from counting the records over three years. But those stations are 30 or 40 miles away, and I took half that number and added it to allow for this local variation, especially of summer thunderstorms that occur in one part and don't occur in others. The
11943 figure of 55 rains causing overflow, is based upon hourly readings for nine years at the Chicago Weather Bureau Station. That is .06 of an inch the first hour or .08 the first two hours or .10 in the first three. It is a sliding scale with a little correction from that.

With reference to these twenty-five storms, I would not expect to get the 10,000 second feet runoff from that. I would only have it on a part of the area, and the runoff would be smaller. It is impossible as a practical matter
11944 to get records of these local storms and know the rate at which rain is falling in different parts of this area. There are no observations that give that, no stations, and no way of keeping track of it. The controlling works will have to be operated on probabilities and trying to be safe. They will have to take water a little in excess of just what would be required if you knew the exact condi-

tions. I don't think it would be efficacious to determine
11945 overflows of the sewers from the current in the river, but if you wanted to determine them it would be better to put a man right there at the outlet of the sewer where he can see it. There isn't any easy way of getting any accurate measurement instantly of the flow in the river. A man standing on a bridge could tell the velocity somewhat, but it could change a good deal in a normal current without his being able to say very definitely about it. Gauges at the mouth of the river and at the control works would give an idea of the relative level; but during the dry weather time they will all be level except for oscillations that will always be occurring, according to testimony here, which will be very great in the last mile
11946 of that main river channel. These oscillations occur whether there is diversion or not. They prevent you from determining from watching, seeing just what the river is doing. It is feasible to gradually increase the flow through the controlling works and gradually decrease it as the flow in the river may concentrate or decrease. That is the object of moving the control works to the river mouth, so that you could get quick control.

Redirect Examination by Mr. Beebe.

With the controlling works at Kedzie Avenue instead of right at the mouth of the river, it is necessary to anticipate to a greater degree storms. The computations
11947 that I have made were based on public data of the United States Weather Bureau, and the rest of the data was from original data taken from the records in the office of the Sanitary District. I have been over the data of the Sanitary District at considerable length and studied it in considerable detail. So far as rainfall goes, that is based upon published records, and the method of

determining what quantity was delivered, is based upon the carrying capacities and the volumes contained in the intercepting sewers. Those data were used in my calculations as to the runoff when there was a rate of .06 inch rainfall per hour. The data in the Sanitary District was material that was used for several years there in their regular work in connection with design. I found that the methods used in making the calculations were correct from an engineering standpoint. The results of the calculations were correct. From the examination that I made of the Sanitary District data, the calculations and results obtained, I believed that data to be sufficiently reliable upon which to base the calculations and conclusions I have made here.

When I was on the Enginering Board of Review four and a half years ago, I was assigned as part of my study to this field of storm runoff and we had it under consideration for several months; so I was in general familiar with the situation. I did not use any of those data in
11949 this particular calculation but I began about five or six weeks ago to go over these data and spent a considerable part of my time on it. I did not consider it material in connection with the calculations I made to determine the amount of cubic feet per second of .06 of an inch rain in one hour over the entire area. I wanted to know what would happen over an area as big as is covered by one storm sewer. The number of storm sewers runs into the hundreds. They are combined sewers.
11950 There may be conditions which would raise the storm sewers in one locality and not another. There might be a storm overflow from a single sewer without having storm overflow from any others, in some light or very localized rain. There might be a comparatively heavy rain that would take in the sewers of a given area and not have anything to do with the sewers of another area, which

happens frequently in a large city like Chicago. The amount that the interceptors when built as a whole carry in volume is not material to the computation here. There is no important connection at all.

This nominal capacity as it was defined in the testimony here, specified that the water surface was to have
11951 a slope parallel to the bottom, that is, a very flat slope relatively. It is possible to make the slope very steep by lowering the water level at the gates at Lockport, and that increases the quantity carried very much. You cannot increase it without limit, but you can perhaps pretty nearly double it in part, probably not for the whole canal from the Lake down. The total amount that we have used in this calculation as the annual runoff from rain water of the Chicago River and Calumet River areas is 543 cubic feet per second. My calculation shows that the amount of lake water withdrawn from Lake Michigan during the period that is called the preparatory
11953 flow and the flow during storm, with subsequent storm overflow period, would be 278 cubic feet per second, as the sum of that for the Chicago River and the Calumet River stated as the annual average.

Recross Examination by Mr. Jackson.

11954 The gates at the lower end of the Canal at Lockport would be closed during the time of no flow. The controlling works would be higher when there was no flow through the control works than they would be with no controlling works and a flow of 5,000 second feet. I am mistaken about that. I think the gates would be higher at Lockport with 5,000 second feet flow than they would be with no flow through the controlling works at Robey Street, assuming 7-foot drop in the elevation of the water east of the controlling works and that west.

I don't think there would be any trouble in maintaining 10,000 cubic feet per second flow at Robey Street, but it
11955 might not have the same flow all the way down. The Canal would be filling up there for quite a long distance. I do not remember what the drop in the water level in the canal would be with normal capacity flow between the Lake and Lockport. I think the gauges would be
11956 lowered about three or four feet with 10,000 second feet flow at Lockport and 8,000 in this upper stretch of the Canal.

Defendants' Exhibit 1118 may be correct, as follows:

> "A slope ratio of one to six is assumed. Then under average conditions, with a limited flow of 4167 cubic feet per second, the total slope would be one foot to six feet for a flow of 10,000 cubic feet per second."

11958 The present gates go down I think 11 feet. Control is largely through the turbines. The gates are used in addition but a large amount goes through the turbines. Roughly, you would have to drop the gates to double the flow as the square of the flow, four times as much. It would be about 24 feet which would produce about 20,000 second feet flow. I know that the flow would never go to
11959 20,000 feet, but I never determined or tried to calculate just what the maximum would be. You might or might not have 8,000 second feet up above the Sag when we had 10,000 second feet at Lockport. It does not always happen that way.

I have gone over the figures of the 1927 test. I think the Sanitary District left the gates open as long as they could during those days just to see what would happen. It took a month or more, as I recall it. It never got to the point of having as high as 16,000 feet in the earth section. I don't think they got as high as 10,000 second
11960 feet. It would be necessary to have a lot more than

10,000 down below. I think you could draw up to 10,000 second feet. With the control at Robey Street you can establish 10,000 c. f. s. very much quicker than with the control at Lockport. The amount flowing would be differ-
11963 ent at different points along the river. My calculations have been based upon the time when the effluent enters the Canal and the sewage purification works are in operation, and a sanitary flow smaller than the present one. It also contemplates that part of the time this effluent would flow into Lake Michigan and whenever it rains, it would flow the other way. This effluent would flow towards the Des Plaines River a little over half the year; for the Chicago River Drainage Area, about 198 days; for the Calumet Area, 200 days.

ants at the Final September, 1929 Hearings on Re-reference:

Defendants' Exhibit 1435 is in part as follows:

CITY OF CHICAGO
BEACHES ATTENDANCE.

Years	79th St.	Walker (25th St.)	51st St.	Clarendon	Rainbow (75th St.)	Rogers Pk.	Oakdale	Ohio St.	Street Ends	Total
1906	128,235	184,050					165,765			478,050
1907	66,175	219,150					164,187			449,512
1908	152,115	270,087								442,202
1909	212,380	70,087								282,467
1910	64,131	85,370								149,501
1911	83,171	125,634								208,805
1912	128,236	165,434								293,670
1913	93,520	219,248						12,085		324,853
1914	111,565		47,392					152,708		311,665
1915	144,994		113,270	134,485						392,749
1916	126,583		111,421	132,967						370,971
1917	88,734		82,306	301,279	13,549					485,868
1918	103,669		82,186	323,656	60,072					569,583
1919	85,384		94,933	374,597	128,328	10,215			621,149	1,314,606
1920	62,675			171,432	126,581	22,137			264,934	647,759
1921	89,895			646,096	246,722	147,682			426,895	1,557,290
1922	78,966			520,677	179,421	121,311			297,930	1,198,305
1923	90,621			817,647	244,871	148,097			750,193	2,051,429
1924	76,423			479,850	142,346	101,781			536,070	1,336,470
1925	91,822			769,596	247,989	149,983			790,780	2,050,170
1926	93,984			1,948,388	249,782	151,484			711,480	3,155,118
1927	92,863			2,183,423	248,991	151,673			964,115	3,641,065
1928	284,705			2,240,519	1,061,289	440,170			643,516	4,670,199
*1929	211,900			466,148	958,811	149,040			537,605	2,323,504
* Figures for June and July only.										
Aug. 11, 1929	8,400			120,405	119,658	89,129			129,680	467,272

Defendants' Exhibit 1436 is in part as follows:

SOUTH PARK COMMISSIONERS.
BEACHES ATTENDANCE.

Years	Calumet Park	Jackson Park	39th St.	25th St.	51st St.	31st St.	Total Paid Admissions	Other Bathers	Grand Total
1905	20,861						20,861	20,861	41,722
1906	37,863						37,863	37,863	75,726
1907	31,510						31,510	63,020	94,530
1908	52,629						52,629	104,258	156,887
1909	44,371						44,371	133,113	177,484
1910	42,307						42,307	126,921	169,228
1911	48,053						48,053	144,159	192,212
1912	55,768						55,768	167,304	223,072
1913	59,993	176,751	87,140				323,884	971,652	1,295,536
1914	68,431	122,855	89,724	55,349			336,359	1,009,077	1,345,436
1915	55,293	200,423	35,303	27,853			318,872	956,616	1,275,488
1916	96,534	196,610	107,286	68,325			468,755	1,406,265	1,875,020
1917	53,995	171,725	66,000	51,495			343,215	1,029,645	1,372,860
1918	94,190	193,385	68,725	57,761			414,061	1,242,183	1,656,244
1919	38,007	399,882	75,345	40,467			553,701	1,661,103	2,214,804
1920	28,996	213,383	58,033	20,196	28,104		348,712	1,046,136	1,394,848
1921	56,165	367,846	133,800	59,840	80,064		697,715	2,093,145	2,790,860
1922	69,690	326,898	75,140	42,133	64,154		578,015	1,734,045	2,312,060
1923	48,000	302,907		14,905	41,840		407,652	1,222,956	1,630,608
1924	58,672	305,336		34,128	31,342		429,478	1,288,434	1,717,912
1925	51,360	434,546		10,125	18,950		514,981	1,544,943	2,059,924
1926	64,200	384,223		14,250			462,673	1,388,019	1,850,692
1927	93,825	454,616		29,850			578,291	1,734,873	2,313,164
1928	40,300	377,363		44,450			462,113	1,386,339	1,848,452
*1929	47,475	203,431				25,765	276,671	830,013	1,106,684
Aug. 11, 1929	14,000	12,350				4,000	30,350	44,650	75,000

* Attendance for June and July at Jackson Park and Calumet Park—July only at 31st St.

Defendants' Exhibit 1437 is in part as follows:

LINCOLN PARK COMMISSIONERS.
BEACHES ATTENDANCE.

Year	Diversey	Fullerton	Belmont Harbor	Oak St.	Waveland	Cornelia	Oakdale	Ohio St.	Total Estimated
1905									10,000
1906									12,000
1907									15,000
1908									20,000
1909									130,000
1910									200,000
1911									180,000
1912									176,000
1913									154,000
1914									196,000
1915									250,000
1916									230,000
1917									450,000
1918									496,000
1919									503,000
1920									792,000
1921									704,000
1922	84,816	30,000		600,000					714,876
1923	97,867	30,000		700,000					827,867
1924	110,240	40,000		800,000					950,240
1925	100,000	35,000		900,000					1,035,000
1926	80,000	25,000	15,000	800,000					920,000
1927	100,000	28,000	20,000	1,000,000					1,148,000
1928	100,000	30,000	25,000	1,000,000					1,155,000
*1929	150,000	25,000	35,000	600,000					810,000
Aug. 11, 1929	30,000	4,000	8,000	90,000					132,000

* Attendance for June and July at Diversey, Fullerton, Belmont Harbor and Oak Street Beaches.

Defendants' Exhibit 1438 is in part as follows:

NORTH SHORE PARK COMMISSIONERS.
BEACHES ATTENDANCE.

Year	Attendance
1919	20,000
1920	40,000
1921	200,000
1922	180,000
1923	450,000
1924	250,000
1925	455,299
1926	392,014
1927	370,000
1928	550,000
*1929	415,000
Aug. 11, 1929	8,000

* Attendance for June and July.

Defendants' Exhibit 1439 is in part as follows:

CITY OF EVANSTON.
BEACHES ATTENDANCE.

Year	Attendance
1924	96,243
1925	149,995
1926	164,748
1927	526,238
1928	527,472
*1929	445,432
Aug. 11, 1929	18,466

* From June 22nd to August 17th, inclusive.

Defendants' Exhibit 1440, which purports to be a tabulation from Exhibits 1435 to 1439, both inclusive, is as follows:

12409
to
12412

Copy of Defendants' Exhibit No. 1440

Sheet No. 1

THE SANITARY DISTRICT OF CHICAGO

Yearly Attendance at Bathing Beaches

Name of Municipality Operating Beach	Attendance Per Year									
	1905	1906	1907	1908	1909	1910	1911	1912	1913	1914
South Park Commissioners.....	41,722	75,726	94,530	156,887	177,484	169,228	192,212	223,072	1,295,536	1,345,436
City of Chicago	.....	478,050	449,512	442,202	282,467	149,501	208,805	293,670	324,853	311,665
Lincoln Park Commissioners.....	10,000	12,000	15,000	20,000	130,000	200,000	180,000	176,000	154,000	196,000
North Shore Park Comm.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
City of Evanston.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Total	51,722	565,776	559,042	619,089	589,951	518,729	581,017	692,742	1,774,389	1,853,101

12413
to
12416

Copy of Defendants' Exhibit No. 1440.

Sheet No. 2.

THE SANITARY DISTRICT OF CHICAGO

Yearly Attendance at Bathing Beaches

Name of Municipality Operating Beach	Attendance Per Year							
	1915	1916	1917	1918	1919	1920	1921	1922
South Park Commissioners.	1,275,488	1,875,020	.....					2,312,060
City of Chicago.....	392,749	370,971	485,868	569,583	1,314,606	647,759	1,557,290	1,198,305
Lincoln Park Commissioners	250,000	230,000	450,000	496,000	503,000	792,000	704,000	714,876
North Shore Park Comm..	.....	.....	.....	.....	20,000	40,000	200,000	180,000
City of Evanston.....	.....	.....	.....	.....	.....	.....	.....	.....
Total	1,918,237	2,475,991	2,308,728	2,721,827	4,052,410	2,874,607	5,252,130	4,405,241

12417
to
12420

Copy of Defendants' Exhibit No. 1440.

Sheet 3.

THE SANITARY DISTRICT OF CHICAGO

Yearly Attendance at Bathing Beaches

Name of Municipality Operating Beach	Attendance Per Year						
	1923	1924	1925	1926	1927	1928	1929
South Park Commissioners	1,630,608	1,717,912	2,059,924	1,850,692	2,313,164	1,848,452	*1,106,684
City of Chicago	2,051,429	1,336,470	2,050,170	3,155,118	3,641,065	4,670,199	a2,333,504
Lincoln Park Commissioners	827,867	960,240	1,035,000	920,000	1,148,000	1,155,000	a 810,000
North Shore Park Commissioners	450,000	250,000	455,299	392,014	370,000	550,000	a 415,000
City of Evanston	.....	96,243	149,995	164,748	526,238	527,472	b 445,432
Total	4,959,904	4,360,865	5,750,388	6,482,572	7,998,467	8,751,123	c5,100,620

* June and July at Jackson Park and Calumet Park and July at 31st St.
a June and July only.
b June 22nd to August 17th incl.
c Part of year only.

Harold J. Knapp, for Defendants:

Direct Examination by Mr. Adcock.

12007 Reside at Cleveland, Ohio. Am physician in the service of the City of Cleveland; Director of Laboratories, Food and Drug Control. Am first assistant to the Health Commissioner of Cleveland. When the Health Commissioner is away, act as the Health Commissioner. I was subpoenaed here.

Epidemics of intestinal infection have been traced in the past to bathing in polluted water, circumstantially.

12008 "Circumstantially" means that in the investigation of an outbreak of communicable disease, all possible leads that might have caused the factors of an outbreak are considered, whether it be food supply, contact with known cases or carriers, or water supplies.

12013 Whenever there is any outbreak of typhoid, where
12014 water might be under suspicion, then it is the duty of my office to trace down, and, if possible, rule out or affirm the water supply, either bathing or drinking water.

There have been four or five cases circumstantially traced to water supplies.

I made investigations of the typhoid cases in the years 1924, 1925, 1926, 1927 and 1928 during the bathing season at Cleveland.

12015 During the years 1924 to 1928 all of the typhoid cases which occurred in the City of Cleveland were studied, those in which bathing might have been under suspicion, regardless of whether it was in the City of Cleveland or outside of the city—a certain large percentage of cases in our city are so-called non-resident cases. In the study of those cases there were a certain number in which the only lead led to bathing, whether it was in the city or out of the city. A certain percentage showed a condition

which we called "no lead" or "'no lead cases," but in which bathing might have been a factor. So, they were grouped on a paper which was published this last summer,—two sets of figures—a certain number of cases which were listed on our epidemiological report were traced to bathing. Then in another column was stated "bathing under suspicion," meaning that some time during the incubation period of the disease the particular parties had been in bathing.

12016 In other words, I traced some of the cases to bathing, circumstantially. In other cases they were under suspicion as having contracted typhoid fever at bathing beaches.

Cross-Examination by Mr. Jackson.

In my investigations in the last five years I did not find any case of typhoid which I could say definitely was traceable to a publicly supervised bathing beach. I referred to cases, not deaths.

Redirect Examination by Mr. Adcock.

12017 Of course, it is true that our cases of typhoid fever were traced through circumstances.

I say in that article (referred to on direct):

> "It is hardly necessary to point out the relationship of water supply to communicable disease, other than to mention that epidemics of intestinal infections have been traced in the past to bathing in polluted waters."

I found, in 1924, out of 47 cases of typhoid fever during the bathing season of that year at Cleveland, four were traced to bathing, and eight were under suspicion as having come from bathing.

12019 I found in 1925, during the bathing season at Cleve-

land out of 29 cases, one I traced to bathing, and twelve were under suspicion.

For 1926, out of 48 cases at Cleveland, four were traced to bathing, and six were under suspicion.

In 1928, out of 32 cases at Cleveland, five were traced to bathing, and seven were under suspicion.

Traced to bathing doesn't mean the public bathing beaches maintained by the City of Cleveland. Bathing was regardless of the location, as I pointed out or endeavored to point out. It was taken into consideration whether it was a public bathing beach or whether it was a stream or sewer effluent; whether it was inside the City of Cleveland, or it may have been miles distant.

This season no bathing beaches at Cleveland have been
12020 closed on account of pollution; but people were warned not to bathe in Lake Erie.

Dr. F. W. Mohlman, for Defendants:

Director of Laboratories for Sanitary District.

Direct Examination by Mr. Adcock.

Reside at Chicago.

Have been director of laboratories for the Sanitary District of Chicago; for ten years in that position.

12021 Graduated from the University of Illinois in 1912, from the Department of Chemistry, with the degree of Bachelor of Science. I stayed at the University for graduate work in chemistry and allied subjects, and received the degree of Master of Science in 1914. I continued until 1916, when I received the degree of Doctor of Philosophy from the University of Illinois.

My major subjects during this graduate work were, first, sanitary chemistry; first minor, bacteriology, and second minor, sanitary engineering.

During this time while I was in the graduate school of the University, I was working as a chemist and bacteriologist with the State Water Survey of Illinois. We had charge at that time of the quality or the testing of the quality of water supplies throughout the state, and in my work I did the chemical and bacteriological analysis on the waters.

In my last year there, in 1916, I was in complete charge of the laboratory under the direction of Dr. Edward Bartow.

Early in 1917 I went to New Haven, Connecticut, where I took charge of an investigation into the treatment of the sewage of New Haven, under the general direction of Professor C. E. A. Winslow, of Yale University.

In those studies, which lasted somewhat over a year, we went into the question of the treatment of the sewage of New Haven, and rendered a report.

Following that, in 1918, I worked for the Connecticut
12022 State Department of Health and again took charge of the chemical and bacteriological investigation of the industrial wastes in Connecticut, and the condition of the polluted streams in that state.

In this work, we covered practically the entire state, making chemical and biological investigations.

In 1919 I came to the Sanitary District of Chicago as chief chemist, and have been in that position until the present date, with the title at the present time of Director of Laboratories. In the Sanitary District of Chicago I have under my direct supervision ten or twelve laboratories, where we do a very large volume of work, both chemical and bacteriological.

In all these laboratories there are approximately 25 chemists and bacteriologists located at various laboratories who are doing work under my direction; and in

addition we have a large number of samplers and other assistants for this work.

When I came to the Sanitary District I had the experience gained in Connecticut and Illinois, and the problem of the Sanitary District which appealed to me, and which
12023 I studied most carefully, was the pollution of the Illinois River. From the first year of my entry into the Sanitary District personnel, I studied and made investigations of the Illinois River, during the summer of 1919, 1920, and 1921. These were not on a very comprehensive scale, but they gave me valuable information concerning the condition of the river.

Approximately five years ago I organized and started under way a very comprehensive study of the conditions of the Illinois River. In this work it was necessary to lay out a half dozen field laboratories and to arrange for collection of a large number of samples. In that work I had samples collected at intervals of one hour throughout the 24 hours at as many as 16 stations all the way down the river for a distance of 200 or more miles. In the past five years we have averaged at least fifty or sixty thousand determinations of dissolved oxygen on the Illinois River, a total for the five years of possibly three hundred thousand determinations. This has led me to know something about the Illinois River in connection with my own personal observation.

I also have made a very careful check on the condition of our Chicago River system by analyses taken at various points of the main channel and the dilution system.

12024 With regard to Lake Front work, we collect and analyze a large number of samples from the Lake Front of Chicago, extending from Gary to Waukegan, a distance of about sixty miles. As the samples are analyzed for bacterial content and B-coli, we have a very comprehen-

sive schedule that enables us to keep track of the condition of these water supplies.

We make approximately fifteen thousand of these determinations each year. For the past five years there have been probably a total of 75,000 or more. As a result of this work I have become quite familiar with the Chicago condition.

12025 In the past summer of 1929 I carried on an investigation of the condition of the rivers, beaches, harbor and lake front at Milwaukee.

In laying out this study of Milwaukee conditions I found it desirable, in order to extend our knowledge, to include the whole system as it is now in operation; namely, the sanitary condition of the Milwaukee River System

12026 from the standpoint of the oxygen content of the waters; the conditions of whether or not the rivers were flushed; the contrasts in condition of these rivers and all factors that I could find that would give me knowledge of what the conditions would be under such a program of complete treatment of sewage and interception of sewage from the river system and discharge of a sewage effluent and of the river water into the Lake. This required, in addition to the river studies, a careful survey of the bacteriological conditions along the Lake front, and this, in turn, required a subdivision to determine what effect such a program had on the bathing beaches of Milwaukee, and, secondly, on the Lake front and the harbor conditions off the mouth of the Milwaukee River.

12027 Our investigation started early in June, 1929; in fact, late in May. I had samplers on the river, out in the Lake and along the beaches. The river samples were taken in approximately 22 trips, extending from May 28th to August 30th. The samples taken during these trips amounted to approximately 360, taken in these 22 trips; and these sam-

ples were taken from all parts of the Milwaukee River System, the navigable channels of this river system. Now, these, of course, were only the samples from the rivers. The samples from the Lake comprise approximately 400, as I recall it, and the samples from the beaches approximately 140. Somewhere around 900 samples altogether were taken.

12028 Flushing was under way during our investigations, because I saw the water coming into the rivers from the flushing tunnels myself, that is as to the Kinnickinnic and Milwaukee Rivers. There was no flushing of the Menominee River.

I attempted to estimate the amount of this flushing of the Milwaukee and Kinnickinnic Rivers by visits to the pumping stations that were in operation at the time, and also by having my assistants get what information they could regarding the amount and the time of flushing.

12029 I made an investigation to determine the relation of the conditions of flushing.

12030 I also made an investigation to determine the general trend of the drift of pollution in the lake at Milwaukee during that period.

I determined the B-coli index of water at the different bathing beaches in Lake Michigan along Milwaukee's Lake front.

I determined the dissolved oxygen content of the Menominee River where there is no flushing, and also the dissolved oxygen content of the water of the Kinnickinnic and the Milwaukee Rivers where there was flushing.

The Milwaukee River extends from the junction of the Kinnickinnic and Milwaukee Rivers to the lake. Of course, in all of these determinations I did not take all of these

12031 900 samples personally, but I did take some of them personally, and I supervised carefully the collection, the place of collection, and the manner of collecting samples

and the manner and methods for making the analyses for all of these samples.

All of this work was done under my direction by men who had been in the employ of the Sanitary District for some years, and they were competent.

I traversed these various rivers myself, and observed the conditions of the Menominee River on various occasions, as well as the conditions of the Kinnickinnic and the Milwaukee Rivers, and the main stem of the river on four occasions, and collected samples on those same occasions out of the 22 trips I believe I mentioned previously.

12032 On those occasions I observed the conditions of water with reference to odors and ebullition of gas and such things and the appearance of particles in the water, whether they were of sewage origin or not.

I observed everything that would lead me to form an opinion as to the sanitary condition of the entire water system.

Extending along the same period of time with the investigations that were made in Milwaukee, I arranged to have samples taken in Chicago from our beaches in as closely as possible the same manner in which the samples were taken in Milwaukee. I planned to have these samples taken on the same days, if possible, and by making the same analyses I drew comparisons as to the quality of the bathing beach waters in Milwaukee and Chicago.

In that connection I made an examination of a public health service report of the water off the Lake front at

12033 Chicago, which is a report of the U. S. Public Health Service and it gives the results of studies off the Chicago Lake front.

It is the Crohurst-Veldee report.

In my examination of the water at bathing beaches at

Chicago I determined the B-coli index of the water, the same as I did at Milwaukee.

By "B-coli index," I mean the number of B-coli per hundred cubic centimeters.

12034 I am familiar with the sewage treatment program which the Sanitary District has presented in this case, and also with the efficiency of such works.

I have been present at most of the hearings.

I have an opinion as to what the conditions would be at Chicago in the Chicago River and its branches and the canals of the Sanitary District if the effluents from these sewage purification works, and storm water, are discharged to the Des Plaines River from the main drainage channel and if there is no water diverted directly from the lake when these works are in operation under this Sanitary District program.

I have given a great deal of thought to this question of the discharge.

12035 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 solids 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 a condition of pollution that will be highly offensive That is in the absence of any diluting water from the Lake.

In my opinion there would be no dissolved oxygen in

the waters of the Chicago River and its branches and the canal system, under the foregoing assumed conditions,
12036 except for 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.
12037 I have an opinion as to the volume of water that will be required to be taken directly from Lake Michigan under conditions of discharge of all effluents, storm flow and drainage to the Des Plaines River, in order to produce unobjectionable conditions in the Chicago River and the canal system, and provide the necessary dissolved oxygen.

My opinion is based to a considerable degree on these studies that I have made in Milwaukee this summer. As I said before, I have made many computations on this question of what water will be required, and all of the estimates have been based on the oxygen requirements of the effluents from the treatment works. I have not known what the effect of all other factors which enter into this will be. For example, we have deposits of solids in storm water discharge. I have not had any direct method of knowing what would be the effect of those solids in the river system, such as our Chicago system is. I have not
12038 been able to determine what would be the effect of flushing, if flushing were put into effect, toward the Lake. I have not been able to determine what other conditions would affect the sanitary condition of the Chicago system after our treatment plants are put in operation. But, having gained this knowledge of the effect of some of these other factors from my study in Milwaukee, I believe that a substantial volume of diluting water will be required after the sewage treatment program of the Sanitary District is completed. I base this to a considerable

extent upon what was found in Milwaukee through our studies this summer, of the effect of those solids.

I believe that any hard and fixed ratio of dilution set at the present time is subject to unavoidable contingencies that make it undesirable to determine the exact amount of water at the present time. I believe that the exact
12039 amount can only be determined on the basis of very complete surveys such as we have made at Milwaukee this summer, only on a much more extensive scale. I feel that there are so many unknown factors affecting future conditions, that the exact amount cannot be determined until we know more about these practical, unknowable factors which enter into the problem.

By "unobjectionable conditions" I mean conditions that will not allow the dissolved oxygen content to be depleted to zero; I mean conditions that will not allow black or septic condition of the river system; I mean conditions that will not permit evidence of sewage matter to be seen on the surface of the rivers.

The ebullition of gases occurs if solids are deposited in the river.

Assuming no discharge of any kind from the Drainage Canal to the Des Plaines River, the completion of the program of sewage treatment and the discharge of the effluents from these plants at the places I have described or that have been described in the evidence, and the addition of 2,000 cubic feet per second from the Calumet Sag
12040 Channel at its eastern terminus, 2,000 second feet from Lake Michigan to the South Fork of the South Branch of the Chicago River, 1,000 cubic second feet to the North Shore channel at its Wilmette terminus, I have an opinion as to what the condition of the water of the Chicago River and the Canal systems and the waters of Lake Michigan at and near Chicago's lake front will be.

The use of this volume of flushing water toward the

Lake under the conditions mentioned would provide conditions in the Canal System such that in my opinion the system, including the channels of the Chicago River and its branches, would not be highly objectionable. On the other hand,. 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. I believe that it would contaminate the water supply and be in marked contrast to the present condition.

Based on my experience and my investigation that I have made and described, the B-coli indices at the various bathing beaches, I believe, contrasting our conditions with what I found at Milwaukee, would be a million or more. I have formed my opinion as to that point on the basis of what was found this summer at Milwaukee.

12042 That is a million B-coli per 100 cubic centimeters.

I refer to all bathing beaches within a radius of five miles of the mouth of the Chicago River.

12043 The term "stable," "stability," as applied to an effluent from a sewage treatment plant, refers to a chemical or bio-chemical 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 oxygen present in nitrates. This is the extent of the stability test. It is expressed in either the number of days required for this disappearance or in the per cent of the relative stability based on a scale extending to approximately 100.

The presence of nitrates does not prevent in any degree the disappearance of dissolved oxygen from an activated sludge effluent. The dissolved oxygen will disappear before any nitrates are affected. The presence of nitrates in the liquid flowing over sludge deposits will not prevent

the septic condition or the ebullition of gas from those sludge deposits.

The efficient operation of an activated sludge plant, all
12044 things considered, with regard to its discharge, comprises the production of a minimum amount of nitrate in the effluent, if the process can be controlled to that degree of accuracy.

The production of a large amount of nitrate requires either more air or larger tank capacity. In addition, it is undesirable to produce a high content of nitrate because of the stimulation of organic and aquatic growth. Therefore, all things considered, it is advisable to attempt to operate an activated sludge plant with a minimum production of nitrate.

In my investigations at Milwaukee I also observed the effluent from the activated sludge plant at Milwaukee on several occasions.

I have observed the effluent from various activated sludge plants.

The effluent from an activated sludge plant is not clear, sparkling and odorless.

12045 One of my assistants has here a sample from the Milwaukee plant.

Cross-Examination by Mr. Jackson.

Turbidity is one measure of clearness of a liquid.

12175 I estimate that a good activated sludge effluent which would be produced by the operation of a first class modern activated sludge plant might have a turbidity of 20.

It is not customary in the analysis of sewage effluents to test that. The maximum turbidity of the drinking water at Chicago in April, 1927, at the 68th Street station was 115 parts per million.

12177 The average was 50, and the minimum was 8. This was the month of April.

Q. Doctor, I have here a certified copy of a statement made by Harrison P. Eddy, before the Board of Estimates for the City of Milwaukee on November 12, 1919. I wish to read to you this statement from page 19. (Reading):

> "The activated sludge system will produce an effluent which is, speaking now in general terms, as good in appearance as the Lake water itself."

Do you agree with that statement of Mr. Eddy's?

A. He says that he is speaking in general terms, and in general terms it is as good in appearance as the Lake
12178 water is at times.

Q. Mr. Mohlman, I have here an article by Mr. Harrison P. Eddy in the issue of the "American City" for March, 1929, entitled, "North Toronto Activated Sludge Sewage Treatment Plant," and I read to you from page 125 as follows, after outlining the activated sludge treatment:

> "This process of treatment will remove from the sewage practically all of the suspended matter, turbidity, coloring, and upwards of 95 per cent of the bacteria."

A. The first statement, qualified by "practically," I agree with, because it is a general statement. My opinion is that the average reduction of bacteria will not be 95 per
12179 cent and also that this refers in general to bacteria, and not to B-coli, or any specific type of organism.

The term that he uses, bacteria, refers to the total number, and not to the B-coli. The B-coli is included; but the percentage of reduction might not be as large in the reduction of B-coli.

Referring again to the same article by Mr. Eddy, reading from page 126:

"The final effluents will be practically clear, colorless
12180 and odorless, and will be stable." I agree again with the general statement of "practically"; and with the

statement that it is stable I agree, to the extent that I qualified the definition of "stability" yesterday, that is, the chemical determination as made in a closed bottle.

An official report made to the Board of Estimate and Apportionment of the city of New York by Mr. George W. Fuller, consulting engineer, dated April 30, 1928, at page 84 reads: "The activation process should be carried out by agitation of the sewage with activated sludge in tanks for a period of four to six hours, by means of compressed air. After passing through settling tanks, the sewage will become well purified and non-putrescible and freed of 95 to 98 per cent of its bacteria."

12181 I agree, to the extent that the definition of non-putrescibility would be qualified, again, by my definition of "stability;" second, that he refers to bacteria and not to B-coli. If you refer simply to the analysis of the sewage, we use the same term, of course. But if you refer to the disposal of an activated sludge effluent, I do not agree with the definition of putrescibility.

I do not agree that the B-coli reduction always exceeds the reduction in total number of bacteria.

12182 I think the percentage of reduction based on the total count will be higher than the percentage of reduction based on the B-coli count. I cannot say that B-coli are more resistant.

The resistance of typhoid fever germs depends on the conditions under which they are discharged. They are very highly resistant in some instances, and have caused epidemics by that very reason.

I have not made any test with reference to keeping them alive, but that is my knowledge of the work that has been done with the typhoid organism.

As to the report of the Division of Water Supply and

12183 Control, 1925, for the City of Chicago, page 460: "A study of the diagram will show that, contrary to common

opinion, the waters of the South Side beaches, with the exception of those at Calumet Park, are less contaminated by sewage organisms than those on the North Side. The reason for this is not clear, since the Lake front, in general, along the South Shore side is exposed at times to serious pollution from the Calumet River and the Illinois Steel Company plant. The waters at the extreme southerly beaches south of Jackson Park were often reported as noticeably discolored by some foreign matters; but even at these times the degree of sewage contamination, as shown by analyses was low."

12184 That may be a correct statement as far as it goes.

It is correct with regard to the diagram that is shown there. I think that our own analyses indicate to the contrary, but not for 1929.

I have not the 1925 figures with me, and I cannot say for sure.

I would not want to testify that that statement is incorrect, but whether that actually represents the facts or not is another question.

12185 It is a statement of what they found, limited by the number of samples taken, the place where the samples were taken, and many other factors.

It appears that in 1925 the Calumet River was reversed and flowing into the Lake over 51 per cent of the time at the South Side, according to page 52 of the report of the Department of Public Works of the City of Chicago for 1927. I happen to know how the measurement was made, and I do not agree with it.

12187 Whenever the Calumet River flowed into the Lake in 1925 there was a proportion of raw sewage, not, of course, as we would define raw sewage, 100 per cent raw sewage, but only the raw sewage that was tributary to the Calumet River.

12188 In a good activated sludge effluent there is up to 5

parts per million of dissolved oxygen. We have operated our plant at Maywood and at Calumet with 5 parts of nitrate and nitrite.

12189 That represents potential oxygen around 14½ parts per million.

Redirect Examination by Mr. Adcock.

In an efficiently operated activated sludge plant, we have frequent analyses showing a B-coli index of 1,000,000.

The index always refers to 100 cc.

In my opinion there would be a greater percentage in reduction of all bacteria in this activated sludge process than there would be in the B-coli reduction.

The percentage reduction based on the total count is

12190 based on a far greater initial count than on the B-coli count; therefore the percentage reduction might be higher for the total count, but the actual number of B-coli might be greater in proportion because of the lower initial B-coli count.

At the present time the human sewage from the Illinois Steel Company is tributary to the Calumet Treatment Works.

Referring to the paragraph in that report (page 460, Report of the Division of Water Supply Control, Chicago, for 1925) modifying the portions read by Mr. Jackson, the Fullerton Avenue Beach is located on the west side of the inner lagoon. The waters are shallow and the beach is used entirely by children. At this point the lagoon is narrowed in passing under the bridge to the motor boat harbor entrance. On the east side of the

12191 lagoon, opposite the beach, there was a considerable gowth of sub-aqueous plants. The current of water through the lagoon depended largely on the direction of the wind, consequently circulation was not always good.

I think the enclosed location of that beach without circulation accounts for the relatively high count obtained.

Recross Examination by Mr. Jackson.

12192 The pollution from bathers, without circulation, is a heavy contributing factor in the Fullerton beach to which I have referred because it was enclosed.

I would say the average B-coli index of the activated sludge effluent is around 200,000.

12046 **Horace P. Ramey,** heretofore called for Defendants:

Direct Examination by Mr. Adcock.

12049 I have made a calculation from recent data in the possession of the Sanitary District as to the frequency of runoff of the Chicago River Drainage area, as to different amounts of water, during a year.

I have studied the record of rainfall in Chicago and runoff, and I have come to certain conclusions as to the quantity of runoff in the Chicago River watershed and in different amounts and the frequency with which they occur.

I estimate that 2,000 second feet will run off from 55 to 60 times a year.

12050 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 per 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. That is based on conditions as of 1929.

In 1923, I made an estimate, similar to this present estimate, based on 1922 conditions. Those results appear in Defendants' Exhibit 1118, and in Complainants' Exhibit No. 1, which is the so-called Putnam report.

12051 In those statements in Defendants' Exhibit 1118 I gave the amounts of runoff, with their frequency, and I stated that, as the built up sections of the district—that is, by "district" I mean the watershed of the Chicago River—the built up sections of the district increase, the sewered area will increase and the runoff rate will increase; so I made a reservation in that.

That is stated in that memorandum; that is, Defendants' Exhibit 1118. And the study as of 1929 is based on present-day conditions, for more paving, more sewers, and, naturally, higher rates of runoff.

Of course, as the sewered area, the built up area, increases, there may be changes in the future.

Cross-Examination by Mr. Jackson

I have made estimates of the runoff at various sizes of the Chicago Drainage area in Exhibit 1118 in 1923. I do not recall whether I testified in 1927 with respect to that runoff.

12059 I have not made any study or analysis of this runoff since I made that study in 1923 up to this year. I made an analysis in 1923 and stated the figures as of that date. The next time I made an analysis of that was within the past two months.

In my statment I referred to records of rainfall and runoff in the Chicago Basin.

We have records of flow through the Chicago River and Main Drainage Canal, and it is by observing the action of the canal under certain conditions that I refer to.

I refer to records of flow through the canal when that flow all came off the Chicago River watershed.

I took a condition where the canal is flowing a certain
12060 quantity of water, say, 10,000 cubic second feet, in the upper reaches of the channel above Sag.

As to how I determined it was flowing 10,000 second
12061 feet there I might have something over 10,000 second feet flow at Lockport. I might have a record or estimate of the flow through the Calumet Sag channel, worked out at Blue Island. Assuming I have a certain quantity of flow in the Main Channel above Sag, I get a rain that falls on the Chicago River watershed and runs into the river, the river at the Lake becomes stagnant. That is, there is no current in either direction.

Those observations are made and reported. If the river at the Lake is stagnant, then it is proper to assume that all water that goes to make up the flow of the river further down comes from the runoff.

12062 It takes that water to get down to Lockport, various times. I am citing just one instance. We watch the action of the Canal during all of these rains, and particularly during the heavy rains, and it is from a study of the action of the Canal that I have made this conclusion.

The river might, and it might not, with a different distribution of flow, become stagnant between the junction of the North Branch and the Lake when there is a runoff of 6,400 second feet there, with a flow of 10,000 second feet on the whole watershed.

Perhaps I did testify that with a maximum runoff on the Chicago River watershed of 10,000 second feet, that 64 per cent of that runoff would come from the main channel, the North Branch, and a part of the Chicago River between the junction of the north branch and Drainage Canal.

12063 With 6,400 second flow there would not necessarily be a maximum storm. Ten thousand second feet is not necessarily a maximum storm that will fall on the Chicago

River watershed. What you have is a distribution of the water going to make up 10,000 second feet.

I have not changed my opinion. I used 10,000 second feet as a convenient figure.

A rainfall of something like—I haven't those figures right at hand, but I believe a rainfall as low as .06 inch would produce 2,000 second feet runoff.

I cannot say how long that rainfall would have to continue because there are so many varying conditions of soil——

Q. So that, as I understand you, without knowing what
12064 rainfall would produce 2,000 second feet runoff, or without knowing how long that intensity of rainfall would have to continue, you have estimated that there would be 2,000 second feet runoff from 55 to 60 times per year?

A. Yes. Knowing that there are from 55 to 60 rains per year, that will produce that much runoff on the average.

Q. But you do not know how large those rains would have to be, or how long they would have to continue?

A. Oh, yes; I have the records, but I haven't the details of those analyses at hand.

Q. Is the same thing true with respect to all these other runoffs with respect to which you have assumed to state the frequency—that is, you do not know how much rain would produce such runoff, or how long it would have to continue?

A. The length of time that the rain would have to continue does not affect the problem since this is a rate of runoff.

Q. You do not mean to testify, Mr. Ramey, that if you had a rainfall concentrated throughout the area of the Chicago River, of a certain concentration, that if that were to stop in ten minutes, for instance, it would pro-

duce the maximum runoff for that rainfall in the lower reaches of the river?

A. No; but if I had a rainfall of a certain rate of run-
12065 off it would produce these figures. That is the assumption.

Q. If you had a certain rate of runoff for a long enough period of time?

A. Certainly.

Q. So as to concentrate it all in the lower river? I mean toward Lockport; is that correct?

A. Yes. That is the basis on which these observations were made. They were made when we had a rainfall lasting long enough to have a stated condition, extending clear from Lake Michigan at least down to the upper main channel.

Q. But you cannot tell us what they are, so that your accuracy can be tested by comparison with the Weather Bureau records?

A. Well, I cannot tell you offhand all the details of that computation.

Q. Now, I am asking you the details about just two factors.

By Mr. Adcock: Q. You have the record here, haven't you?

A. I have the records.

12066 Mr. Adcock: They are available for examination by the other side, if they want them.

By Mr. Jackson: Q. If you can do it without taking much time, just tell me what those two factors are that you used for each of these estimates.

A. I will have to get the runoff curve. I cannot answer that offhand.

Q. I do not mean the runoff curve. I want to know what rainfall you estimate and what intensity of rainfall; how many inches an hour, and how long that had to con-

tinue over the whole watershed to produce the results you have estimated. May I ask you what records you are referring to now?

A. I am referring to Defendants' Exhibit 1118.

Q. That is the previous estimates that you made?

A. Yes. A runoff of .03 inch an hour will produce about 2,000 second feet.

Q. Continuing how long?

A. I am giving you a rate.

Q. But a momentary runoff of .03 inch per hour would not give you that?

A. It would give you a momentary runoff of 2,000 second feet.

12067 Q. That would concentrate in the lower Chicago River?

A. I am talking about rates. You are talking about the rate of rainfall and rate of runoff.

Q. Yes. How much rainfall do you say would be required to produce that runoff of .03 inch per hour?

A. Under some conditions a rainfall of about two and one-half times .03 inch would produce it.

Q. That is over the whole watershed at the same time?

A. Yes.

Q. As to these recent computations that you have made, you are now testifying from computations that you made in 1923, are you not?

A. Well, the runoff rate—the total area has not changed, so that the statement in 1923 that .05 inch per hour will runoff 2,947 second feet has not changed.

Q. But your result has changed since 1923?

A. Yes. Since 1923 the runoff rate has increased. That is, the condition of the watershed has changed. It is less pervious, so that we get more runoff from the same amount of rainfall now than we did in 1922. It is a more rapid runoff flow.

Q. But you have just stated your rate of runoff from your 1923 computations. Now tell me what rate you
12068 used for 1929 if it is different.

Q. What ratio of runoff did you use for the rainfall?

A. I used about 40 per cent runoff on the sewered areas and 26 per cent on the nonsewered areas.

Q. What did you use in 1923?

A. The same factors, but in 1923 there was a less proportion of sewered area than there is now, so that the 40 per cent rate would apply to a greater portion of the area today than it did in 1923.

The runoff is limited by the capacity of the sewers. The difference in the capacity of the sewers now and in 1927 I don't know, because I did not make any estimate of capacity in 1927, and as a matter of fact I have not made any estimate of the sewer capacity today. I base the general statement of runoff as to the high figures on observations in the action of the Canal when we were flowing these certain amounts.

12069 When I first observed, or had observed, the stagnant condition appearing in the upper Chicago River, the water that was then flowing through Lockport had passed in from the lake something like twenty-four hours before and there was no part of the rainfall, unless it be purely local, that was passing through the controlling works at Lockport.

It is also true that if there be a seiche, it may render the river stagnant or even partly reverse it for the time, without any rainfall.

12070 The record shows that there was no seiche affecting it. The lake was comparatively still. I can not show you in the records where it shows that.

These records are made when we know that the stagnant condition of the Chicago River at the Lake was the result of rainfall and no other cause.

I have a record of the Lake level, a continuous record, and I didn't take the particular times when there were seiches; I picked times when there were no seiches, because a change in Lake level would affect a study of what was happening in the river clear out.

12071 I have a continuous record of Lake levels near the mouth of the Chicago River, and I have a record of the direction of the current in the Chicago River at Dearborn Street, which is about half a mile inland.

Our observations of stagnation or reversal of the Chicago River are not all taken at Dearborn Street. There are certain reports made by the bridge-tender at Michigan Avenue.

But the records that I have introduced in evidence here as an exhibit of reversals are taken from Dearborn Street.

That is some .7 of a mile from the mouth of the river.

12072 They show the direction of the current. They show whether the current is towards the Lake or whether the current is inland, and whether there is any current at all, or whether there is no current.

I don't know how much additional paving has been done in Chicago since 1927.

Q. Well, how did you arrive at your conclusion that the number of times when a runoff of 3,000 second feet had occurred per year had increased from the ten or twelve times which you testified to on page 3365 of the record in 1927, to 35, as you testified to here today?

A. I would like to see that.

The Witness (after examining record): Apparently

12073 that is a statement of some figures that were in Exhibit 1, that were prepared by me, and apparently that is a statement that is in that report.

When I testified in 1927, I had not made any study of that situation since 1922.

In concluding that the frequency of 3,000 c.f.s. run-offs

had tripled since 1923 calculations I did the increase in paved area.

These statements of runoff are all estimates; they cannot be stated definitely; I have stated them within certain ranges. I think they can be stated within certain ranges, but there isn't any absolute knowledge of it, because it is
12074 not susceptible of absolute determination.

I estimate that 2,000 second feet would run off from 55 to 60 times per year. I believe that the average ran something like three hours. I cannot give it to you for all of those as I have not it. The same is true of the 3,000, 4,000, 5,000, I said so many times per year. I did not endeavor to give you the length of those times. I
12082 was giving you a table of frequency, rather than a table of quantity or of volume.

I have just as much data about the length of these run-offs as I have of their frequency, but I did not work it out in that manner. I did not consider that a material factor as I was working for a certain rate. I assumed that the total run-off for a year of the Chicago Basin would be a little more than 200 second feet.

12083 This study is based on the rainfall record at one station.

I believe there are three different stations in the total time that I have used. One was on the Federal Building, and in late years we have used the University of Chicago station, but for a particular period there was just one station used.

I assumed that the run-off that was shown at that one station was practically simultaneously equivalent throughout the area of the Drainage Basin.

Redirect Examination by Mr. Adcock.

There is a gage operated near the mouth of the Chicago River, which automatically records, continuously records,

the elevation of Lake Michigan. In this study I used
12084 those gages at the mouth of the river and at Western Avenue and on down the channel to see that there was no great change in the flow in the channel; that is, the channel was not rising and was not falling.

The Government maintains a gage right outside the mouth of the Chicago River.

We have some of those government records. In the main, though, we have used our own records at the mouth of the river. But from time to time we have compared those records with the government records at the mouth of the river and, in general, they have checked.

12085 The recording gage maintained by the District at the mouth of the Chicago River is a different type of gage to the one that is maintained by the Government, but it produces the same result.

I have checked the records of that gage with a government gage.

The gage at the mouth of the Chicago River maintained by the Sanitary District records the elevation of the Lake from time to time.

The record made at Dearborn Street shows the time when the river is stagnant, or when it is flowing towards the Lake, or when it is flowing inland.

So that, by comparison of the time of that record with the record of the gage indicating the rise and fall of the surface of Lake Michigan, I can find out whether there is any seiche on the lake.

12086 I have assumed that if there is 10,000 second feet of water flowing in the main drainage canal from the Chicago River to Lockport, and if there should be a stagnant condition, that is, no flow in the Chicago River proper—that is, at Dearborn Street—then I assume that the flow from the place of stagnancy is due to run-off.

It will come in at various places in the river—some in

the South branch, some in the North branch, some at the Stockyards slip, some in the canal down at Western Avenue. The same would be true with the flows of these various magnitudes.

And it is on the record indicating those stagnant conditions of the Chicago River at various times that our present study is made.

Recross Examination by Mr. Jackson.

12090 I did not get 2,000 second feet from a study of the high flow. I made a study of several storms to get the high points on the curve, and I used the water pumpage as the minimum run-off.

The water pumpage was included in the 2,000 second feet as part of the run-off and a part of the 2,000 second feet which is true of all run-off computations.

I am speaking of total run-off from the watershed; that is, through the sewers. I did not measure the velocity with a current meter.

Certain Acts of the General Assembly of Illinois appearing in published Statutes of Illinois, were offered and received in evidence and are not here set out, but it is understood that both parties may in their briefs and oral arguments refer to any of such acts as they appear in authentic or recognized publications.

Subject to objection as to materiality and relevancy, Defendants' Exhibits 1456 and 1457 were received in evidence. Exhibit 1456 is photographs or pictures of locations on the shores of the Great Lakes or connecting waters taken during the summer of 1929, about which testimony was offered by complainants' witnesses Henry De Graass, M. P. Sawyer, F. W. Atkins, E. M. Bunce,

John B. Taylor and G. M. Dane, on prior 1926-27 hearings.

Exhibit 1457 is a plat showing the locations of the shore shown on the pictures or photographs.

Langdon Pearse, recalled, interrogated by the Master, among other things stated that the area of the site recommended by the Engineering Department of the Sanitary District and desired for the Southwest Side Treatment Plant, is 600 acres.

12421 COPY OF DEFENDANT'S EXHIBIT No. 1448.

U. S. LAKE SURVEY NOTICE TO MARINERS, DETROIT, MICH.

March Lake Levels

The United States Lake Survey reports the monthly mean stages of the Great Lakes for the month of March as follows:

Lakes	*Feet above mean sea level*
Superior	602.49
Michigan-Huron	580.66
Se. Clair	575.63
Erie	572.47
Ontario	246.15

Lake Superior is 0.03 foot higher than in February (since 1860 the March level has averaged 0.10 foot lower than February); it is 0.76 foot higher than the March stage of a year ago, 1.19 feet above the average stage of March of the last ten years, 0.17 foot above the high stage of March, 1917, and 2.30 feet above the low stage of March, 1926.

Lakes Michigan-Huron are 0.10 foot higher than in February (since 1860 the March level has averaged 0.18 foot higher than February); they are 1.70 feet higher than the March stage of a year ago, 1.56 feet above the average stage of March of the last ten years, 2.29 feet below the high stage of March, 1886,
12422 and 3.12 feet above the low stage of March, 1926.

Based on past records the monthly mean level for April is likely to be about 580.9 and not less than 580.4.

Lake Erie is 0.38 foot higher than in February (since 1860 the March level has averaged 0.18 foot higher than February); it is 1.02 feet higher than the March stage of a year ago, 1.21 feet above the average stage of March of the last ten years, 1.38 feet below the high stage of March, 1887, and 2.45 feet above the low stage of March, 1926. Based on past records the monthly mean level for April is likely to be about 573.0 and not less than 572.3.

Lake Ontario is 0.22 foot higher than in February (since 1860 the March level has averaged 0.26 foot higher than February); it is 0.18 foot higher than the March stage of a year ago, 0.89 foot above the average stage of March of the last ten years, 1.66 feet below the high stage of March, 1886, and 2.01 feet above the low stage of March, 1926. Based on past records the monthly mean level for April is likely to be about 246.7 and not less than 245.9.

12423 COPY OF DEFENDANT'S EXHIBIT 1449.

U. S. LAKE SURVEY NOTICE TO MARINERS
DETROIT, MICH., MAY 2, 1929.

April Lake Levels

The United States Lake Survey reports the monthly mean stages of the Great Lakes for the month of April as follows:

Lakes	*Feet above mean sea level*
Superior	602.60
Michigan-Huron	581.39
St. Clair	576.34
Erie	573.56
Ontario	247.28

Lake Superior is 0.11 foot higher than in March (since 1860 the April level has averaged 0.06 foot higher than March); it is 0.75 foot higher than the April stage of a year ago, 1.21 feet above the average stage of April for the last ten years, 0.09 foot below

the high stage of April, 1860 and 2.50 feet above the low stage of April, 1926.

Lakes Michigan-Huron are 0.73 foot higher than in March (since 1860 the April level has averaged 0.20 foot higher than March); they are 1.87 feet higher than the April stage of a year ago, 1.95 feet above the average stage of April of the last ten years, 1.84 feet below the high stage of April, 1886,
12424 and 3.57 feet above the low stage of April, 1926. Based on past records the monthly mean level for May is likely to be about 581.7 and not less than 581.4.

Lake Erie is 1.09 feet higher than in March (since 1860 the April level has averaged 0.54 foot higher than March); it is 1.77 feet higher than the April stage of a year ago, 1.69 feet above the average stage of April of the last ten years, 0.62 foot below the high stage of April, 1862, and 2.75 feet above the low stage of April, 1926. Based on past records the monthly mean level for May is likely to be about 573.9 and not less than 573.4.

Lake Ontario is 1.13 feet higher than in March (since 1860 the April level has averaged 0.59 foot higher than March); it is 0.86 foot higher than the April stage of a year ago, 1.48 feet above the average stage of April of the last ten years, 1.15 feet below the high stage of April, 1886, and 2.44 feet above the low stage of April, 1872. Based on past records the monthly mean level for May is likely to be about 247.5 and not less than 247.0.

12425 COPY OF DEFENDANTS' EXHIBIT No. 1450.

U. S. LAKE SURVEY NOTICE TO MARINERS

May Lake Levels

The United States Lake Survey reports the monthly mean stages of the Great Lakes for the month of May as follows:

Lakes	*Feet above mean sea level*
Superior	602.62
Michigan-Huron	582.01
St. Clair	576.92
Erie	574.28
Ontario	248.27

Lake Superior is 0.02 foot higher than in April (since 1860 the May level has averaged 0.31 foot higher than April); it is 0.47 foot higher than the May stage of a year ago, 0.99 foot above the average stage of May of the last ten years, 0.43 foot below the high stage of May, 1861, and 2.44 feet above the low stage of May, 1926.

Lakes Michigan-Huron are 0.62 foot higher than in April (since 1860 the May level has averaged 0.30 foot higher than in April); they are 2.07 feet higher than the May stage of a year ago, 2.25 feet above the average stage of May of the last ten years, 1.51 feet below the high stage of May, 1886, and 3.85 feet above the low stage of May, 1926. They are higher than any monthly mean level since September, 1888,
12426 but are only slightly above the stage of June, 1918. Based on past records the monthly mean level for June is likely to be about 582.2 and not less than 582.0.

Lake Erie is 0.72 foot higher than in April (since 1860 the May level has averaged 0.34 foot higher than April); it is 2.21 feet higher than the May stage of a year ago, 2.05 feet above the average stage of May of the last ten years, 0.14 foot below the high stage of May, 1862, and 3.11 feet above the low stage of May, 1926. It is higher than any monthly mean level since July, 1876. Based on past records the monthly mean level for June is likely to be about 574.5 and not less than 574.1.

Lake Ontario is 0.99 foot higher than in April (since 1860 the May level has averaged 0.34 foot higher than April); it is 1.66 feet higher than the May stage of a year ago, 2.13 feet above the average stage of May of the last ten years, 0.68 foot below the high stage of May, 1870, and 3.31 feet above the low stage of May, 1872. Based on past records the monthly mean level for June is likely to be about 248.4 and not less than 247.9.

12427 COPY OF DEFENDANTS' EXHIBIT No. 1451.

U. S. LAKE SURVEY NOTICE TO MARINERS

DETROIT, MICH., JULY 3, 1929.

June Lake Levels

The United States Lake Survey reports the following approximate mean stages of the Great Lakes for the month of June, determined from daily readings of staff gages.

Lakes	*Feet above mean sea level*
Superior	602.72
Michigan-Huron	582.22
St. Clair	576.94
Erie	574.27
Ontario	248.46

Lake Superior is 0.10 foot higher than in May (since 1860 the June level has averaged 0.28 foot higher than May); it is 0.26 foot higher than the June stage of a year ago, 0.83 foot above the average stage of June of the last ten years, 0.71 foot below the high stage of June, 1876 and 1916, and 2.22 feet above the low stage of June, 1926.

Lakes Michigan-Huron are 0.21 foot higher than in May (since 1860 the June level has averaged 0.23 foot higher than May); they are 2.08 feet higher than the June stage of a year ago, 2.30 feet above the average stage of June of the last ten years, 1.39 feet
12428 below the high stage of June, 1886, and 3.81 feet above the low stage of June, 1926. Based on past records the monthly mean level for July is likely to be about 582.3 and not less than 582.0.

Lake Erie is 0.01 foot lower than in May (since 1860 the June level has averaged 0.18 foot higher than May); it is 1.88 feet higher than the June stage of a year ago, 1.93 feet above the average stage of June of the last ten years, 0.25 foot below the high stage of June, 1876, and 3.09 feet above the low stage of June, 1925. Based on past records the monthly mean level for July is likely to be about 574.2 and not less than 573.9.

Lake Ontario is 0.19 foot higher than in May (since 1860 the June level has averaged 0.14 foot higher than May); it is 1.87 feet higher than the June stage of a year ago, 2.21 feet above the average stage of June of the last ten years, 0.17 foot below the high stage of June, 1870 and 3.57 feet above the low stage of June, 1895. Based on past records the monthly mean level for July is likely to be about 248.4 and not less than 248.1.

12429 COPY OF DEFENDANT'S EXHIBIT NO. 1452.

U. S. LAKE SURVEY NOTICE TO MARINERS

DETROIT, MICH., AUGUST 3, 1929.

July Lake Levels.

The United States Lake Survey reports the monthly mean stages of the Great Lakes for the month of July as follows:

Lakes	*Feet above mean sea level*
Superior	602.93
Michigan-Huron	582.33
St. Clair	577.03
Erie	574.12
Ontario	248.36

Lake Superior is 0.21 foot higher than in June (since 1860 the July level has averaged 0.21 foot higher than June); it is 0.08 foot higher than the July stage of a year ago, 0.80 foot above the average stage of July of the last ten years, 0.89 foot below the high stage of July, 1876, and 2.07 feet above the low stage of July, 1926.

Lakes Michigan-Huron are 0.11 foot higher than in June (since 1860 the July level has averaged 0.07 foot higher than June); they are 1.90 feet higher than the July stage of a year ago, 2.33 feet above the average stage of July of the last ten years, 1.25 feet below the high stage of July, 1876, and 3.79 feet above the low stage of July, 1925 and 1926. Based on past
12430 records the monthly mean level for August is likely to be about 582.3 and not less than 582.0.

Lake Erie is 0.15 foot lower than in June (since 1860 the July level has averaged 0.03 foot lower than June); it is 1.45 feet higher than the July stage of a year ago, 1.80 feet above the average stage of July of the last ten years, 0.29 feet below the high stage of July, 1876, and 3.00 feet above the low stage of July, 1925. Based on past records the monthly mean level for August is likely to be about 574.0 and not less than 573.6.

Lake Ontario is 0.10 foot lower than in June (since 1860 the July level has averaged 0.04 foot lower than June); it is 1.63 feet higher than the July stage of a year ago, 2.17 feet above the average stage of July of the last ten years, 0.36 foot below the high stage of July, 1862, and 3.77 feet above the low stage of July, 1895. Based on past records the monthly mean level for August is likely to be about 248.1 and not less than 247.7.

12431 COPY OF DEFENDANTS' EXHIBIT NO. 1453.

U. S. LAKE SURVEY NOTICE TO MARINERS

DETROIT, MICH., SEPTEMBER 4, 1929.

August Lake Levels.

The United States Lake Survey reports the monthly mean stages of the Great Lakes for the month of August as follows:

Lakes	*Feet above mean sea level*
Superior	602.93
Michigan-Huron	582.18
St. Clair	576.79
Erie	573.81
Ontario	248.00

Lake Superior is at the same level as in July (since 1860 the August level has averaged 0.11 foot higher than July); it is 0.08 foot lower than the August stage of a year ago, 0.68 foot above the average stage of August of the last ten years, 1.00 foot below the high stage of August, 1876, and 1.91 feet above the low stage of August, 1926.

Lakes Michigan-Huron are 0.15 foot lower than in

July (since 1860 the August level has averaged 0.05 foot lower than July); they are 1.64 feet higher than the August stage of a year ago; 2.24 feet above the average stage of August of the last ten years, 1.33 feet below the high stage of August, 1876, and 3.74 feet above the low stage of August, 1925. Based on
12432 past records the monthly mean level for September is likely to be about 582.0 and not less than 581.5.

Lake Erie is 0.31 foot lower than in July (since 1860 the August level has averaged 0.18 foot lower than July); it is 1.23 feet higher than the August stage of a year ago, 1.66 feet above the average stage of August of the last ten years, 0.30 foot below the high stage of August, 1876, and 2.73 feet above the low stage of August, 1925. Based on past records the monthly mean level for September is likely to be about 573.6 and not less than 573.3.

Lake Ontario is 0.36 foot lower than in July (since 1860 the August level has averaged 0.30 foot lower than July); it is 1.36 feet higher than the August stage of a year ago, 2.08 feet above the average stage of August of the last ten years, 0.26 foot below the high stage of August, 1862, and 3.65 feet above the low stage of August, 1895 and 1925. Based on past records the monthly mean level for September is likely to be about 247.6 and not less than 247.2.

William R. Matthews, for Defendants:

Direct Examination by Mr. Lynde.

12469 I reside at 2322 Commonwealth Avenue, Chicago. I am engineer of the Bureau of Sewers of the City of Chicago. I have been employed by the City of Chicago since 1903 and for a period of about 26 years. My first employment was in the Board of Local Improvements in the Division of Sidewalk construction. For about a year's time I served as an inspector of sidewalk construction and then for a year as a rodman in the sidewalk department. I was then certified as a junior engineer

into the Sewer Division of the Board of Local Improvements, as the result of a competitive examination. For about a year or a year and a half I was engaged as junior engineer on the construction of sewers, mostly on one single large system of sewers built in the southern part
12470 of Chicago. Later I was assigned to the Intercepting Sewer Bureau, which was a special organization which had been set up to build the intercepting sewers of Chicago which was built as a part of the Drainage Canal and general diversion scheme. During that time I was largely engaged on the Lawrence Avenue intercepting sewer, on the Lake section. There was also some incidental work to connecting up some of the parts of the system that had been completed and were ready for operation. Later, and perhaps about 1908, I was transferred to the Bureau of Sewers of the Department of Public Works and I have been in that Bureau since that time. For the first four or five years I was an assistant engineer and later was made engineer for the Bureau with the title "Assistant Engineer in Charge." I have been engineer for the Bureau perhaps 15 years. My duties and responsibilities include the design, construction and inspection of sewers in the City of Chicago; the examination for approval of changes and additions to the sewer systems made for the City of Chicago.

12471 The Bureau of Sewers examines for approval the plans of all sewers and sewer changes for the entire city. The work includes an inspection of for acceptance all of the sewers built in the City of Chicago; also all investigations of engineering matters pertaining to the maintenance of a large system of sewers in a great city. This has included surveys for floods in various parts of the city; included the preparation of tentative plans for relief systems of sewers and similar work. In the last ten years I have made surveys and prepared tentative plans

for sewers for the larger part of the area of the City of Chicago.

I prepared an estimate of the cost of construction at the present time of a separate system of sanitary sewers
12472 in the City of Chicago and commenced work on this about three months ago.

12480 This estimate, in my opinion, is the probable minimum cost of providing a system of sanitary sewers for the City of Chicago. The present sewer system is a combined system, one system of sewers for the removal of both the sanitary sewage and the storm water. If a separate system be required for Chicago, the present system may be used as a storm system. It would then be necessary to install a sanitary system to serve all the frontage streets of the city. In addition the drainage systems in each building would require the necessary changes to give a separate system to each.

In general, these sanitary sewers would consist of a number of systems leading to and discharging into the intercepting sewers, and treatment plants now being built or planned by the Sanitary District of Chicago, each system serving a drainage district. I am reading from the statement on page 2 in the estimate. This system would
12481 consist of main, of submain, and of branch or service sewers. The drainage districts would vary in size and shape. Some systems would drain perhaps about one square mile and other perhaps twenty. That is, we might have one district that would be perhaps only half a mile from an available interceptor; we would have another area that would be ten or twelve or fifteen miles away from the nearest interceptor. So that we would have small districts and large districts. Some systems would drain perhaps one square mile, and others perhaps twenty.

12482 A typical district might be one five miles long and two

miles wide, and the cost of a system for such an area will be the basis for this estimate.

This typical district would consist of a main sewer running through the middle, with sub-mains at right angles and at every half mile. Service sewers would branch from the sub-mains to serve every frontage street. This plan I believe to be in general an economical arrangement. That is the arrangement that I would recommend if I were called upon as an engineer in a matter of that kind.

It must be kept in mind that the general arrangement would vary much in the different districts. This typical district would be the method that I would adopt in draining the larger areas. Generally speaking, in arriving at my estimate, I have taken an area 5 miles by 2 miles, or 10 square miles, and figured out the cost for the various items that go into the costs that you arrive at, and thus arrive at a square mile unit figure.

I have arrived at a unit cost per square mile for mains,
12483 for sub-mains and for service sewers. It is necessary to provide for a definite flow in order to determine the capacities of the various parts of the system. There will be considerable variation in the unit flows to be provided for in the various districts. For example, in Chicago, in the Loop district the rate of flow out of that district might be ten times the ordinary average rate in areas of other characteristics, but for the purpose of this estimate I have provided for a flow of .02 cubic foot per second per acre. That flow would be equivalent to 240 gallons per day for 5,000,000 people on 200 square miles, which is the approximate area of the City of Chicago.

I cite on page 2 under my estimate three different items in reference to this flow matter.

12484 It is a consideration of those three items among others that led me to use the unit which I adopted. The third

page is a drawing of the typical system that I have mentioned. The upper portion of the drawing shows a district 5 miles long and 2 miles wide with a main through the center and a sub-main branching every half mile. The lower portion is an enlargement of a single sub-main with sewers in the intersecting streets for service, also a statement of grades and quantities. The first blue-print is a typical cross-section of a sewer in tunnel. This particular sewer is a circular sewer lined with concrete. In the lower table are the quantities in such a sewer.

The next sheet gives the unit costs for such sewers in tunnels.

The sheet following is a typical cross-section of a tunnel in which a tile pipe has been laid.

12485 The sub-main sewers must, of necessity, be largely in tunnel. It is not possible, of course, to mine a tunnel that will contain pipes from 8 inches to 27 inches in diameter. It is necessary to build a tunnel of sufficient size to work in.

It is not possible, or at least not economical, to built the sub-mains in open cuts. That is, from the top down. It could be done in some cases, but it would cost more money, because of the depth at which they have to be laid, and surface conditions.

The next blue-print shows unit costs for tile pipe laid in tunnel. The page marked "6" shows, in the upper portion a statement as to the design of the system. The mains are designed for velocities of 3 feet per second; the sub-mains for velocties of 2½ feet per second; and the

12486 service sewers for a velocity of 2 feet per second. Those slopes are fixed to give reasonable self-cleansing velocities in the sewer, and to give minimum cost of construction. These figures are selected on the basis of my experience and judgment in those matters.

The capacities of the pipe depend on the so-called

roughness factor, and it is customary for engineers to have some variation in this factor, although that variation is slight. I used 0.015 and show it to permit these sizes that I have chosen to be checked.

On the balance of the page I show estimates for the main sewer lines.

The next page is an estimate for the sub-main lines; vitrified tile pipe in tunnel.

Sheets 8 to 15, inclusive, are unit costs for the construc-
12487 tion of the service sewers in the various positions in the streets and alleys.

The basis of the figures, in general, is a determination of the quantities, the proper unit prices for them, and the product of them with the quantities of sewers. In selecting a particular figure I am exercising my judgment, based on my experience as to what the proper unit cost for that item is. I have four summaries on pages 16, 17 and 18. I have determined first, in Summary No. 1, on page 16, the total cost of a sanitary system of sewers in Chicago with the service sewers built in the alleys, and including changes in the buildings of Chicago. The estimate for such a system is $426,356,000.

12488 It is not possible, from my knowledge of the sewer situation and the general layout of Chicago, to construct a separate system through the alleys throughout the city. There are many blocks in Chicago that have no alleys. There are many blocks in Chicago in which the alleys are not continuous. There are many jogs in the alleys. The alleys do not run through the entire block, but turn at right angles to meet parallel streets. They could be built in the alleys when we have a continuous alley extending from one end of the sub-district to another. I do think, however, that a proportion of this system could be built in the alleys.

The next summary, "System of sewers in streets, single

system," is an estimate of the cost of building a complete system of sanitary sewers with a single service sewer in
12489 each street, one sewer to serve both sides of the street and the total cost for such a system would be $568,766,000.

From my knowledge of the present sewer system of Chicago it is not possible to add to the existing system a single system throughout the city. Under the system of two sewers, a sanitary system and a storm system, the present system which would then become the storm system lies in the middle of the streets in Chicago, and in most cases would effectively block connections from one side of the street if a single sewer be provided for sanitary connections for the buildings.

It would not be good practice to build a siphon below the existing storm sewer. Page 17 is an estimate for a
12490 system in which there would be two service sewers in each street, one on each side of the street for the buildings on that side. The total cost of such system would be $658,484,000. My final conclusion is a total estimate for what we might call a mixed system. That is, service sewers would be built in the alleys where alleys were available. We would do this to as great a degree as possible, because it is cheaper to build sanitary sewers in the alleys. Where no alleys were available a single system would be built in the streets, and where a conflict of grades occurred between the sanitary system and the present sewer system, it would be necessary to built a system of double service sewers. It is my opinion that approximately one-third of the service sewers could be built in the alleys and about one-half of the city would require a sewer for each side of the street. Such mixed system would cost approximately $566,000,000, and this is what, in my opinion, is the probable minimum cost of a sanitary system for the City of Chicago.

12491 I have included figures for pumping stations, although

I have made no estimates, and as a matter of fact I am not qualified to make estimates for pumping stations, as it is not within my experience; but pumping stations will be required for a separate system.

12492 Of the total summaries which I have stated for costs of these various systems there is a total of $3,500,000 for pumping stations for the entire city.

12493 That is based, as I stated, on a typical district; one pumping station to serve ten square miles with a probable pumping capacity of about 250 cubic feet per second, and I used an arbitrary figure of $175,000 per pumping station. That item is about one-half of one per cent of the total estimate.

Defendants' Exhibit No. 1473 received.

Questions by the Special Master:

The Witness: In this separate sewer system as to

12494 which I have testified I collect the sewage from all buildings in Chicago, every place where sewage is to be found. It is then carried to the interceptors which the Sanitary District of Chicago have built or are building, so that all of it is diverted directly to the treatment plants built or being built by the Sanitary District of Chicago. So a large part of this plan of a separate sewer system I have outlined is to get the sewage to the sewage treatment plants.

Cross Examination by Mr. Jackson.

12565 Q. Referring to Drawing No. 1 of my estimate, Defendant's Exhibit 1473, a typical lay-out of a 10-square mile area. In this typical lay-out, which, by the way, is for a double system in the streets, there would be 32 miles of service sewers per square mile, so there would be 320 miles of service sewers for 10 square miles; and

12566 the total length of main sewer would be 5 lineal miles.

There would be 5 miles in the main sewers, and there would be 10 sub-branches, each 2 miles long, which would be 20 miles; 345 miles altogether. I estimate on an area of 200 square miles in the corporate limits of Chicago. For the sub-mains and mains, there would be a variation,
12567 due to the size and shape of the district. I do not intend to convey the impression that the city of Chicago would be divided up in districts each of ten miles.

In the first place, this is a typical lay-out on one basis, that is, for a double system of sewers in the street, that is, two service sewers. And as I have stated in the estimates, there was one summary of an estimate made for a double system, one estimate made for a single sewer in the street, and one estimate made for a single sewer in the alley. So that in the case of a sewer on two sides the mileage of service sewers would be twice as much as in the case of a single sewer or a sewer in the alley. This drawing is typical of the maximum miles of sewer you
12568 could get in a 10-mile area. I had a single sewer, instead of a double system. There would be only half as many miles of service sewers. It is reduced by half on
12568 the single system. But you do not change the total mileage of mains or sub-mains. They remain the same. For this typical district, the mains would be 5 miles and the sub-mains 20 miles. That is 25 miles, or 2½ miles per square mile.

12570 If you only put one sewer in the street to serve both sides, you only require half the mileage of sewers, obviously. I am using the term of "branch" and "service" in the same way; that is, a sewer which will run through the frontage streets and take the actual connections from the buildings. I have used the term "main" to indicate the trunk line which would run down through the middle of the district, and the term "sub-main" to cover the branch which would be at right angles to it every half

mile, and these sub-mains, which are branches of the mains, would take in turn the service sewers.

12571 Of my 200-mile area to serve, I consider there would be sewered on this double sewer basis one-half, which would require 345 miles, which would require 3,450 miles of sewers altogether.

12572 Then I have 185 miles per 10-square mile area on another scheme—a single sewer system—1,850 miles of sewers on that, or 5,300 miles on the whole thing. The total mileage of all of the sewers of the City of Chicago today is about 3,200 or 3,100 and a fraction. That is about 60%, or a little less than that of this 5,300. 200 square miles

12573 represents the whole area of the Chicago incorporation in round numbers it does. I believe the figures are around 208 or 210. I have forgotten the exact amount. But some of that is water surface. For this computation, we take 200 square miles as the area within the corporation limits of the City of Chicago. It might be somewhat less; it might be a trifle more. There are very considerable areas of Chicago occupied both by railroads and industrial plants. The industrial area requires drainage facilities, in

12574 the same manner in which the residential district does. There would probably be a lesser proportion of street sewer facilities. I woud imagine that the total length of sewers required would probably be less. But there would be a corresponding increase within the limits of the property. In a railroad area it would be necessary to design your major system to include those areas, but not necessary to put in the branches.

You would have to design all these branch sewers for a sanitary system in the area covered by the railroad tracks in many cases.

The point I had in mind is this: Much of this property occupied by railroads eventually goes for other uses; that is the tendency, for the railroads to restore to ordinary

use large tracts of land held within the city limits, for other purposes.

12575 We have certain areas which are occupied, or partially occupied by the railroads, which, in time, would pass to other uses. I do not know whether they are large areas. I have not attempted to sum them up.

There are large districts devoted to industrial purposes 12576 in Chicago, using that term very generally. There are areas in Chicago that are practically not in use for any purpose. I did not estimate or figure how many miles there are within the corporate limits of Chicago that are now devoted to industrial plants or occupied by all of the railroads entering Chicago. I did not have any idea of extending such a system into Chicago's parks only in so 12577 far as it was necessary for the uses in that park. I can't say whether I estimated the number of square miles occupied by parks. It would not require the same as a residential section.

12578 I had the impression, which is, only, an impression, in my mind that there were some approximately ten square miles that were devoted to park purposes.

I roughly summed up in my mind the parks that make up the particular park system, not considering minor playgrounds. We have a limited number of parks in Chicago. There are only five major parks in Chicago, and while I would not attempt to say what area each one covers, they are not, in toto, large.

We have two major parks in Chicago, on the west side— 12579 three, rather.

There is a substantial area in Chicago that is not sewered.

There is approximately 25 square miles in Chicago not now sewered.

But I did not compute the areas occupied by railroads

or by industries and roughly estimate the parks at ten miles.

I did not deduct them from the two hundred miles, I allowed roughly eight or nine miles over two hundred.

I do not now think my assumption of two hundred square miles in the area inside the corporate limits was incorrect.

12580 I say that the area which would require a separate system of sewers might be less than two hundred.

It is not my understanding that the area of Chicago includes any portion of the waters lying outside.

The areas are computed by the city map department from time to time, as additional areas are annexed to the City of Chicago. They have a continuous record from the beginning as to the square miles within the city limits.

I say that it is not my understanding that the waters
12581 of Lake Michigan are part of the City of Chicago, and I assume, but do not know, that no portion of them or other water areas are included within their records.

As far as Calumet Lake is concerned, which now has a considerable area of water, I took that into consideration, that perhaps in the near future much of that water space would disappear, as there is a plan on foot to fill the larger portion of it. I did not consider Lake Michigan. The record of the map department I have taken as being correct.

In designing this sanitary system of sewers, I had to provide for a domestic pumpage of around 1,500 second-feet.

12582 The present combined system, which carries both the sanitary sewage and the storm water of the City of Chicago, has a capacity of somewhere about 13,000 cubic second feet. I did make computations some years ago, but I have forgotten it, but that might be a reasonable statement.

I do not remember the number of sewer outlets. I do not think it would have any such number of major outlets. My recollection is—but it is hazy—that it is something under 200, or perhaps nearer to 150.

My proposed plan here would not necessarily have twenty outlets.

It might have many more. In the first place, it will be remembered that this plan is to build a system of sewers that would be a continuation of the system of interceptors which the Sanitary District has built or are building. Now, there are some areas that are so close to that inter-
12583 ceptor that you would not require any main sewer, you could build what would then be really a submain for a short distance. There are other districts in Chicago where a district five miles long would not measure the length of the main.

We built sewers for Chicago in 1928 and 1929.

How many miles we built, I don't remember.

A total of $59,420,180 for a sewer system to provide for the sanitary sewage and all of the storm water overflows for the entire City of Chicago is the figure as carried in the report of the Chicago Department of Public Works.
12584 In addition, Mr. Matthews, your report states that this combined system at the end of 1927 had 157,892 catch basins.

I believe the report to be approximately correct.

I am not necessarily accepting the correctness of the statement in the report. But I say it should be approximately correct.

On your proposed sanitary system you would have no catch basins.

But limiting that to a discussion as to the street sewers, you would require basins in buildings, but aside from that there would be no basins in the public highway,

keeping in mind that a basin as you are using the term is a storm inlet.

12585 In my set-up I think over 90% would be 8-inch. In this present combined system, there is no sewer less than 12 inches. I would not attempt to state the proportions of sizes.

It says in my report here, on page 290, for 1927, that 799.99 miles in place on January 1st, 1928, were brick and concrete sewers. They would be 24 inches or larger.

Q. On that page you show your overload that you just add to your other computations of cost?

A. What page is that?

12586 In all these estimates I have provided a percentage of the cost of construction for overhead. Insurance is 2½%, contingencies 5%. The next item, "Overhead and Equipment," is 12½%, profit you have got at 10%, and then engineering and the inspection 5%. That makes a total of 36%.

All of those items which you have there included and added to your figures otherwise every one of them, except engineering and inspection is included in contract prices.

12587 I have added them all here to my estimate of cost, to arrive at the contract price.

Turning to page 10 of my exhibit my estimate of cost for an 8-inch sewer in a 12-foot cut and on an unpaved street is $4.14 a foot. That is the net cost for an 8-inch sewer in place in an unpaved street.

I have to do with the estimates of the Board of Improvements in Chicago.

I am not familiar at the moment with the particular price for the particular size that you mention. We do very little 8-inch pipe work in the City of Chicago, but I would think that $1.50 a foot would be about the correct amount.

12588 I have no recollection of the city taking any bids for

any 8-inch sewer at $1.18 per foot on a 12 foot cut either in 1927 or any other recent year, because the City of Chicago has not built any, but I would not want to answer one way or the other. There is no portion of this sewer work in an open cut for a 12-inch sewer. A 12-inch sewer would cost more.

The board has been estimating for 12-inch sewers in an open cut on an unpaved street in Chicago from $1.85 to about $2.50, and perhaps the average price is around $2 or a little more.

12589 In the first place, if you will read the estimates, you will find that that $4.14 foi an 8-in. sewer, on an unpaved street, includes man-holes, which is an item of considerable size.

We can build man-holes in Chicago for ordinary cuts, say an 8-foot cut, for about $90. They may sometimes run a little less and sometimes a little more.

I am giving you what I think is a fair price when I stated $85 to $90. Sometimes $100. In this particular case these man-holes are about 12 feet deep and that calls for an additional height of about four feet. These man-holes would run roughly $7 or $8 a foot, over and above what you might take as the average depth. If they cost $100, you would have a man-hole every hundred feet, but as a matter of fact in this particular case you could not build them for $100.

12590 The man-hole spacing on sewers, be they combined or otherwise, depends largely on the diameter of the sewers; that is, for the small pipes that serve the buildings, tile pipe at least 12, 15, 18 and 24 inches, vary in Chicago from 4 to the block to 5 to the block, and I am referring to a 660-foot block. So, they vary from 165 feet to about 125 feet. On page 6, I give my base estimates of cost for a 9-foot sewer at $85 per foot. I really do not know what

they have done in Detroit or whether Detroit built 9-foot sewers in tunnel for $34.75 per foot.

12591 I have only considered what they have done in Chicago. We have not within the last two years built 9-foot sewers in clay in the City of Chicago. I estimate here for an 8-foot sewer a cost of $74 a foot. I do not know that the current cost of these 8-foot sewers, built in tunnel in clay, in Detroit, has been $32.10 a foot.

12592 On the Cicero Avenue system we had some tunnel work in that job. The size has escaped me. At that time I was aware of the costs of that, and they conformed in a general way to the curve shown by these prices. I really do not remember the size, but I think it was about 8-foot tunnel. It might have been a little more or a little less.

I haven't built any separate sanitary sewer systems. Referring to page 8 of my exhibit, I provide for replacing 15 feet in width of paving in the alleys. Where an alley is paved, this estimate is for removing the existing

12593 pavement and replacing it after the job is completed. It is not the custom to build sewers in alleys in Chicago. Alleys present a different problem. It is cheaper to build sewers in paved alleys by removing the pavement than it would be to maintain the pavement by trenching. I have taken the cheaper method. We do not build sewers in paved alleys in Chicago. My conclusion that it is cheaper and more practicable to remove the whole pavement and lay new pavement is based upon actual experience which I have personally had.

12594 As I stated, I have never had occasion to build a sewer in a paved alley, but, none the less, experience would guide you in building a sewer in a paved alley as to the better and cheaper way by which it could be done.

On page 8 of your exhibit, it costs $7.50 per foot to replace the pavement torn up in an alley per lineal foot of sewer out of a total cost of $11.58. That is the large item.

And to that restoring of the pavement you then add your 36 per cent overhead item.

12595 On page 9, I state that the item for restoring the pavement over the sewer in a paved street is $2.50 per lineal foot of sewer, restoring pavement one-half square yard at $5.00.

Re-direct examination by Mr. Lynde.

12596 The ordinary sewer construction which affords the prices that have been referred to takes place under conditions where the sewers are the first improvement on the land, with this limitation, that sometimes in Chicago we may have sidewalks, but they have no effect on the sewer construction. The problem that I have been estimating here is the building of a sewer construction in a city where all of the other improvements and property exist as it does today in the City of Chicago. You face the problem of paved streets, sidewalks in place, grass plots improved, and buildings close to the line of your sewer.

12597 Page 8 is the cost estimate for laying sewers and very little of that would be affected by these improvements. The alleys are paved but there are seldom any utilities in the alley so we would not have to contend with utilities. The buildings are not usually close and are limited to such structures that are of no great importance. The first two items, breaking pavement per foot of sewer and removing broken pavement, $1.10; occasional timber left in, which is an item of about 25c. per foot; and the restoration of the pavement, $7.50. Those items out of $11.58 for labor and material are because of the paving in the alley.

If you leave the paving in you are first obliged to cut the trench through a pavement only 15 feet wide, a trench that would be at least 2½ feet wide. You would then be

12598 obliged to completely sheet the ditch so as to maintain what was left of the pavement in place. It would be practically impossible to excavate only by hand methods. The

cost of the sheeting of the ditch and the cost of replacing machine work, which I have provided for, would be more than plus the cost of cutting the trench and replacing all portion of the pavement which would be destroyed, would be considerably more than it would be to destroy the pavement and use machinery and repave behind you. I made estimates for both of them and adopted the cheaper method. The present mileage of sewers in Chicago is somewhere around 3,100 or 3,200. I calculated that the total mileage in my estimate was 5,200. The difference was due to this double system that I use in a certain portion of the area.

12599 For instance, in an industry we might have two types; perhaps one that is located in a single building. We might have another larger one that would have a group of buildings. It would be necessary in the case of a group to build some sort of a main with branches leading to each building and leading into and through each building to take up the fixtures. For a single building it would be necessary, of course, to carry a branch from the nearest public line to the building and through it.

The prices that I have arrived at were generally arrived at on the basis of the work being let by contract, except the items for plans and engineering and inspection. That would be an item which the City of Chicago would bear before making contracts and after the contracts were let.

12600 These overhead percentages are those which are proper in letting contracts of this kind.

I think they are properly entered into the estimate as providing a proper contractor's price.

The bids and construction that were referred to by Mr. Jackson in the last two years, the 8-foot sewer, etc., would be a sewer out in the open ground in which there would be only three items to consider; the use of a machine to trench, the placing of the pipe, the back-filling by machine.

Those three items are the only items that enter into the ordinary sewer construction.

I have an item for cost of connection with houses, between the sewers and the houses.

I figured an ordinary small structure, such, for instance, as a single dwelling house, a standard three-apartment
12601 building, a building that might be, we will say, 24 feet wide and 40 feet in depth, standing on a lot perhaps 32 to 35 feet in width and 125 feet deep to the alley. That item would increase with the size of the building.

Recross examination.

In an industrial area where the streets do not go through, the city does not build sewers onto the private property.

12602 They build along where there is an open public street.

And then the industry, if it had occasion to do so, would construct sewers from its buildings or plants to the public sewer.

In determining my estimate I did not give any consideration, with reference to sewers built in tunnel, to contracts which had been let by the Sanitary District of Chicago.

12495 **Henry A. Berger**, for Defendants:

A Trustee of Sanitary District.

Direct Examination by Mr. Beebe.

I am attorney at law.

Since 1911 I was Assistant Corporation Counsel of the City of Chicago; Assistant State's Attorney of Cook County; Attorney for the Board of County Commissioners of Cook County. Am now a Trustee of the Sanitary District of Chicago.

12496 I was elected for a six-year term in November last and held the office by virtue of an election by the Board during the preceding four and a half months.

Am Chairman of the Judiciary Committee and the Legislative Committee. Have had experience prior to this year in dealing with legislative matters for the City of Chicago and the County of Cook.

There are nine on the Board of Trustees of the Sanitary District. The more important officers and committies are Finance, Judiciary, Legislative and Engineering.

12497 Howard W. Elmore is President of the Board, and elected in January of this year. He was elected trustee for the first time in November, 1928. The chairman of the Finance Committee is Ross Woodhull. He was first elected trustee in November, 1928. The president is in the real estate business.

I recall the opinion of the Supreme Court of January 14, 1929.

12498 No bond issue has been submitted to a referendum vote by the Sanitary District. The first requirement made by the Illinois Legislature was in 1925 to be effective December 31, 1927. In the session of 1927 it was extended by amendment to become effective December 31, 1928. I was appointed chairman of the Legislative Committee of the Sanitary District in January of this year.

12499 Immediately following the decision referred to by the Supreme Court the District, in conjunction with the Law Department, discussed the introduction of a so-called bond bill. A bill was prepared which was unlimited as to amount but limited to the specific purpose of carrying out any decree of the United States Supreme Court or any order of a department of government or any act of Congress. Immediately upon its introduction at Springfield in the Legislature much

opposition developed, both on the part of the down-state valley claimants; that is, claimants who had claims against the Sanitary District by reason of damage that they claimed accrued to them because of the sanitary waters, and by various business and civic organizations in Chicago. Extensive conferences were had with civic organizations and meetings were called of those organizations. The Association of Commerce was called to come in conferences with officials of the Association. The revenue committee of the Senate and the executive committee of the Senate each had separate hearings on the bill, and then later a hearing was had before the
12500 Committee of the Whole. Opposition even on the part of those that believed that the Sanitary District ought to have some relief developed too as to the unlimited bonding power provided for in the bill. An amendment was offered by Senator Kessenger which the Senate adopted, limiting the expenditure to $15,000,000 annually, but no limitation as to the aggregate amount. That did not satisfy the oppositionists, and, after much discussion in the Senate, we understood that the Governor would not approve the bill in that form, and we understood also that Mr. Harris Keeler, who represented the civic organizations, was speaking for the Governor in connection with the maximum amount to be incorporated into the bill. As a result of these various discussions and that opposition, a conference was had between Mr. Keeler and Mr. Beebe and Mr. E. J. Kelly, the Chief Engineer, and myself, at which specific items contemplated under the permit of the Secretary of War of March, 1925, were discussed and, finally, pared down to approximately $47,0000,000. Then Mr. Keeler arbitrarily lopped off another $7,000,000 and made the figure $40,000,000 and said that he would recommend to the Governor that the civic organizations would approve that amount. An amend-

ment then again was offered in the Senate and the
12501 amount was limited to $40,000,000, with no limit as to time. There was considerable discussion as to a limitation as to time. At that time the specific projects were incorporated into the bill so that the bill instead of providing that the expenditure was to comply with the Supreme Court decree or an order of a governmental department or an act of Congress, there was substituted for that language the present language, specifically enumerating the projects for which this expenditure was to be made. Then the bill passed in that form. We met considerable opposition in the House. The Speaker of the House was openly against the bill, insisting that no bond bill should pass without a referendum.

12502 The bill filed in the House, of course, was the subject of so much discussion, and then we understood that the Governor was dissatisfied with the maximum amount of $40,000,000, so we arranged a conference with the Governor and met him in his office. Mr. Beebe, Mr. Elmore, Mr. Woodhull, and Mr. Kelly and myself, and the minority leader of the House, Mr. Igoe, were present. The Governor then expressed himself to the effect that in the fall of 1928 the Sanitary District had authorized the issuance of $27,000,000 in bonds, knowing that the referendum provision would attach the following December 31, and that the limitation as to amount had been placed there by the District itself, and that therefore he thought it would be inadvisable to ask now for an amount over $27,000,000.

We pointed out to him that at the time the District authorized that $27,000,000 bond issue in the fall of 1928, it was intended to go to the legislature immediately after the first of January and ask for relief from the referendum provision in the Laws of 1925 and 1927, and that that amount only contemplated the construction work for

the balance of the year 1928 and 1929; whereas the bill pending in the legislature contemplated at least the balance of 1928—that is, the outstanding contractual obligations of 1928—and the years 1929 and 1930. That arrangement, however, was of no avail, and the Governor seemed to indicate that the bill in its present form would not meet his approval, and that in view of the fact that we
12503 had issued bonds only to the extent of $27,000,000 which a lawsuit and injunction bill which had been filed in our court had tied up, because of some defect in the bond ordinance, and prevented its sale, he thought that if we were allowed the $27,000,000, so that we could place ourselves in the same position that we would have been in had the lawsuit not been brought, that that was as much as we ought to ask.

We left the Governor's office and, after careful consideration of the matter we concluded that it was better to get $27,000,000 than nothing, and we consented—that was the only amendment that we consented to in connection with the entire legislation—we consented to the reduction to $27,000,000.

On the second reading in the House an amendment was offered to attach a referendum clause, and on that amendment we won by one vote. In the Senate the bill passed with a margin of one vote. In the House the bill passed in its final form with a margin of seven votes.

Following the passage of the bill in both branches of the legislature, opposition also developed before the Gov-
12504 ernor, as still one or two of the civic organizations made objections and attempted to secure the veto of the bill.

We again asked the civic organizations and the improvements clubs and valley associations and others who were interested, finally became interested in the passage of the bill, to communicate their desires to the Gov-

ernor, and the Governor permitted the bill to become a law without his signature, and at the time issued a statement stating his reasons.

Legislation becomes effective in Illinois on July 1 and this legislation became effective July 1, 1929.

12505 Immediately after the first of July the law department was directed to prepare the necessary bond ordinances—my recollection is there were nine of them—and those bond ordinances were passed in July, the latter part of July, which was the first meeting held—it was a meeting, I think, on the second or third of July, but that was too soon for these ordinances, but it was the first meeting held at which these ordinances could be submitted. After the passage of the ordinances we immediately authorized the clerk to advertise for the printing of the bonds.

The amount being in excess of $500, the statute prohibited the Board from contracting for the printing except upon competitive bids, and as soon as the subsequent meeting in August was held, the printing contract was entered into and the bonds offered for sale.

In the latter part of August, the last meeting in August, the bonds were—they had been advertised for sale and the bids were received. The bidding price, the highest bidding price, was approximately 92½, which was the lowest bid ever received, certainly by the Sanitary Dis-

12506 trict, for municipal bonds, and to my knowledge in the last twenty years, at any rate, for any municipality in Cook County. The bids were rejected.

We re-advertised the bonds and, at a meeting held September 12 or 13, I am not sure as to the date, new bids were received, and the maximum bid then was 93.89. We had a conference of trustees, the engineering department, the law department, with reference to the advisability of accepting that bid, and only in view of the present situation and the present litigation and the present needs did

we, as a matter of policy, finally conclude to accept that bid, although that bid is the lowest ever accepted by the Sanitary District.

Those bonds had a very ready sale, because they were very attractive to large investors, and I am told that the bank immediately, even before delivery, had contracted for the sale of all of them, $10,600,000 bid.

The physical bonds were delivered to the bank Thursday and Friday of last week, and the credit to our treasury was extended, as I understand it, on Friday or Saturday of last week.

12508 I refer to Defendants' Exhibit 1474 for identification.

Ever since I came upon the Board in June, 1928, the acquisition of the site for the Southwest Side Treatment Plant has been discussed. I recall that there were some definite discussions concerning it at the time the North Side Treatment Plant was opened, as to what the next plant would be that we would have to give our attention to.

Following the decision of the Supreme Court in this matter I had several conferences personally with Mr. Beebe and with the engineers, with reference to the location of this site. We had some little difficulties, however, in condemning. Under the statutes of Illinois it is a condition precedent to make a bona fide offer to the owners as to the purchase price.

12509 We were without funds. We could not make a bona fide offer without the moneys available and on hand. We had in mind in this bond bill that I have mentioned to provide funds for the acquisition of this site, and when the bill took its final form, one of the specific objects for which the moneys were to be expended was the acquisition of the Southwest Side site, and it was specifically mentioned in the bond bill and in the legislation, and until we had the funds on hand, as I say, we could not

make a bona fide offer, because if the offer were accepted we would be in no position to carry out the offer, and until such offer was made, no condemnation proceedings could be commenced.

The first moneys available for the purpose of acquiring this site came to us last Friday or Saturday, as I have stated.

I think it was at the meeting before last, a week ago Thursday, and last Thursday, these particular blueprints (Defendants' Exhibit 1474) were brought into the President's office by Mr. Pearse and Mr. Kelly. The
12510 trustees were present; Mr. Beebe was present, and the matter of immediately acquiring this site was discussed.

A week ago last Thursday, as a result of the discussion, the engineering department was asked, after they had explained the general situation, the additional cost that there would be per mile in the way of constructing intercepting sewers if the site were further west; the accessibility of this site and its adjacency to the so-called West Side treatment plant; and, notwithstanding the fact that it might be necessary to condemn the subdivided property at an increased cost to the District, we asked the Engineering Department to recommend the acquisition of either the site commencing with Cicero Avenue or the one immediately adjoining it, or half a mile from it, at 48th Avenue. Cicero Avenue is on the right-hand side of this blueprint, and, as I say, this portion along the city limits at Cicero Avenue is subdivided and sold to many individual owners, as I understand it. Either the acquisiton of that or the immediately adjoining piece of property, a part of which is owned by the Alton Railroad, should be recommended. They said that they would come in with a definite recommendation as to one or the other site.

12511 It seems that the adjoining piece, if acquired, would

necessitate a complete change in the physical layout of the buildings, whereas at the first site, the more costly site, an easier construction program could be carried out, and would leave room for future development. If we went further west, as was discussed at the time, a site being available four or five miles west, it would necessitate an additional expenditure of one and a half million dollars per mile for the construction of the intercepting sewer.

On last Thursday at the meeting I know that I personally asked the Engineering Department, Mr. Pearse, if they were ready to recommend the acquisition of one of these sites, and he said he thought they were ready, and would.

Now then the moneys are in the hands of our treasurer, and only since last Friday or Saturday, we can, at the next meeting, if we adopt the recommendation of the engineer—and I think personally that that will be done—we can at the next meeting pass the necessary ordinances for the acquisition of this site, make our bona fide offer; if they accept it, we can close, and if they do not, we can institute condemnation proceedings.

12512 I discussed the exercise of the power under the 1927 law, with reference to the regulation and control of industrial wastes and the right to contract with industries in connection therewith, with Mr. Beebe early this spring, and, because of the opposition to our bond bill in the legislature, and for the additional reason that if we then undertook the exercise of that power, the Stockyards interests and industrial interests would immediately go to Springfield for a modification or repeal of the present law, it would be advisable to wait until the legislature adjourned, and serve two purposes—prevent further opposition to our bond bill and prevent also the Stockyards and industrial interests from attempting a modification

or repeal of that power. However, as a result of that talk with Mr. Beebe, attorneys were assigned to a study of the subject, and the preparation of ordinances, and immediately following the adjournment of the legislature those ordinances were taken up, and they are now under discussion.

12513 One ordinance was drafted to which there was a great deal of opposition on the part of industries and the Stockyards, claiming it was too drastic; that it would strangle industry; drive it out of Chicago; and a modified ordinance was prepared; and we are now considering the question of further modifying that ordinance. It is a live subject right now.

Cross-Examination by Mr. Jackson.

We have authority under the law to submit a bond issue to the people at all times. We never did submit a bond issue to the people.

There was a good deal of opposition at Springfield to giving our board unlimited power to issue bonds which was about the time there were many charges with reference to the padding of our pay-rolls; and when we had just reduced our pay-rolls from substantially 5,000 to 1,300.

12515 It was, also, when it had been brought out that there was a large part of the legislature in our employ.

At or about that time or just afterward there was an investigation by the grand jury of alleged misuse and misappropriation of the funds of the Sanitary District by some official or officials.

12516 With reference to this area which we had had under
12517 consideration for the Southwest Side site I understand it has been subdivided, and that to some extent individual lots have been sold. It is not acreage. I have never seen the site.

12518 My information is based entirely on the recommendation of the engineering department.

I have no personal knowledge whatever in regard to the matter.

Referring to Defendants' Exhibit 1474, that part of the area between Cicero Avenue and Laramie Avenue shown on that exhibit as inside of what is indicated as the proposed property lines of the Sanitary District of Chicago, is now subdivided running up to the Canal. I am told that the subdivision runs right up to the Canal. I do not know.

As far as I know, there are no sewers and buildings on that.

12519 This area that is proposed to be taken, in acreage, is between 500 and 600 acres.

I know that in conection with that plant at least for a year the discussions have run along the line of 500 acres, the North Side plant being slightly in excess of 200 acres. I think the West Side plant is 500 acres. The intention here was to provide for 1,200,000 population. The com-
12520 mercial feature of the sludge has never been discussed with me or in my presence.

How many acres required in the event that we do not have sludge beds, to manufacture our sludge for commercial purposes I could not answer.

12521 I had heard discussions concerning that site and its acquisition, this particular site.

12522 I know it was not recommended since I have been on the Board. I do recall that in October, 1928, immediately following the opening of the North Side plant, there was specific reference made to this plant in the discussions.

Redirect Examination by Mr. Beebe.

Prior to the decision of the Supreme Court on January 14, 1929, there was not considered to be any emergency for acquiring the Southwest Side plant.

At the September, 1929 Hearings on Re-reference, complainants concluded their testimony and evidence as follows:

The following is an excerpt from Complainants' Exhibit 274, being a copy of the contract between the War Department and Alvord, Burdick & Howson, pursuant to which the report in evidence as Master's Exhibit B was made:

> "Determination of a pollution standard for the Chicago Drainage Canal for each of the following average flows therein: 2,000, 4,167, 6,000, 7,500, 8,500, and 10,000 cubic feet per second; this standard to be the lowest that will prevent the occurrence of nuisance in the Des Plaines and Illinois Rivers and will permit a thriving fish life therein.
>
> "Determination of the extent to which purification measures must be taken by the Sanitary District of Chicago for each of the flows specified in Section 2a of this agreement in order that the pollution standard be maintained and unimpaired."

12449 **General Charles E. Keller:**

Direct Examination by Mr. Jackson.

Reside at Evanston, Illinois. Graduate of the United States Military Academy 1890; served in the Corps of Engineers between the grades of 2nd Lieutenant and Colonel, serving largely on rivers and harbors, including two years as resident member of Board of Engineers for Rivers and Harbors; member of Special Board of Engineers for a Waterway from Lockport, Illinois, to the mouth of the Illinois River, reported in House Document 762, 63rd Congress, 2nd Session; now retired, now assistant vice-president in charge of engineering of the Byllesby Engineering & Management Corporation, Chicago.

12450 For about four and a half years I, as the District Engineer officer, had charge of all harbors on the east side of Lake Michigan. During that same time for a few months temporarily I had charge of those of the harbors on the west side of Lake Michigan that are included in what is known as the Milwaukee district, including roughly those from Sheboygan north on the west side of the Lake. I also had charge for a period of approximately four years of the minor harbors on Lake Huron, and at that time, while it is not directly responsive to your question, I was in charge, approximately four years, of the United States Lake Survey, which had under its cognizance the surveying of all harbors on all the Great Lakes and of connecting channels (1906-1910).

12451 The Lake Survey, during the season of navigation, every month published a brief bulletin calling to the attention of navigators any changes in the conditions of navigation that were regarded as being of sufficient importance to publish to the navigation community in that fashion. Those publications included the mention not only of obstructions and difficulties theretofore unknown, but also of improvements in navigation that should be drawn to the attention of navigators and vessel masters.

In the course of such duties, I did not have occasion to advise of the existence of any difficulties to navigation at any points on the lakes, by reason of sewage pollution.

During this tour of duty that I have described on the lakes, both in charge of the United States Lake Survey

12452 and in charge of these various harbors, I did not receive complaints from navigators as to difficulties occasioned by sewage pollution.

Since I last testified I have continued to be associated with the Byllesby Engineering firm of Chicago.

I was retained in May of this year by the River and Harbor Committee of the Chamber of Commerce of

Cleveland to make an investigation of the Cuyahoga River for the purpose of recommending a plan for the improvement of navigation of the Cuyahoga River, and I have, since May, been engaged intermittently—not continuously—in that investigation.

I have been and am familiar with the larger harbors on the lower Great Lakes. I have been in a great many of them and I am acquainted with all of them, or I was acquainted with all of them as a result of my connection with the United States Lake Survey.

12453 Have resided in Chicago about five and a half years. As far back as 1894 I first became familiar with Chicago harbor and waterways. At intervals in a general way I have been familiar with them since.

I was a member of a special board created by an Act of Congress of June 25, 1910.

I think that is the Board, which had as one of its duties the investigation of the contemplated channel connecting the Chicago River with the Mississippi River.

In the course of my experience, or from that experi-
12454 ence, I can state whether the extent of commerce is determined by the absence of pollution or the absence of discharge of liquid sewage from the sewers or streets of cities surrounding the ports and harbors on the lakes.

I can give my opinion on the subject, based not only on that investigation but on my service in connection with shipping and navigation, extending over 30 years. My opinion is that the presence or absence of pollution has nothing whatever to do with commerce or the extent of commerce.

In a general way I am familiar with the program that has been proposed for treating the domestic sewage and trade wastes at Chicago and as to whether it is contemplated to treat all of those wastes or a part of them, or
12455 how and merely as one who is acquainted with the sub-

ject as any moderately intelligent man might be, I am under the impression that the proposal is to treat all the wastes, including the domestic sewage and trade wastes.

In my experience, in planning river and harbor improvements, the presence or absence of the discharge of liquid sewage from the sewers of the city never was a factor which affected the planning or carrying out of a river or harbor improvement.

No flow whatever would be necessary, in my opinion, at Lockport, to maintain navigation of the Chicago River in the event that all diversions for the purpose of taking care of the sewage of the Sanitary District of Chicago were discontinued.

The termination of all flow at Lockport would increase the navigable depths in the Chicago Drainage Canal and the Chicago River.

12456 The cessation of all flow at Lockport would diminish the current in the Chicago River and Drainage Canal, except possibly at extreme floods when the flow would be reversed.

The diminution of that current would be favorable to navigation.

Cross-Examination by Mr. Adcock.

I have no objection to saying again that I was a commissioned officer for 33 years, which was prior to Oc-

12538 tober, 1923, when my application for retirement went into effect.

I am not a vice-president of the Byllesby Company; I am assistant to the vice-president, in charge of engineering.

During all of that period I was upon river and harbor work, with the exception of the first three years, which I spent at the Engineering Post-Graduate School, which at

that time was on Long Island, now here at Fort Humphrey.

A good part of that time I was stationed in and about the Great Lakes, and I was also a member of the Board of Engineers for Rivers and Harbors, of the Engineer Corps, for nearly three years; most of the time as resident member here in Washington.

Part of the duty of the Engineer Corps and members of the Engineer Corps is to administer navigable waters
12539 of the United States and to make recommendations with reference to the improvement of navigation, as directed by Congress or as authorized by law.

I am not aware that I have ever made one recommendation that was not asked for by Congress.

It would be exceptional to find a voluntary suggestion of that sort. If it were made, it would not get past the Chief of Engineers.

In looking after navigable waters in the way I did, or in the way the Engineer Corps does, it is the purpose to obtain reasonably free, easy and unobstructed conditions for navigation.

Some of the appliances or regulations with reference, say, to the Great Lakes, that tend to produce free, easy and unobstructed conditions for navigation are characterized by breakwaters that afford shelter to a harbor entrance, piers, which usually are placed along in the mouths of the rivers, in which most of the harbors are situated, and carry the rivers to deep water by revetment
12540 of banks, by adequate bulkheads or similar structures, and by the necessary dredging which sometimes includes rectification or straightening of unduly crooked channels.

The Corps of Engineers has no jurisdiction whatever over aids to navigation, which include lighthouses and buoys. Those are under the jurisdiction of the Light-

house Bureau. The object is to mark channels or to mark danger points.

Harbor lights are not under the jurisdiction of the Corps of Engineers, but they are put in by the Government.

I was lighthouse engineer for five years, and my territory included Lake Huron, Lake Superior, the St. Marys River and the Straits of Mackinac as far west as Sheboygan, Michigan, and it was part of my function to build or to supervise—plan and construct fixed aids to navigation. I had nothing whatever to do with buoys. Those were under the jurisdiction at that time of the Inspectors of Lighthouses, who were naval officers assigned to that duty.

12541 Foghorn signals are part of the equipment of light stations. Whistles are the same thing. Harbors of refuge come in the general class of harbor or ports, on the Great Lakes. I know of only one, at Harbor Beach, on the east side of the State of Michigan.

These appliances tend to promote safety and ease of navigation, and prevent loss of life and property. They are a convenience to the navigator, and to the passenger. They make him feel more secure.

12542 He probably would be more inclined to travel on boats where there were such safety devices provided on the Lakes. I think the commerce is promoted, increased to some degree by that which is true also of freight traffic. In spite of all those devices, a good old-fashioned mariner might be able to sail the Great Lakes with reasonable safety, but not nearly so conveniently. But I think he could get around all right. There might be some loss of life, some destruction of property and so forth, as the result. I have stated that sewage or other waste pollution of harbors or streams or navigable waters has no effect of any kind upon commerce on such

waters. I think the statement is correct. If I were a
12543 workman on a boat navigating these waters, or waters of the United States, and handling ropes and doing other work which would bring me in contact with the water in which the boat plies I would not rather do such work in waters which were polluted with sewage or otherwise, to the extent that there was no, or very little, oxygen content in the water, ebullition of gases, odors and obnoxious conditions due to sewage pollution; but I would rather do such work in waters free from such conditions. Naturally I would rather do it in water that was free of pollution and objectionable conditions.

If pollution were general, it is probable that it might have some small effect upon those who go to sea in ships. But I do not understand that that is the case here.

I am familiar with conditions at Newtown Creek, New York, and the Gowanus Canal in a general way. I have been there in years gone by. There used to be very seri-
12544 ous oil pollution there. I think it has been reduced and measures have been taken to eliminate that situation. I am not familiar with the death rate due to typhoid fever among sailors on the Great Lakes, or the case rate of typhoid fever. In my 35 years experience, more or less, upon the Great Lakes, it is not within my knowledge that governmental agencies have put into force regulations relating to the taking of water for lake shipping, and other regulations to protect the health and safety in commerce and navigation. I do not know about regulations with reference to taking water for drinking purposes upon boats. That may be a regulation of the Public Health Service. If it exists, it is something that
12545 has happened since I was directly connected with navigation. If such regulations have been made, they would promote the bringing of navigation to a point of reason-

ably easy, free and unobstructed conditions. I am familiar with regulations with reference to the use of water upon interstate trains merely in a general way. I understand the public health service does make an examination of the quality of the water that is used, and that it seeks to prevent the use of improper water supplies. That is for the convenience of the traveler and the trainman as well, and it is for the safety of the traveler.

In fact, the railroads are not permitted to take water upon interstate trains that does not have a certain standard of purity. It is not my opinion that navigation and commerce upon the Great Lakes, or otherwise, is dependent solely upon the depth and width of the fluid, and
12546 the boat and the condition of the velocity of the fluid. I think it also depends upon the availability or otherwise of profitable cargo. But, other than that added factor, I think there is nothing that covers, to any appreciable extent, the amount of traffic carried on the Great Lakes. I do not believe that any conceivable degree of pollution of the Great Lakes themselves would affect it. I do not think that pollution of a harbor has very much to do with it. It would have nothing at all to do with it. My answer was an expression of my opinion. I know of no case within my own knowledge in which pollution or abscence of pollution in a harbor or port on the Great Lakes or anywhere else has affected navigation or traffic by water.

I have a vague general knowledge of what the controversy with reference to the Passaic Valley sewage
12547 being discharged into New York Bay was about, but I had no official connection with it. I was Assistant to the Chief of Engineers for a few years, and some of these questions may have come up at that time.

12548 If the United States intervened in that controversy

on behalf of navigation, I think the intervention was not justified.

I venture to disagree with the Supreme Court on that subject, merely because of my general contact with the subject itself.

Q. Supposing all the Great Lakes, including their connecting waters, should become so polluted with sewage and other waste that they would become odorous and covered with sewage particles and waste settling therein, would that affect commerce on the Great Lakes, I do not think it would affect the volume of commerce.

I think it would go on just the same as before. Whenever there is a cargo to be moved, it would be moved. The rule, as I understand it, is that a vessel will go wherever it can get a cargo or deliver a cargo.

12549 I do not think that the passenger traffic on the Great Lakes is a very large factor in the situation, and I am not thinking in terms of passenger traffic.

The only traffic on the Great Lakes that is of any great importance is freight.

The large passenger-carrying boats that travel from one end of the system of the Great Lakes to the other might just as well be eliminated entirely, as far as their business importance is concerned.

I am excluding yachts from business considerations, and all uses of the water for recreational purposes, by way of boats—I would eliminate those—as those were excluded in my answer, yes.

12550 I did not receive any compensation in this case. This time I was engaged a matter of two weeks ago or approximately that length of time. Negotiations looking toward my appearance were begun, a matter of two months ago.

There is a tendency, as shown by my experience and the events of the last few years, to improve the health

and safety and sanitary conditions affecting travelers and workmen upon interstate carriers.

Assuming that there is navigation to and from the Chicago River through the Drainage Canal and through the Illinois River, I doubt that the cessation of all flow or discharge at Lockport from the Drainage Canal would destroy that navigation on the Chicago River, particularly if navigation turns out to be commercially impor-
12551 tant, as I think it will. It would interfere with the navigation during periods of low discharge on the Des Plaines and Kankakee Rivers.

Speaking of the navigation that comes into the Chicago River and that also passes through the Illinois River, the cessation of diversion through the Drainage Canal into the Illinois River would not destroy that navigation. It would impair it.

There is a certain amount of run-off from the drainage basin of the Des Plaines River. Whenever that was sufficient to maintain navigation you could continue navigation.

12552 There is a lock, however, at Lockport from the Drainage Canal into the upper basin of the Illinois-Michigan Canal, which would have to have a little water to lock through there. That would not amount to anything.

These bulletins of the Lake Survey, published every month, called attention merely to changes in conditions of navigation, either as obstructions or as betterments.

The condition of water in the harbor of a great city, due to sewage or waste pollution of that city, would be a condition which would have existed for a long time prior to the issuance of any particular monthly bulletin. Sewage would not be discharged in there in a minute.

12553 It would have existed for perhaps years.

Q. So at the time any particular bulletin was issued, the conditions you have stated as to the obstructions or

betterments that would appear in these bulletins, you would not have felt called upon to call attention to the condition of water in any harbor, even if it were at that time grossly polluted and thereby an impediment to navigation, would you?

A. We would not have felt called upon to draw attention to it in any event, because in those days—I am going back a considerable length of time—the only things that we paid any attention to or accumulated any information about were these changes in navigation of which I spoke this morning.

There would be no changes because of pollution.

I was not directed by Congress to take any interest with reference to that, except so far as the Act of 1899 bore upon the subject, and that bore upon it in very general terms.

12554 Our directions under whatever the Congressional acts were, were to deepen harbors or channels on the Great Lakes, or widen them. That was the general mandate, and to chart them—to provide depth and width, and so forth.

12555 I understood that the proposal here with reference to the treatment of sewage is to treat all the wastes, including the domestic waste and trade waste—all the flow from the sewers—but there would probably be times when the storm run-off would have to be by-passed and that would carry with it a certain measure of raw, untreated sewage pollution.

Q. Why does the city of London settle its sewage and use six sludge steamers each with 30 men in continuous service and take the sludge out of London and out into the English Channel and dump it in deep water except

12556 to provide freer and easier and more unobstructed navigation in the Thames River?

A. I do not know. I suppose there might be a good

many reasons. I would guess at one and that is to make the conditions in and near the Thames more attractive, more bearable, for the citizens of London themselves.

Q. The traveler, you do not think, has any interest in that?

A. Well, I doubt whether the main interest is the traveler. I imagine it must have been a local nuisance of such proportions that it became offensive to everybody concerned and resulted in this drastic source of treatment.

If it were a nuisance to the people along the shore it would be a nuisance to the people navigating the Thames, in the same way and probably to a greater extent, but it would not be always a nuisance to those navigating the Thames, whereas to the man living in London it is ever present.

Q. As a traveler upon a boat, which would you rather travel upon, a boat plying upon water grossly polluted
12557 from which gas is coming, that had matters of sewage origin in it, or would you rather travel upon a boat in waters that were free from such conditions?

A. I would travel in the latter class of boat in the latter class of stream.

Witness continuing: Assuming the navigation from and to the Chicago River through the Drainage Canal and through the Illinois River; and assuming further that there is placed in operation sewage disposal plants and appurtenances at Chicago provided for by the Sanitary District program that I have mentioned as knowing about in a moderately intelligent manner; and further, assuming that the effluents from such plants, including storm water and drainage, only were discharged from the Drainage Canal to the Des Plaines River, and assuming further, that the effect of that discharge would be to cause the Illinois River to become malodorous, unsightly and offensive; and assuming that such condition of the waters of the Illinois River would be an impediment to navigation; that navigation upon the Chicago

River which has to pass through the Illinois River would be affected to the extent or to a per cent of the extent that the condition of the waters of the Illinois would be an impediment to navigation.

12558 *Redirect Examination by Mr. Jackson.*

Assuming that there was pollution in the Milwaukee River which constituted an impediment to navigation, and assuming that there was navigation from Milwaukee to the Chicago River, I would consider that indirectly an impediment to navigation in the Chicago River and that
12559 would be true of any place from which you could take a vessel to Chicago.

I am familiar with New York harbor. There has always been pollution ever since there was a community in New York City.

It is a matter of common knowledge that there is a very great coast Atlantic and coastwise traffic that originates or terminates at New York. I have been asked with respect to the navigation of passenger vessels to and from various ports on the Great Lakes now in existence. I do know that those vessels have been navigating between harbors which are the subject of sewage pollution.

They ply between all the great harbors of the Great Lakes and all of them are more or less polluted. I have
12560 been familiar with Chicago harbor for quite a number of years, and there was great pollution in that harbor by the discharge of untreated sewage during that time. During that entire time there have been passenger steamers that originated at Chicago or came there from other places.

Projects on the Great Lakes were carried out at the direction of Congress, subsequent to the recommendations and plans which had been submitted to the Congress by the Corps of Engineers in every case. Those projects then represented to Congress the judgment of the Corps of Engineers as to the practical navigable projects.

ABSTRACT OF EVIDENCE

Relied Upon by Defendants, Offered at 1926 and 1927 Hearings.

3282 **Horace P. Ramey,** for Defendants. January, 1927:

3283 *Direct Examination by Mr. Adcock.*

Live in Chicago. Civil and hydraulic engineer. Am Assistant Chief Engineer of the Sanitary District of Chicago and have held that position since 1922. Graduated from Carlisle, Kentucky, High School in 1901; attended Kentucky State College from 1901 to 1903, and the University of Michigan from 1903 to 1907, specializing in hydraulic engineering, and graduated in 1907 with a degree of Bachelor of Science in Civil Engineering. Ten years later, in 1917, was given the degree of Civil Engineer by the University of Michigan. In 1906 was instructor in surveying at the University of Michigan. Since 1907 have been with the Sanitary District as rodman, computer, junior engineer, resident engineer, assistant engineer, senior assistant engineer, and since 1922 assistant chief engineer, and acting chief engineer at intervals.

3284 Am a member of the American Society of Civil Engineers and of the Western Society of Engineers and a licensed structural engineer of the State of Illinois.

3287 Since 1840 Lake Michigan has been the source of municipal water supply for the city of Chicago. In that year a 15-inch intake pipe was extended out about 150 feet into the lake from the central distributing plant at Lake Street. That is in the central portion of the city. Municipal operation of the Chicago waterworks began in 1852. The first pumping station was on the shore of Lake Michigan at the foot of Chicago Avenue about three-

quarters of a mile north of the mouth of the Chicago
3288 River which is marked on the map as "Chicago Avenue Pumping Station." The intake for this station was a 30-inch pipe extending about 600 feet into Lake Michigan. The system of building water intake cribs far out into the lake was started in 1864. The first one built was the Chicago Avenue crib or the two-mile crib, as it is marked on the map, located two miles northeasterly from the Chicago Avenue pumping station.

3289 The same practice is followed today; the intake cribs far out into the lake, water supply tunnels from the cribs under the bed of the lake and on inland to pumping stations located at strategic points for good distribution of the water supply. The Wilson Avenue crib is three miles off shore, with a thirteen-foot tunnel leading in, diminishing to a 12-foot tunnel, leading over to the Mayfair pumping station located on the northwest side of the city. From this 13-foot tunnel there is a 6-foot and an 8-foot connection with the Lakeview pumping station. This is the last crib and it was built between 1913 and 1918. South of this Wilson Avenue crib is the Carter-Harrison crib three miles off shore from the foot of Oak Street, with a 10-foot tunnel leading from the crib inland to two
3290 pumping stations located on the west side of the city. This system was built between 1896 and 1899. Southwest of the Carter-Harrison crib we have the 2-mile crib with a 5-foot tunnel built between 1864 and 1867 and a 7-foot tunnel built between 1872 and 1874, and another 7-foot tunnel built between 1886 and 1896 leading to the Chicago Avenue pumping station. Farther south, opposite the central portion of the city, is the 4-mile crib with an 8-foot tunnel leading in, branching into two 6-foot tunnels, leading to different pumping stations. This 4-mile crib was built between 1887 and 1892. On the south side is the Hyde Park crib about two miles off shore from

68th street with a 7-foot tunnel leading back to the 68th
3291 street pumping station. This system was built between 1892 and 1898. Then immediately adjacent to the Hyde Park crib we have the Edward F. Dunn crib with a 14-foot horseshoe shaped tunnel leading from the crib to shore and on inland down to the Roseland pumping station located in the far south side of the city. Between this 14-foot tunnel and the 68th Street pumping station there is an 8-foot connection. In all there are now in use some 25 miles of these lake tunnels; that is, tunnels under the bed of the lake, and about forty miles of land tunnels in Chicago, about 65 miles, with an average size of a little larger than 8 feet. The water comes into the pumping stations and from these various pumping stations the water is fed out through the mains.

3292 The present capacity of the Chicago waterworks is 1,400,000,000 gallons per day or about 2100 second feet. The average amount pumped from the lake is about 1395 second feet for the last two or three years.

3293 There are 20 municipalities outside the city of Chicago which obtain their water supply through the Chicago waterworks system such as Oak Park, Cicero, Blue Island, Berwyn, Calumet City, Harvey, Riverdale, Dolton, Park Ridge, Norwood Park Township, Elmwood Park, Niles, Niles Center, and Tessville.

Exhibit 1103 is a map entitled "The Sanitary District of Chicago, location of the intakes on shore of Lake Michigan from Wisconsin to Michigan." That map was prepared under my direction. It shows the intakes of the various towns in Illinois and Indiana from Wauke-
3294 gan on the north of Chicago over to Michigan City southeast of Chicago and there are indicated the water intakes for these towns. Waukegan is about 50 miles north of the mouth of the Chicago River. It shows the towns in Northern Indiana taking their water supply as

indicated, such as East Chicago, Gary, Whiting, Hammond and Michigan City.

3295 The Chicago limits are shown on the map by a heavy black line. The limits of Chicago extend about ten miles
3296 north of the Chicago River, and the territory north of the city limits to Lake Forest and the Great Lakes and North Chicago is built up by residences. There is very little vacant space between Waukegan and Chicago.

Exhibit 1104 is a map entitled "Sanitary District of Chicago, map showing main sewers within the Sanitary District of Chicago as constructed to July, 1921". This map was prepared under my direction. The sewer sys-
3297 tem of the city of Chicago was started in 1855 and the first sewers were built in 1856. The sewers in the original system were built to drain mainly into the main branch and North and South Branches of the Chicago River on the combined plan so as to carry storm water as well as sanitary sewage. A separate sewer system is really two sewers, one built to carry off storm water and one built to carry off sanitary sewage. All of the sewers in Chicago are built on the combined plan, as are also the sewers in the Sanitary District.

3298 In the northern suburbs they are all separate sewers. The original system was from Ashland Avenue to Diversey Boulevard south to about Sixteenth Street, which constitutes but a small part of what is now the central portion of the city. They all drained into the Chicago River, except one, which drained into Lake Michigan at about 12th Street. In the portion of the city on the South Side east of State Street and on the North Side east of Clark Street, which are adjacent to the lake, the sewers were built to drain directly into Lake Michigan. South of 87th Street they were built to drain into Lake Calumet and the Little Calumet River.

In 1896 a commission was appointed by the city of

Chicago to draw up plans for a system of intercepting sewers which would divert all sewage which then flowed directly into the lake back into the branches of the Chicago River, whence it would find its way to the main channel of the Sanitary District, then under construction. These intercepting sewers were built in 1898, one starting near the lake at 12th Street into the river at 14th Street, as shown at about the center of this map by the heavy line, and another near the lake at 22nd Street into the South Branch at 21st Street, as shown by another heavy line on the map.

3299 The third sewer in the system of South Side intercepting sewer is shown in heavy black lines approximately parallel with the lake shore, down about one-third of the way from the bottom of the map. It takes up the sewage which formerly flowed into the Lake from 87th Street North to 31st Street, leading it to the 39th Street Pumping Station, located on the lake shore at 39th Street, and there it is pumped west into the South Fork of the South Branch of the Chicago River. The pumping station at 39th street was built in 1904.

The flushing water is added to the sewage at 39th Street and used to flush out the south fork of the South Branch. Pumping of flushing water began in 1908. The last sewer on the South Side, in the South Side intercepting system was entirely completed in 1910. That was the date of the last diversion of sewage from Lake Michigan.

The fourth sewer in the system of intercepting sewers, the North Side intercepting sewer, is shown on the upper portion of the map by a heavy black line, and took the sewage which formerly flowed into Lake Michigan from Diversey Boulevard, about the center of Lincoln Park, up to Howard Street at the north city limits, leading it to the Lawrence Avenue pumping station, where

it is pumped west through a 16-foot conduit into the North Branch. Water is taken from Lake Michigan by the Lawrence Avenue Pumping Station and added to that sewage and also used to flush out the North Branch of the Chicago River.

3300 Sewers south of 87th Street drain south and east into Lake Calumet and the Calumet River, or did drain into Lake Calumet and the Calumet River until the Sanitary District built the Calumet intercepting sewer that intercepted this sewage, leading it into the Calumet Sag channel near Blue Island.

The Calumet intercepting sewer starts from near the lake near 87th Street, and runs in a general southwesterly direction, approximately parallel to the west shore
3301 of Lake Calumet and of the Calumet River, and empties into the Calumet Sag channel which extends west into the main drainage canal.

In the towns on the north, such as Evanston, Wilmette, Winnetka, Glencoe, the sewage is drained directly into Lake Michigan, or was drained there until the Sanitary District built the North Shore intercepting sewer on the lake shore, and the Evanston intercepting sewer, and diverted that sewage from the lake back into the North Shore Channel.

The sewage in these towns south of Chicago, Dolton, Burnham, West Hammond, Riverdale and Harvey, is drained into the Calumet and Little Calumet Rivers. In towns in the DesPlaines Valley it drains into the DesPlaines River, but a considerable portion of that sewage is now treated at the DesPlaines River sewage treatment plant before being discharged into the river.

Prior to the opening of the Sanitary and Ship Canal on January 17, 1900, the sewage on the North Side of
3302 Chicago went into the lake, and from the central portion discharged into the branches of the Chicago River.

At times there was a reversal of the South Branch of the Chicago River through the Illinois and Michigan Canal. Probably the greater portion of the time that sewage went down the Illinois and Michigan Canal although in flood times it went directly into Lake Michigan. The sewage interceptors on the North Side were put into operation, the one at Lawrence Avenue in May, 1909, and at 39th Street in 1904, although some of the sewers on the south side were not completed until 1910. The North Shore channel started from Lake Michigan at Wilmette and ran down to a connection with the North Branch of the Chicago River at Lawrence Avenue, and was built between 1907 and 1910 and put in service in 1911.

3303 Connecting with that is the North Shore intercepting sewer which picks up the sewage of these North Shore towns. It was built between 1913 and 1916. The Evanston sewer was built between 1916 and 1920. It leads along the lake front and back to the pumping station where the sewage is pumped through a 10-foot conduit into the North Shore channel. The Calumet Sag channel was started in 1911 and put in service in 1922. It is an outlet for the sewage of the Calumet region, everything south of 87th Street. The Calumet intercepting sewer was completed in 1924 but most of it was put in service
3304 in 1922. At the present time there is no sewage going into the lake between the Cook County line on the north and the Indiana State line on the south. It has been diverted, as I have described, through the main channel of the Sanitary District, through these intercepting sewers.

3305 The drainage area of the DesPlaines River above Joliet, is 773 square miles.

The drainage area of the Little Calumet River before its junction with the Calumet River may be divided into two areas of 229 and 372 square miles, respectively. The

latter now drains directly into Lake Michigan east of the Indiana line.

3306 The flood run-off of the North and South Branches of the Chicago River is about 10,000 cubic second feet. The run-off of the Calumet varies from less than 100 second feet up to more than 9,000 second feet in storms.

The northern terminus of the canal where it connects with the Chicago River at Robey Street, Chicago, is about six miles, by river, from Lake Michigan.

3319 The South Branch of the Chicago River was improved by the Sanitary District. The main branch of the Chicago River extends about a mile inland from its mouth, to the junction of the south and north branches.

3320 At the junction the North Branch comes in from the Northwest, and the South Branch comes in from due south. Going along the South Branch you come to a place where it forks into the south fork and the west fork which extends on toward Ogden Ditch. The west fork extends a little over half a mile from the junction of the west and south forks to Robey Street where the main channel of the canal begins, and the west fork then extends on westerly some two miles into the Ogden Ditch, which was dug from the DesPlaines River to a connection with the west fork. That channel is still in existence. The Ogden Ditch has no connection with the DesPlaines at

3322 present, but it does have a connection with the west fork of the South Branch of the Chicago River.

The lock at the south end of the canal was 22 feet wide and 130 feet long with a maximum width of 40 feet. It was built merely to pass small craft which had been navigating the Illinois and Michigan Canal, but a space

3323 was left alongside the small lock for a large ship lock, which is now being built by the State of Illinois. This ship lock is 110 feet wide, 600 feet long and 14 feet deep over the mitre sills.

The Federal Government has completed all of the work on the North Branch below Belmont Avenue. The Sanitary District has improved the North Branch between Belmont and Lawrence avenues, by digging a new channel for it, 90 feet wide and 12 feet deep. The Sanitary District has built thirteen movable bridges over the canal. They were all built so that they may be moved by machinery, when the machinery is installed. Two of them
3324 are equipped with operating machinery and have been operated since 1918. They are all either swing bridges or bascule bridges, which lift.

The Calumet Sag Channel was built from the Little
3325 Calumet River over to a connection with the main channel at Sag. The bridges over the Main Channel have a clearance of 16½ feet above the flow line and the depth of the water is from 22 to 24 feet.

3326 In the Sag Channel the clearance is 16½ feet above the flow line, with a depth in the water of 20 feet. The North Shore Channel was built to extend from Lake Michigan at Wilmette, down to a connection of the North Branch of the Chicago River at Lawrence Avenue, a distance of eight miles. It has a depth of 13½ feet, a bottom width of 26 feet, and a surface width of about 80 feet. It is built as an outlet for the sewers of the North Shore towns, such as Evanston, Wilmette, Glencoe and Kenilworth. The full capacity of the North Shore Canal is 1,000 second-feet. This capacity is produced by pumping from Lake Michigan at the Wilmette Pumping Station. There is a lock at the Wilmette Pumping Station which has a 3-foot lift, through which boats may pass from the North Shore Channel to and from Lake Michigan.

The Sag Channel is 60 feet wide in the rock section, and in the earth section the bottom width is 36 feet and the surface width is from 115 to 120 feet.

3328 The natural depth in the Little Calumet River is from 4 to 6 feet, and just at present the Sanitary District is engaged in deepening the Little Calumet River, from the turning basin, southeast of Lake Calumet, over to the end of the Calumet Sag Channel, near Blue Island. This river is being dredged to a depth of 13 feet below the flow line to a bottom width of 90 feet. By a "flow line" I mean the water surface at ordinary stages. The deepening of this river was begun in January, 1925, and is about 70 per cent completed. It will be finished in 1927.

3329 The Little Calumet River connects with the turning basin southeast of Calumet and from that point on out to Lake Michigan the Government has improved the Calumet River to a depth of 21 feet and contracts have been let for building a harbor in Lake Calumet under authority of the State of Illinois and of the City of Chicago.

The Sanitary District has improved the south fork and the west fork of the South Branch of the Chicago

3330 River from the junction, where the North and South Branches unite and form the main river to the entrance of the Ship Canal. The Sanitary District has improved these stretches to a minimum width of 200 feet and a depth of 26 feet below the flow line for the middle 100 feet of the river shallowing to a depth of 16 feet at the dock line. The south fork of the South Branch has been improved by the United States to a depth of about 21 feet. In the North Branch to Belmont Avenue the project depth is 21 feet. From Belmont Avenue north to Lawrence Avenue the depth is 12 feet except for two blocks that were dredged to a depth of 15 feet by the United States Government during the war. The depth of

3331 the channel in the main river is 21 feet.

3332 The South Branch of the Chicago River and west part of the South Branch to the northern terminus of the canal has been improved to a width of 200 feet and a depth of

26 feet. In this stretch the Sanitary District has removed about twelve center pier bridges and replaced them with bascule bridges, for a clear span. It has also removed two center pier bridges in the main branch of the Chicago River, and replaced them with bascule bridges. All that work was done between 1897 and 1912.

3333 There are some elevators or navigation docks on the south fork of the South Branch and there is considerable
3334 navigation on the south fork from and to the other rivers and harbors.

3363 The maximum flow of the Chicago River Drainage area is approximately 10,000 cubic feet per second. A large part of that area is paved.

3364 In Exhibit 1, the Putnam report, are some run-off figures of that area prepared by me.

3365 A run-off flow from that area of 9500 second feet will occur about two times in three years; 7500 second feet three times a year, 5000 second feet five times a year, 4167 second feet seven or eight times a year, and 3000 second feet ten or twelve times a year. Under normal conditions the percentage of the diversion through the different intakes is as follows: through the North Shore channel, 9 per cent; through the Chicago River, 72 per cent; through the 39th Street conduit, 4 per cent; through the Calumet River and Calumet Sag Channel, 15 per cent.

3366 Under flood conditions the flood run-off will originate as follows: in the North Branch, 37 per cent; in the central and western portions of the Chicago River, 27 per cent; in the south fork and South Branch of the Chicago River, about 16 per cent; in the Calumet Sag Channel, about 20 per cent. The Sag Channel does not take off all the flow of the Calumet River in flood time, so that any quantity in excess of 2000 second feet in the Little Calumet River area will still flow to Lake Michigan. The sewage from West Hammond and six other small towns

still flows into the Little Calumet River. All of the rest of the sewage draining toward that river is intercepted by the Calumet intercepting sewer.

3367 Plans have been prepared for a sewage treatment plant at Harvey, and West Hammond. In dry weather no part of the Little Calumet overflow will go into Lake Michigan. In dry weather about 400 to 800 second feet is taken from Lake Michigan through the Calumet River.

I studied the extreme flood data that we had in 1918, which amounted to about 12,500 second-feet in the lower end of the main channel, and estimated that, on that figure, 4700 second feet, about, came from the North Branch; from the central and west fork of the Chicago, about 3300, about 2000 second feet from the south fork of the South Branch, and about 2500 second feet from the Calumet Sag Channel.

The capacity of the Calumet Sag Channel is 2000 second feet, with Lake Michigan at datum, and 8000 second feet flowing in the upper portion of the main channel and 10,000 second feet flowing in the lower portion of the main channel, that part of the canal below the Sag. The amount that is normally taken through each one of the various channels directly from Lake Michigan is as fol-

3369 lows: from 600 to 800 feet through the Wilmette Pumping Station; about 6000 second feet through the Chicago River; and about 1000 to 1200 second feet through the Sag Channel.

3370 The Sanitary and Ship Canal was designed for a maximum capacity in the rock section of 10,000 second feet. As originally designed there was to have been taken through the 39th Street Pumping Station and conduit 2000 second feet, from the main river about 6000 sec-

3371 ond feet, from the Lawrence Avenue conduit about 750 second feet and through the North Shore Channel about

1000 second feet. The above figures relate to water abstracted directly from the lake.

3372 The hydro-electric plant of the Sanitary District was put in service late in 1907.

To supplement the dilution project the Sanitary Dis-
3392 trict has adopted a program of artificial sewage treatment. Experiments were begun in 1908.

4467-4469 Counsel for defendants read into the record Section 26 of the Sanitary District Act, providing that cities owning systems of waterworks may be required under certain conditions to supply adjacent cities with water therefrom; and cited the case of *Cicero* v. *Chicago,* 210 Ill. 390, in which that section was upheld and it was found that the town of Cicero could compel Chicago to deliver water to it.

4469 These twenty villages I mentioned obtain their water supply from the City of Chicago.

George M. Wisner, for Defendants, January, 1927:

Consulting Engineer for Sanitary District.

3666 *Direct Examination by Mr. Adcock.*

3667 Reside at Chicago, Illinois, and I am a Civil Engineer. I am now and since 1920 have been the consulting engineer for the Sanitary District of Chicago. Have been connected with the District since July 1892. My first position was rodman, after which I was made instrument man in charge of giving levels and grades on the construction of the main channel between Lockport and
3668 Lemont. I was sent there before any actual construction took place, but after some of the contracts for the excavation of the main channel had been awarded. I remained there for three years, until 1895, when I was promoted and made sort of an engineering secretary to

the assistant engineer. In 1897 I was made assistant engineer in charge of Chicago River improvements, which position I held until 1901, when I was made assistant chief engineer and served in that capacity until 1907, at which time I succeeded Isham Randolph as Chief Engineer, which position I occupied until June 1920, when I became Consulting Engineer for the Sanitary District.

I received my grammar and high school education in the City of Detroit, afterwards graduating, after a four years' course, from the University of Michigan with a degree of Bachelor of Science in Civil Engineering, in 1892. I went to the Sanitary District right after my graduation.

3669 In respect to my experience, naturally after becoming connected with the Sanitary District, I became interested in the study of that question, and after 1900, when the drainage canal was opened and the particular study of sewage disposal became more prominent, it was found at that time that very little had been done in the science of disposal of sewage other than by dilution.

In 1906 there was a report made by Messrs. Hering and Fuller to the International Waterways Commission, of which my father was a member.

In 1907 a further report was made by Mr. Hering. The first report referred to the disposal of the sewage of the Calumet district by means other than dilution. The second one by Mr. Hering was in 1907.

We were requested by the President of the District (at that time Mr. Robert R. McCormick, now the editor of the Chicago Tribune), to report upon all methods of sewage disposal, including dilution. From these reports and the interest that the public was beginning to take in greater purity of water for drinking and better methods of disposal of sewage and cleaning up of sanitary conditions, I recommended that the Sanitary District engage the services of a chemist and biologist.

In 1909, or the latter part of 1908, upon my recommendation, we engaged a sanitary engineer.

In 1909, we built a testing station located at 39th Street and Lake Michigan, at the place indicated on one of these exhibits where the 39th Street Pumping Station is now located, the object being to make experiments to find out what was the best method of treating sewage other than by dilution, having in mind that it would soon be necessary to experiment with artificial methods by other than the so-called dilution method, particularly so far as the removal of settling solids were concerned.

I stated that upon my recommendation a sanitary engineer was engaged, Mr. Langdon Pearse, now Sanitary Engineer for the Sanitary District. A testing station was built under my supervision and his, and an elaborate system of every known method at that time was tried out in the sewage coming to the 39th Street Station, which was largely of domestic origin as distinguished from that which we call industrial waste, which would come from such plants as the packers, corn products and the tanners.

These tests were carried on for a number of years. Necessarily it took time, as we find in the treatment of sewage that the treatment is more successful in some seasons than others; that some methods would treat sewage satisfactorily in the summer time, but not in the winter. So everything we could think of was tried and some successful methods developed, which entered into our further study and application of these principles.

Following that an elaborate set of experiments was carried on to determine how to dispose of the waste coming from so-called Packing Town, where the stock slaughtering industry of Chicago is located, which occupies a square mile of the City of Chicago, right in the heart of the city, you might say, at the present time. They had been creating great nuisances, one of which had become

nationally known as "Bubbly Creek." The situation was almost intolerable. These experiments extended over several years. I think we finished our first investigation in 1914, when Mr. Pearse and myself made a report upon the available methods of handling these trade wastes. This report was not satisfactory to the packing industry and we had hardly got it printed when another method known as the activated sludge method of sewage and waste disposal came into more or less general knowledge in this country, and so that method was tried out for a couple of years.

Now, these two years I speak of may seem long, but when it is appreciated that waste of this kind had never been successfully treated anywhere, it is not a long time to get results. After carrying out these experiments with the activated sludge method, it was agreed by the representatives of the stockyards that this method would successfully handle the waste coming from that industry as well or better than any other known method, and probably as well as it is possible for this science to do.

After the completion of these experiments the same thing was done with the waste coming from the tanneries. Elaborate experiments were carried on and different results obtained. Following that the waste coming from the Corn Products Company was experimented upon, and these experiments were carried to a successful conclusion, and, to my mind, the most successful of any of them, because through our work, working in co-operation with the officials of the Corn Products Company, a method not only of treating these wastes was found, but a method of conserving them, making an economic saving. This plant at Argo, located within the Sanitary District and on the bank of the main channel, had been grinding in the neighborhood of 70,000 bushels of corn per day, of which amount we found upon investigation

3,000 bushels were being wasted through a sewer into the main drainage channel. As I stated, through our investigation a method had been found by which this waste has been reduced so that the waste which originally came from this plant equivalent only to the waste coming from 400,000 people is now equivalent only to the waste coming from 10,000 people. That has been a big financial saving to the company, and they are very much pleased.

Also during that time, upon my recommendation, investigations have been carried on showing the condition of the DesPlaines and Illinois Rivers below the end of the drainage canal, so we would have a complete record as to what condition it was in at any particular time, to show whether it is getting worse as years go by. That was also done in connection with the main channel. The condition of the mixture of sewage and diluted water in the channel itself was investigated. So that generally the Sanitary District since 1909 has had a very good record of conditions in the Chicago River, main channel, Des Plaines and Illinois Rivers. Our studies have not extended below St. Louis.

In addition to that, in 1910 I visited the works in Birmingham, Manchester and London, England; Paris, France, and Berlin, Germany. I did the same thing again in England and France in the winter of 1922-1923. In addition to that I might say that I have visited many of the sewage disposal plants that have been built in the United States since 1906, and some that were built before 1906, but I did not visit them until after that year.

That generally has been my experience in sewage disposal.

3673 In 1892 when I came to the Sanitary District the Chicago River was a stagnant stream. Standing on the banks of the main river or the branches, you could not notice any current going either way, except as the lake

fluctuated. If the lake dropped six inches or a foot there would be a current you could see moving toward the lake. If it happened to rise a foot the water from the lake would run into the storage area of the Chicago River. The river was in a filthy condition. It was a large septic tank. I saw it first in July, 1892, before any work had been done on the construction of the drainage canal, or upon the Chicago River by the Sanitary District. The river was full of sewage mud that was festering in the bottom and generating gases, and these gas
3674 bubbles finally became so large as to give a buoyancy to the mud, and large masses of sewage mud would bubble up to the surface of the stream and break in rivulets that ran to exceed sometimes almost the entire width of the river. At other places the river was covered with a sewage crust, such as is found in a septic tank which at places would extend across the river. I have seen chickens walk upon this crust.

It would also in certain spots catch on fire, due to these gases and to tar products that came from industries. There was a continuous ebullition coming from the gas flame. The only real current you ever saw in the river, outside of the one I mentioned due to fluctuation of the lake level, was when a heavy rain would come and the sewers would commence to discharge into the Chicago River, as many of them did, driving that filth out into the lake as far as the cribs from which Chicago was obtaining its water supply. One of them is south of the Chicago River, about four miles from the shore, known as the Four-Mile Crib. The North Branch was full of
3677 polluted water, anaerobic.

3678 There was connected with the south fork of the South Branch of the Chicago River, near Ashland Avenue, the old Illinois-Michigan Canal, at which there was a pumping station which pumped water from the South Branch

into the old Illinois-Michigan Canal to the extent of 7 or 8 hundred cubic feet of water per second. That was such a comparatively small amount that it did not give any current in the river that was perceptible to the eye, and only took away a fraction. It did not clear the river up, although it did help to the extent that it kept the amount of sewage that was pumped into the ditch from being washed into the lake in times of flood.

As you went up the west fork of the South Branch you came to the end of it beyond where Howard Avenue and Kedzie avenue ran into what was known as the Ogden ditch. That ditch continued up the DesPlaines River where there had been a small dam put over the east bank of the Des Plaines River, known as the Ogden Dam, which prevented in a small way the flood waters of the DesPlaines from flowing into the west fork of the Chicago River and washing the filth into the lake.

3679 That, generally, was the condition of the Chicago River.

In regard to the sewers, the sewers, as stated by Mr. Ramey, the previous witness, had been built under the direction of a man named Chesbrough in 1850, and these sewers had been added to from time to time. As he stated, they were of the combined type, which carried domestic sewage, industrial waste and storm water coming from the run-off of rainfall on the roofs and streets of the city. In the beginning they had generally been built so as to discharge into the river, either the main branch or the branches of the main branch. As the city grew they got to discharging them into the most convenient places, and many of these large sewers discharged directly into Lake Michigan.

The Illinois-Michigan Canal simply served to relieve the load of certain matter in the Chicago River that would be washed out into the Lake, to the extent of seven

3680 or eight hundred cubic feet per second, which was

pumped into the old Illinois-Michigan Canal, which flowed generally in a southwesterly direction to Lockport and Joliet, where it was mixed with the waters of the Des Plaines River, when there were any, and from there on down it flowed through the Des Plaines and the Old Illinois-Michigan Canal into the Illinois River below the confluence with the Kankakee, or it went through the Illinois-Michigan Canal into the Illinois River at La Salle.

3681 In 1890 the population of the City of Chicago was about a million. When the canal was opened in 1900, it had 1,500,000 people, and by 1910 that had increased, speaking from memory, over 500,000, and by 1920 it had reached nearly 3,000,000 people. At the present time, as nearly as we can estimate it, it is increasing at the rate of from seven hundred to seven hundred and fifty thousand every ten years. It is a real problem with the engineers to keep track of the population and its increase, as it becomes a real problem in taking care of the sewage as the city grows, particularly when one appreciates that this seven hundred to seven hundred and fifty thousand is a population that is fifty per cent, in round numbers, in excess of the present population of the City of Milwaukee. In 1890, as I understand, the population of Chicago was approximately the population that Cleveland is said to have now.

3682 I know the condition of the water supply in 1892 and in 1900 when the Sanitary District Channel was opened. In the late eighties and the early nineties there was not very much known in this country about water purification or of the germ theory of disease. The only things that were known were the results that came from polluted water as shown by the typhoid fever death rate and the death rate from other intestinal diseases. The press was full of warnings to the public to boil their water. The

typhoid death rate rose as high in the nineties, I think it was, or the late eighties, as 174 per hundred thousand. There is a theory with us engineers that for every death from typhoid there are three other deaths from allied diseases, if I may use that term, or diseases that are water-borne. The average rate was high.

Through a series of years there would be epidemics which showed that the water was unfit to drink. Of course, with a city like Chicago, made up of a large population of foreign people who had immigrated to this country, and many of whom could not read or write, particularly the English language, this warning that was printed in the paper did not do much good, or to those who were careless or ignorant and who would not pay much attention. The result was that Chicago was a pest hole of typhoid and intestinal diseases.

As stated before, floods came into the Chicago River washing the filth into the lake. By the mere eye this could be traced beyond the cribs and probably if we had had the same knowledge then that we do now, by making bacterial counts this pollution could have been traced a great deal further than it is able to detect it by the eye.

I would like to correct one statement. My recollection was that prior to 1900, in the opening of the canal, it was in the neighborhood of 40 deaths from typhoid per 100,000 per year as an average. It may have been more and it may have been less. That, however, is stated in the report that I made to the Board of Trustees in a table showing it in October, 1911, which I would prefer that
3683 you use rather than my recollection. I have not looked that up lately.

After the opening of the canal the epidemics were materially reduced and the average was reduced. This was not entirely accomplished, however, until after 1910, when the intercepting sewers which collected and pre-

vented the sewage of the sewers of Chicago from discharging directly into the lake were built, and that sewage diverted to the Chicago River and thence through the drainage canal.

At that time the Illinois and Michigan Canal was about 60 feet wide and had been constructed, as I recall it, 6 feet deep, but it had become so filled with sewage mud that it would accommodate a boat drawing only 4 to 4½ feet of water, and along one side the canal there was a sort of a trough through which the boats were drawn, either by mule power or propelled themselves by steam.

From Chicago to Joliet it was practically, with the ex-
3684 ception of this trough, filled with sewage mud. The Des Plaines River at Joliet was also filled above the dams that were in that stream at that time, there being three of them, creating three pools about the dams. This was septic and was very noisome both to the eye and nose. In fact, in Lockport, the gases coming from this canal were so bad that the gas attacked the paint on the houses situated in some cases from half to three-quarters of a mile away from the Illinois and Michigan Canal, turning the paint black where it had been white, and causing it to peel or blister seemingly after a few years.

I was with the Sanitary District during the entire period of construction of the main channel. I was present at the so-called "Shovel Day" in 1892 when the first shovel was turned with some ceremonies.

3686 From an engineering standpoint the construction of the main channel of the Sanitary District was particularly novel on account of its magnitude.

3687 In 1892 the Government of the United States had made some improvement upon the Chicago River and its branches. The first work that the Sanitary District did was to build what was known as a by-pass from a point just about a hundred feet north of Adams Street to a

point just about 75 feet south of Van Buren Street. It was a channel to provide a larger cross section for the Chicago River in that section because it was very narrow and to permit the flow to go through without creating any excessive current in that reach.

Prior to 1897 and up to 1900 the Government had deepened the main river and the North and South Branches to about 16 or 17 feet and had cut off some points along the North and South Branches where dangerous corners had been built into the river.

After 1900, and the canal had been opened and there was much complaint from the navigation interests about the current in the river, the Sanitary District developed plans for the improvement of the South Branch from 12th Street to Ashland Avenue, and then later from Lake Street at the junction of the North Branch with the South to 12th Street.

The Sanitary District replaced two center pier bridges
3689 in the main river with bascule bridges and generally in the South Branch removed nearly all of the center pier bridges and replaced with bascule bridges.

They deepened in the South Branch from 16 to 17 feet to 26 feet below what has been called the flow line here, but which really is water flowing down hill through the South Branch. There is a declivity to its surface and our 26 feet was below this plane of declivity which we have called the flow line.

It widened the river, the South Branch, from Lake Street to Ashland Avenue. So that at all points, excepting bridge openings, it was 200 feet wide, 26 feet deep in the center, sloping to 16 feet in depth to the dock line. That was done under my direction. I was on the river work. All the work the Sanitary District did on the Chicago River was the building of two bridges. The Government deepened it after 1900, as I recall it, from

16 or 17 feet to 21 feet; both the main river and the North Branch.

3690 The occasion for deepening and widening the South Branch was so there would not be a current in excess of one and one fourth miles per hour. The work of deepening the river from 16 to 26 feet and widening it was commenced in late 1900 or early 1901, as I recall it. The excavation of deepening was carried on with considerable rapidity and the widening was delayed somewhat on account of having to go to condemnation proceedings to obtain the property to widen it. As we obtained the property it was widened and it proceeded faster at first than it did in the latter part. I think it was practically all finished by 1909 or 1910. The limitation of the flow by the Secretary of War about 1901 was finally set at 4167 second feet.

3691 There had been different permits.

3692 The diversion from Lake Michigan was increased from time to time as the cross-section of the South Branch and west fork of the South Branch of the Chicago River was enlarged, always with the end in view of not exceeding 1¼ miles per hour velocity of the current.

3693 There was no controversy or objection made by the Engineer Corps to the increase over the 4167 second feet as the cross sections of these rivers were increased until after 1910. I came in contact in a business way with the division engineers of Chicago, and I know from them that they knew the flow was greater than 4167 cubic feet per second, prior to 1910.

3694 The maximum run-off of the Chicago drainage area was, prior to the time I came to the Sanitary District in
3695 1892, approximately 10,000 cubic feet per second, at maximum flood. That has increased since that time. We believe now, from our engineering data, that it will approximate 12,000 cubic feet per second.

I am familiar with the history of the art of sewage disposal in the last 35 years. The plan that was adopted
3697 by the Sanitary District, pursuant to the Act of 1889, was not only the proper plan at that time, in the light of the knowledge the engineers had of the treatment of sewage, but it is the proper plan at the present time.

From a sanitary engineering standpoint, the peculiarities with reference to the disposal of the sewage of the
3698 City of Chicago as compared with other cities are that on account of a geographical location, it is so situated that it can divert the sewage entirely from the city's water front and keep it out of its source of supply. The amount of diversion of approximately 10,000 second feet has this significance in connection with that problem, in addition to its value as a diluting and purifying agent, that the run-off of the Chicago River was thought at the time the canal was designed to be, and was, practically 10,000 cubic feet per second. By having that flow, it is possible to keep the Chicago River from reversing into the lake in time of excessive run-offs from rainstorm. If the flow is materially less than that amount, the Chicago River would certainly at times go into the lake. I have reached that conclusion through an experience with
3699 the operation for the last twenty-six years, and particularly due to the fact that, in the beginning, the canal was only flowing between, say, 4,000 and 6,000 cubic feet, and sometimes less than that; that the reversal of the main river so that the sewage-laden water went into Lake Michigan, was more frequent with the same general character of rains than it has been in later years, when the flow has been greater. And further, from experiments that I had made in 1914, I believe, by which the canal in both cases—the two experiments were some two or three weeks apart—was gotten into a state of equilibrium of flowing 4,000 cubic feet per second,

throughout its entire length, and then suddenly increased to 10,000 cubic feet per second; and it was found that the full effect of that increase was not felt in the Chicago River, near the heart of the city, in the 23 hours that we ran the experiment. We were never able to get the flow in that 23 hours up to the 10,000 cubic feet per second, in the vicinity of the forks where the North Branch and South Branch came together. The significance of this is that the peak of storms on the Chicago River basin will appear in the river in four to five hours, whereas we could not increase the flow from 4,000 sec-
3700 ond feet to 10,000 second feet in less than 23 hours, by manipulating the works at the lower end of the canal.
3701 You could not draw off the storage of water at the southern end of the canal in time to take care of the increase that would be delivered at or near the lake. It is certainly dangerous to the water supply when the rainstorms occur, because of the flat grade of the sewers of Chicago. Where the street level, even 7 or 8 miles back from the lake, is only fourteen feet above the lake level, necessarily, the grade of the sewers was not steep, and during dry weather filth accumulated in the bottom of the sewer, and when a rain came along it forced that out and into the river, and the storm water from the rains became very heavily polluted with sewage material.

In connection with that question of disposal of sewage by artificial means, we carried on experiments to determine the proper method to be used over a period which covered practically from 1908 down to date. We are still carrying on experiments to get the best method of handling it.

3702 We built purely experimental stations that I have mentioned before, and in addition to that, we have built several small practical stations. I always regarded the station known as the Des Plaines Sewage Disposal Station as a large experiment, and it was.

The ordinance of the Sanitary District Board of August 7, 1919, laid out a program for the building of artificial purification works to experiment with this dilution system. I had contact with the Engineer Corps of the Army with reference to working out that program. I had two or three or four interviews with General Black,
3703 then Chief of Engineers, I think in 1918, at which time I had authority from the Board with our attorney to see if there was some way of settling this controversy. There had been a report made by General Bixby and four other gentlemen, in which it was stated that compensating works could be built on the Niagara and St. Clair Rivers for $475,000, I believe, which would fully compensate for any lowering that the Chicago Drainage Canal had caused to the Great Lakes.

As I recall it, we told General Black the Sanitary District was willing to pay this money. He asked "How about Canada? This will be an international affair." Whereupon, our attorney, Mr. Adcock, and myself went to Montreal, as he referred particularly to Montreal, and had an interview with Mr. Cowley, who was engineer for the Harbor Commission.

3704 In the negotiations I had with the engineers at Chicago, General Black then said in substance to take the matter of sewage disposal up with Colonel Judson, the engineer then in charge at Chicago, and see if some scheme or plan of program could not be arrived at that would satisfy him that Chicago was doing everything within its power to meet the situation, as it had developed at that time. There was considerable opposition to that continued flow of water through the channel, and it was feared that the Chicago Sanitary District was going to take more than 10,000 feet, or wanted to. I had many interviews with Colonel Judson, and we finally arrived at an agreement as to what Chicago could rea-

sonably do in taking care of the increasing population and reducing the burden of sewage or sewage material upon the drainage canal. Briefly, the ordinance which was afterwards passed, which was that Colonel Judson told me he thought was all that could reasonably be expected from the Sanitary District.

3706 Colonel Judson said that if the Sanitary District would reduce the load then coming into the main channel by 50 per cent, and provide works to do that and to take care of the increasing population of Chicago, so that this result would be accomplished in twenty-five years or by 1945, that was all that could be reasonably expected of the Sanitary District, under the conditions as they then existed. Work was to be laid out and performed progressively during that period to accomplish that final result. After that the ordinance of the Sanitary District of August 7, 1919, was passed.

In respect to what progress may be made or the difculties that are encountered in the execution of construction work and laying out plans in the Sanitary District or other municipal bodies, one of the principal objections to making speed and headway has been the uncertainty as to how much water we would be permitted to divert from Lake Michigan, as one kind or class of treatment work would be required in one case that would not be required if we were permitted to continue as we are. The principal delay, however, to performing a work swiftly in a public body is the change in administration of elective officers.

3709 I am referring to the Sanitary District or any public organization that has to work under elective officers, or any organization that has to work under elective officers.

3713 It is almost unthinkable to imagine that the diversion from Lake Michigan be cut off and entirely eliminated tomorrow or next day, but it would bring on worse con-

ditions than existed in 1892 and in 1900, for the reason that there would be more pollution that would go into the lake now than at that time, because the population has increased greatly and also the manufacturing and industrial waste has increased, and I know of no way in which scientific sewage disposal or water purification could take care of this situation practically over night. The disposal of the sewage of the Sanitary District is absolutely intimately connected with the water supply of the people of Chicago and environs. I do not recall offhand that that situation exists in any of the large cities of the United States, except those located upon the lakes. There is not available to Chicago other water supply than that of Lake Michigan sufficient to meet its needs. Prior to 1900 and generally prior to 1910, but not so much so, there was practically no bathing in Lake
3715 Michigan. The water was sewage-contaminated, and until after 1910 or about 1910 the people of Chicago commenced to use the lake front for health and pleasure giving pursuits in the summer time, so that at the present time there are hundreds of thousands who bathe in and use the lake on a hot summer day during June, July, August and September.

If the diversion at Lockport were limited to 1,000 second feet, the effect would be practically as bad as though we had no diversion. The condition that would result in the Chicago River drainage canal and the Des Plaines and Illinois Rivers would be practically the same as I described the Chicago River was in the nineties, except there would be more sewage going down due to the larger population.

The Illinois and Des Plaines Rivers have never been used as a source of water supply for the people. The towns all the way along the Illinois River discharge their sewage into it. The limitation of the diversion to noth-

ing or to 1,000 second feet at Lockport would in a short time make the condition of the water along the waterfront so the people should not use it for bathing purposes. It would be unsafe, let alone unsightly. In my opinion, no works could be constructed which would protect the health of the citizens of Chicago and surrounding towns inside the Sanitary District to the same extent as the present diversion allowed by the permit, assuming that the flow were cut to zero or 1,000 second feet and ample time allowed to build such works. We have a better water supply than we would be able to build under the present status of the science of water purification and sewage disposal.

3728 The waste coming from a manufacturing industry like Packingtown is very excessive. For instance, as I have stated, the wastes coming from Packingtown are equivalent to the domestic or organic matter coming from a population of 1,100,000 people, in round numbers. That greatly increases the problem of taking care of the sewage of a city like Chicago.

I have estimated the population of the Sanitary District in 1945 will be about 4,800,000 as near as we can estimate by plotting curves showing its growth and making a study of those, and also the curves of population increases in other cities. There would also be the Packingtown waste and tannery wastes to take care of. That does not include the human equivalent of trade wastes from the packing and other industries.

Referring to the extent to which it is practicable to treat sewage in the percentage of purification, of course, plants vary. Some plants will be operated more efficiently than others and some processes will be more efficient than others, but generally I would say, to give you an idea, that if you take all of the sewage, and have it all treated in a municipality the size of the Sanitary District

and if your general average of purification reaches 85 per cent, then Chicago would have what we engineers would call a very efficient working sewage disposal machine.

3729 Possibly I might illustrate it better by an example. If you take a city of 100,000 people and the sewage is treated as completely as it is possible and practicable to do it within financial reason, the effluent coming from that plant in taking care of these 100,000 people would contain organic matter to the same extent as raw sewage coming from 15,000 people untreated. There would not be the unsightliness about this effluent that there is about raw sewage, but as far as the organic matter in sewage is concerned the effluent from 85 per cent on 100,000 population would be equivalent to the organic matter in raw sewage from 15,000 people.

3730 It had been discovered, after the main drainage canal was completed, that the engineers in computing its size and designing it had been so conservative that instead of the main channel through the rock being built to carry only 10,000 cubic feet per second it would and could carry 14,000 cubic feet of water per second.

3740 *Cross-Examination by Mr. Jackson.*

It is certain, if you keep the sewage pollution away from your water supply, it is much safer than if you let the sewage pollution get to your water supply and attempt to treat it, on the theory that an ounce of prevention is worth a pound of cure.

3741 To a large extent, particularly in the beginning, I attribute the improvement in typhoid death rates in the City of Chicago to the opening of the Chicago Drainage Canal.

The witness was asked if he agreed with the following

statement from page 34 of Exhibit for identification No. 3, the Warren Report:

"The opening of the Drainage Canal seems not to have reduced any of the death rates materially. For the three years before the Canal was opened, the general rate was 15.0 and for the three years following 14.5 per 1,000. For the 13 years which have now passed since the Canal was opened, the average general death rate has been 14.8. In 1913 it was 15.1.

3744 "The average reduction in typhoid for the three years following the opening of the Canal was trifling, 32.4 to 31.1, and appears especially inconsequential when it is noted that this average of 32.4 contains the rate of 40.8 for the exceptional typhoid year of 1898. Since the Drainage Channel was opened, the average typhoid rate has been 19.2. In 1913, it was 10.4. The figures since 1893 have shown a persistent decline, but no sudden and permanent fall. There have been years when the rate has been a great deal higher than these average figures indicate, as for example, in 1902, when the rate was 44.5, and in 1903, when it was 31.8, and there have been nine years when it was less than the average. It is necessary to go back beyond the opening of the Canal, and beyond the epidemic year of the Spanish-American war (1898), in order to equal the rate which obtained in the 3rd year of the Canal's operation.

"Looking through the printed list of specific causes of death, it does not appear that any rate was affected by the opening of the Canal so much as the rate for that indefinite group called diarrhoeal diseases, which includes diarrhoeal and arteritis among infants. The average death rate for diarrhoeal diseases for the three years preceding the opening of the Canal was 257.4 and for the three years subsequently 209.5, a reduction of about 19 per cent. The decrease in the death rate among chil-

dren under 5 years of age for the same period was 17 per cent. There is no reason to suppose that the deaths in this class bear a measurable relation to the sanitary condition of the city, since the statistics are made up largely of children whose diarrhoeal diseases are chiefly caused by local circumstances. It seems as unsuitable to ascribe the reduction which has occurred since 1900 in diarrhoeal diseases to the Drainage Channel as it is to charge up against it the remarkable increases which have occurred in the prevalence of Bright's disease, heart disease and violence.

"Typhoid fever has become less prevalent since the Drainage Channel was opened than it was before, but before the decline is ascribed to that great work, it may be desirable to consider some facts outside of the Chicago death rates which have a bearing on this matter.

"Typhoid is disappearing everywhere, except in those places where its spread is encouraged by gross sanitary neglect. In those parts of the United States where the vital statistics are collected with sufficient accuracy to be used by the Government Census Bureau, there has been an average decline in the typhoid rate of one-half since the opening of the Chicago Drainage Channel in 1900, that is, from 35.9 to 17.9 per 100,000 population. Were it not for the excessively high rates in some states, the average would be much lower. The average rate for the cities in New York State in 1913 was 9.9 and in Massachusetts 8.6.

"In 1913 the typhoid death rate of New York City was 7.0 per 100,000; that of Boston, 8.2; Cincinnati, 6.8; Worcester, 5.6 and Seattle 4.7. These are particularly low rates, but they are not lower than are proper for Chicago.

"Chicago has had a number of explosive outbreaks of typhoid since the opening of the Drainage Channel, not-

ably in 1901-1902 and 1903, and the circumstances which have attended them have led observers to form the opinion that they have been water-borne, in spite of a general opinion to the contrary.

"From a study of the seasonal incidence of typhoid in Chicago and in other cities with about the same rate, McLaughlin formed the opinion that the water supply was largely to blame."

3748 No, sir, for the reason that in the years 1901, 1902 and 1903 and later on the sewage had not been diverted from Lake Michigan on the North or South Side by the construction and completion of the intercepting sewers. As I recall it, that was not entirely completed until after 1910. And also due to the fact that the reversal of the Chicago River was frequent in those days when a small flow was being discharged through the main channel.

I know that the death rates were high in the beginning of the canal but in the later years they have gone away low. It is true that some of that is due, and probably large quantities, to milk inspection and better milk supply; but a fairer comparison would be to take the death rate as a whole of Chicago from typhoid and compare it with the death rate of cities in Northern Indiana where there are the same climatic conditions, the same character of population and the same food supply and where the death rate is higher than in Chicago and which is somewhat unfair to Chicago, too, because often a case of typhoid comes on a person in one of those Indiana towns and that person is brought to a Chicago hospital and is known to die there where the death would be charged against Chicago while the disease had been contracted in an Indiana town.

3749 Chicago attracts a large number of people. It is very attractive. It is a big railroad center and people come there and stay and others simply pass through. I sup-

pose there are a large number of all classes of people who come to Chicago to make their homes. I never classified them as to their age. I think there are more people coming to big cities that are of young age than
3750 of old. That should be reflected in the death rate, and that applies to pretty nearly every city. I think the decrease in the typhoid rate in Chicago was more marked as to 1903, and not having any pronounced epidemic where the curve went away up like it used to do when it would get up to 174 per 100,000 instead of staying around 30. I cannot recall when it got up to 174, but it was back before the opening of the Drainage Canal.

I do not know that Chicago was lagging behind other places. They had taken sanitary measures to the extent of extending their water cribs farther out into the lake to get away from the contaminated shore waters. In those days we did not know very much, before 1900, about water purification. It was just beginning to come into use and there had been very little real sewage purification before that in this country. There had been some cases where septic tanks had been built which only took out the solids and did not do that very well. The epi-
3751 demic I spoke of was about 1891. There was a great agitation all that time about boiling water. I presume that had been so before I came there in 1892. I do know that after this epidemic various health measures, such as boiling water, etc., were enforced. I suppose it had a beneficial effect on the death rates.

3752 On my recommendation in 1911 Chicago started to chlorinate its water. I even recommended to the Sanitary District that it do it if the city would not, and it was after that report. Undoubtedly chlorination of the water supply has helped, but it will not accomplish the whole thing if the water is polluted unless you so chlorinate as to practically ruin the taste of the water. I say

chlorination of water is very desirable to prevent water-borne diseases, and undoubtedly has a marked effect. That was instituted after 1911, as I recall it, because my report was made in October of 1911. I do not recall when
3753 the pasteurization of milk commenced in Chicago. That has undoubtedly helped in decreasing typhoid rates and similar diseases. When we first started to chlorinate water we did not know exactly just how much to use. I do not know whether they used complete chlorination when they started in 1912 or not. I knew its effect on typhoid rates in Chicago and the cause of their decline,
3754 but I do not know when complete chlorination was had nor do I remember when pasteurization of milk was started. I know that it was the combination of all of these circumstances that did bring about the final excellent health conditions, so far as typhoid fever and intestinal diseases are concerned in Chicago; and I also know their death rate is lower than that of other cities on the Great Lakes where they do the same thing, except they have not a Drainage Canal. My recollection is that in the last year the death rate is lower than that of the City of Milwaukee. As I recall it, the City of Milwaukee
3755 was $1\frac{1}{2}$ or 2. I have read so many of those that I would have to refresh my recollection. The Sanitary District has been down previous to last year as low as 1.1 per 100,000, and last year, according to the health authorities, it was 0.79, less than one per hundred thousand. Speaking from memory, my recollection is that it got up to about 1.4 in Chicago in 1925. I do not recall what it was in 1923.

3758 I stated that the diversion at Chicago had resulted in an improvement of bathing facilities, but did not state that prior to 1910 it was impossible to bathe in the lake. I said that bathing was very infrequent up to that time, that the lake front was not used to any great extent for

bathing. I did not mean that no one ever went in bathing in Lake Michigan. I have seen small boys jump into the Chicago River when it was nothing but septic sewage. Generally the bathing beaches developed from the demand, and this demand did not seem to exist, and the water in places along the lake front before the opening of the Drainage Canal was not fit to bathe in. There had been bathing beaches in Chicago privately operated for years, but the lake as a whole did not come into general use for that pleasure and health-giving sport until after 1910, to any great extent.

3759 I do not recall that there were extensive municipal or public bathing houses prior to 1910. Apparently there was no demand for them. It has been my observation that these facilities come when a demand exists. This diversion had no effect upon bathing, pleasure boating, etc., in the Des Plaines and Illinois Rivers. There has not been any bathing in there since I have known the streams, above Peoria. I do not know how far below Peoria.

3762 Before the Chicago Drainage Canal was opened the Des Plaines and Illinois Rivers were in a filthy condition, due to water that was coming through the old Illinois and Michigan Canal, and was not safe to bathe in. The Illinois River, due to the waters coming from the Illinois and Michigan Canal, was in bad shape before the Drainage Canal was ever opened. Below Peoria, from the distilleries, the river was in worse shape before the canal was opened than it was after, according to all my knowledge. We frankly admit the conditions in the Illinois River have not been what they should be, but it was not safe to use as a drinking supply or for bathing for many, many years before the canal was opened. That was because Chicago was already diverting a portion of its sewage down to the Illinois and Michigan Canal and,

of course, for the further reason that that is the only available place where the canal could get enough water for lockage without going to great expense. I am not trying to deny or relieve the sewage condition in Chicago.
3771 If we had adopted a policy of complete treatment of all of the sewage of the City of Chicago, according to the greatest degree of purification known in the present state of the art of sewage disposal, to the end that we might reduce our sewage load to the lowest possible point, it would have been a useless expenditure. It would not have been practical to go out and spend untold millions when it would not be necessary if we were going to get the diversion.

As to whether it is good engineering to turn raw untreated sewage into a pure running stream, if the question were elaborated as to what use is made of that stream, I could better answer it. It seems to me it is going to be an economic question as to whether the stream is of more value as a drain or as a stream without that sewage in it. Of course, I feel there is a kind of half way position, that the streams in a way are the natural drains, to the extent of taking certain waste from
3772 big municipalities, and should be utilized as far as possible to do that and relieve cities of the expenditure of vast sums, when it does not interfere very materially with other peoples. If it came to a question then the number of people that are benefited would have a good deal to do with the solving of that problem. In one case where a stream was serving comparatively few people, and it became necessary from a practical standpoint to use it to serve a much larger community, it seems to me it should be used for that purpose, providing that no great nuisance was created.

On the question of whether the untreated sewage should go into a river depending on the size of the city and the

number of people, I think the tendency is to purify sewage to some extent, and remove possibly what we call the settling solids or the solids that you see in the sewage, not those in solution. I think as we go along the tendency will become more strong to purify the sewage in our cities.

3773 The principal reason for a large flow in the Chicago Sanitary Canal is not in the slightest so as to carry the sewage away from the city rapidly so that the unpleasantness of that method of disposal is thrown upon the people down below. It is simply that the water is needed as a purifying agency. There is not enough at this time to purify it without offense in the Des Plaines and Illinois Rivers. It is not needed to get it away fast. If we had complete treatment of our sewage, we would still need the moving water, for the reason that it is not practical to treat sewage to more than 85 per cent. The remaining 15 per cent should have water to dilute it and oxidize the organic matter in the sewage.

It is my opinion that if the diversion at Chicago were limited to 1,000 cubic second feet it would render the lake unsafe for bathing purposes. It is my opinion that if the diversion were entirely cut off, or limited to 1,000 cubic second feet, it would create a condition in the Chi-

3774 cago River and in the vicinity of Chicago worse than existed prior to the opening of the Chicago Drainage Canal, but I was referring in that testimony to around about 1892 or 1893. I think the question assumed that raw and untreated sewage was going to be poured into the Chicago River. As I recall the question, it was asked both ways. Whatever the question may have been, that opinion is based upon the assumption that there would be raw untreated sewage turned into the Chicago River, and there would be under any conditions; but my opinion that it would be worse than it was prior to 1900 was

based upon untreated sewage coming into the river as it would come today, if that flow were reduced to nothing today.

3775 I think chlorination of the water supply would not protect it, with that awful load of sewage upon it. It is the opinion of the best authorities that it would be too severe a test for chlorination. I doubt if 1,000 cubic second feet would reverse the Chicago River so you could see it. The only motion that you could see, I think, would be that due to the rise and fall of the lake level. You might at certain times see it. The dry weather run-off of the Chicago River is about twelve or thirteen hundred cubic feet per second in extremely dry weather. We take the pumping supply as the dry weather run-off. Usually there is some seepage into the sewers that increases it.

3776 There have been reversals of the Chicago River in recent years. I do not know that there were eight in 1924. Some two years ago there were very heavy storms in Chicago, and there were reversals at that time to some extent. I think there was some trouble with the Chicago water supply in 1923 or 1924. The principal trouble has been complaints that were received due to the taste and odor produced from over-chlorination, if I may use that expression, not meaning over-chlorination as to the amount used for the killing of the bacteria, but to the effect that it has in producing a disagreeable taste and odor. This is particularly true with people that do not smoke. They are more sensitive to the taste and odor of chlorine. I would say that generally it has been perfectly safe.

3777 Chicago has not built any water purification works. Of course, many people buy water and the papers publish notices now to boil the water in times like that. In my opinion of the present state of sanitary plants, I think it would be better that filtering and purification of all

lake water used for drinking purposes be had. It would make the water safer. That is true of any lake city or any city taking its water from the lakes. I would not go so far as to say it ought to be done regardless of whether we have diversion through the Chicago Canal or not. It would depend upon your definition of what ought to be done. If you compare it with where it is done, the results show that our water is equally as good as that at Detroit, where they have water purification and chlorination and take their water from above the sewage intakes, as I understand; and yet a very large epidemic of diarrhoeal disease occurred at Detroit a few years ago, in spite of the fact that they had water filtration and chlorination following it.

3778 With that method of water purification, they would have to use it, but not to such a great extent. I think it would improve it. We would not have quite as much chlorination, but we would still, in order to be safe, use some; but where the water filters do not exist there often is put in so much chlorine that it results in a disagreeable odor and a disagreeable taste. I know that is so at my home in Chicago, on the South Side, which gets most of its supply from the 68th street crib. Probably the water is worse there than at any other crib in Chicago. There are two cribs located there together. At the present time the water in Chicago is badly discolored from wave action, the stirring up of the clay soil from the bottom. Filtration plants would make the water better to

3779 look at. It would be more sparkling. I think it would also be more pure. There would be probably less contamination if the sewage were diverted from the lake and the water filtered also.

I have read the records of what they do in water purification at places. There is no doubt that the operation of a filtration plant reduces the B. coli, I would say

appreciably, particularly followed by chlorination. Assuming a 150,000 B. coli load per 100 c.c., filtration might usually reduce it to 2. There is no doubt but what that is an improvement.

3780 My experience has been mostly with sewage purification. I have never been connected with any water purification plant in a professional way. They ought to go hand in hand. You ought to keep your sewage away from your water supply, and if the water supply needs a further purification and you can not get it that way it should be filtered. There are some cities that have no expenditures for water purification, and that spend considerable amounts on water supply. New York City is a notable example. Of course, they would not take their supply from the Hudson River, because it is a tidal stream and the water is salty or brakish. The cities have met difficulties that happen to exist by reason of their geographical locations, and some have more expenses for sewage disposal and some more expenses for water

3781 supply. That is the same thing that Chicago did.

3790 As to whether the activated sludge in some cases coupled with Imhoff tank treatment, is the highest type of sewage treatment now in use, I would like to qualify that to the extent that in some very small places they get very effective treatment by other methods where the population is not large. I think taken in connection with tanks of some kind an activated sludge followed by proper treatment is probably as efficient a method as we have, although trickling filters are very good, but not as good as activated sludge; and it depends considerably upon the length of time that you activate your sewage.

3791 If all the sewage of Chicago were completely treated by that process, we would probably get an effluent of around twelve or thirteen hundred cubic feet per second, provided the water supply continues to be as it is at present.

As to whether the limitation of 1,000 second feet of this diversion with complete treatement of that character producing that effluent would be injurious to the health of the City of Chicago, considerable quantities of this effluent would find its way to the lake and also it is not practicable to treat all of the storm flow that comes to a sewage system of the size of Chicago. As I stated before, there is an accumulation of filth in the sewers which is scoured out by the first flush of the storm and the storm bow is probably ten or twelve times as much as the dry weather flow, and it is not practicable to build sewage disposal works and intercepting sewers to absolutely treat all of the storm flow. The result is that large quantities of this storm flow, the larger quantity, about 90 per cent of it at maximum floods, goes into the river and that filth is scoured out into the lake, with only 1,000 feet diversion.

3792 If we had separate sewer systems that objection would be obviated to a large extent, but it would cost about three hundred to four hundred million dollars to change that system in Chicago. That figure was based on our experience of cost of other works of the Sanitary District and other places around the Sanitary District.

I think if we had a flow of practically what we are permitted to take now, 9,700 cubic feet, with the sewage that the increase from that to 12,000 second feet would not be so serious. It would increase the flow quicker with our present plant and the chance of its going into the lake would be materially reduced, although I think at times it would get away and some go in.

3793 I do not remember stating that it would take 13,000 to 15,000 second feet to reverse the Little Calumet River. There was a measurement made once, years ago, that showed a flood discharge of the Little Calumet of 13,000, but since that time, as appeared in the evidence, I be-

lieve, there had been a channel cut from the Little Calumet River between Gary and Michigan City, I believe, which diverts flood waters of the Little Calumet above that point and somewhat below it into the lake at that point, some miles east of the present outlet of the Calumet River. The drainage basin of the Calumet is much larger than the Chicago, but I do not know what the drainage basin of the Calumet is up to where this Burns ditch has its effect on the Calumet. I do not know whether the measurement I spoke of was at extreme high water of the Calumet or not.

3794 Of course, you could conceive that all the water that Chicago drank was distilled, but the expense would simply be out of the question. You could conceive that the sewage might all evaporate, carrying it to an absurd conclusion, but in a practicable working of the art as it is done in cities, and as Milwaukee is aiming to do, about 85 per cent is an average condition of purification. It would be practicable to treat all of the sewage of Chicago by activated sludge process coupled with an Imhoff tank, if you do not consider the financial end of it. As an engineering possibility all of the sewage of Chicago, if we throw away some of our works, could be treated by activated sludge method, I think. There would be some in the storm flow, as I have tried to explain, that we would not be able to take care of.

3795 If we had a separate sewer system we probably would get most all of the sewage to the sewage plant with the exception of street wash. It is not always the best in the world to go into a drinking supply, but, generally speaking, it would probably take care of it all, to 85 per cent. When I speak of 85 per cent treatment, that considers, I presume, 65 to 75 per cent of suspended solids to be removed by the treatment, or maybe more. I would doubt that 95 per cent is removed. It may be a little

larger than I have said. I have not looked lately at what results we are getting, but in the preliminary settling we used to figure that we got about two-thirds of the suspended solids out in a reasonable length of time.

3796 I think following that with the settling coming from activated sludge you would get up around 90 per cent removed. 98 per cent bacterial removal has been secured. You could also chlorinate that effluent afterwards. I think that would not render it perfectly innocuous in a great big system where it would be dumped into the Chicago River, and I believe it would be impracticable to chlorinate, and there is organic matter there. I am not saying it is not a good treatment, but I am still saying I think about 85 per cent is the best we can do in a practical way.

3797 As to why this problem is peculiar to Chicago, with the exception of Great Lakes cities, I said on account of its geographical location and the topography of the country, Chicago is able within practical limits to send diverted sewage from its water supply into the Des Plaines River. Such a situation does not exist anywhere else in any large city that I know of on the Great Lakes, unless possibly I might say Buffalo which, in a way, takes its sewage and dumps it into the Niagara River below itself and pollutes the water supply of Niagara Falls. I think the other large cities on the Great Lakes will have to meet that problem in a way that Chicago refuses to do, if they have not done it yet. Milwaukee has not. They have a large sewage disposal plant there which they have been operating for a year and a half. I examined it just before they were going to operate. They are by-passing half their sewage now, and the plant is supposed to be large enough to take it all, but they have not been able to do it successfully yet. My statement that Chicago is peculiar with reference to that problem dealt with the fortunate loca-

tion that Chicago has, in order to be able to take care of its sewage so efficiently by the method it now em-
3799 ploys. Leaving out the benefits of that situation, there are other cities in all parts of the country so situated that they have a similar hard problem of polluted water supply. Cleveland and Milwaukee have. Right offhand I do not think of any leaving out the Great Lakes cities. I presume there are. Detroit has no serious problem. That is a river city.

Assuming a city located below another city, the upper city not having a 100 per cent purification disposal plant and discharging its sewage into the water and the lower city taking its water supply from that river, of course, the upper city has the benefit of the dilution system, and the time element enters into that, purfying the sewage and killing the bacteria.

3800 If the streams where the cities are located are so close it is almost immediate, the time element does not affect the purification as much as though the distance were greater. I do not know how many cities there are in the United States situated in such a position, small villages and hamlets. Of course, there is Niagara Falls which is below Buffalo. I presume those cities so situated do or should meet the problem by filtration plant or chlorination of their water supply. I am not familiar with what all of them do.

The Witness was asked his opinion of the following statement made by Mr. Soper in the report of the so-called International Commission:

"We have been unable to find anything in the situation at Chicago as regards drainage or the sociological condition of its inhabitants which warrants the adoption of lower sanitary standards than are suitable for the most enlightened communities. To attain to these standards, the city needs works of main drainage and sewage dis-

posal such as other great centers of population have found it necessary to construct."

Well, some other cities have constructed sewage disposal works, and others, like New York City, have not to any great extent. Cleveland has not to any great extent. I disagree with them when they say we have not good sanitary conditions and standards in Chicago. It is true, as I stated, that conditions in the Illinois River are not what they should be but we are trying to get them into shape as fast as we can, from a physical and financial standpoint.

3804 I would say the expense of putting in filtration plants in the City of Chicago would be somewhere between fifty and sixty million dollars, although there have been lower estimates. There are about three and one-half million people in the Sanitary District. You can figure out what that would be per head of population. Twenty dollars, or something like that. I recommended that in my report of 1911. I think it is desirable from an aesthetic standpoint, and as a safe treatment. I did not recommend that it be done entirely because of the reversal of the flow of the Chicago River at that time.

3805 I also took into consideration the pollution of Lake Michigan from passing ships. However, that is being somewhat controlled now by the cooperation of the vessel owners. It is remarkable how well they are cooperating in that matter. There is also some pollution from a certain amount of shore drainage, off the streets, that cannot be controlled. I do not believe that amounts to very much. There is some pollution coming in from the Indiana towns and from the Calumet River. The water at the 68th street and Dunne Cribs is usually in a worse condition than the others.

3806 *Redirect Examination by Mr. Adcock.*

When I spoke of "by-passing" sewage in Milwaukee, I meant they are having trouble in operating their works, and with the sludge-handling devices and drying devices, and so they have up to recent times—I have not heard of its being changed—by-passed practically fifty per cent of their sewage, letting it discharge into the lake without treatment. I refer to the dry weather flow. I do not recall at this time the percentage of the sewage the Milwaukee plant will take care of, or the percentage of purification. I have not seen an analysis of what they have done.

3807 The size of Chicago, located on Lake Michigan, has something to do with the solution of the problem of disposal of sewage or protecting the water supply. As the city becomes larger, the problem becomes greater and usually more expensive. Particularly is that so with a city growing rapidly, as is Chicago, increasing at the rate of about 750,000 every ten years. The problem of a lake city disposing of its sewage is one intimately connected with the protection of the water supply. All of these lake cities like Chicago, Milwaukee, Cleveland, get their water from the lakes, and that is their only water supply.

In referring to a flood or heavy rain in Chicago when there was a reversal in the flow of the Chicago River,

3808 in 1923 or 1924, there had been severe rains in Chicago at that time, very unusual for that season of the year. That was estimated at about 11,000 second feet. I doubt if that would happen more often than once a year, if that often. I do not recall how long the river was reversed at that time. If the diversion had been reduced to as low as 500 second feet, and a heavy rain at that time came along, such as the one referred to of 11,000

feet, the reversal would be greater in volume and time than it would be with that dilution.

3809 A separate sewer system, so that we would have a sewer only for the sewage, and a sewer for the storm run-off or other drainage, would mean the reconstruction of all the sewers in Chicago, or the adding of another system, the tearing up of all the streets, the making of new connections between every building and its domestic sewer, the shutting off of all connections between the buildings, and the present storm system—or the combined system; and it would be impossible to estimate the damage it would cause, with the intangible loss to the City of Chicago by having to do this. Outside of the cost, while it would be a guess, I think it would take twenty or thirty years to do this.

3810 The matter of the flood times has an important bearing on the question of what the percentage of purification would be, because it is impracticable to purify all of the storm water that is mixed with the domestic sewage in the combined sewers. In order to free all of that storm flow, in the first place, you would have to build your intercepting sewers to about eight or ten times of their capacity under the present condition—maybe that is a trifle large; I might say seven times—and the disposal works would have to be built correspondingly large, to take this large volume that would come there in times of storm. That would run the cost up to a prohibitive figure. I do not know of any city of any size in the world that has installed any such system as that. I know of some small towns and villages that have a separate system, but I do not know of any large city that compares in any way with Chicago, where they are treating the storm water.

3815 The 68th street crib and the Dunne crib are practically alongside of each other. I do not think they are

over 100 feet apart and they are the cribs that are nearest to the mouth of the Calumet River, and to the Indiana towns, and the water supply there is more apt to be contaminated than at the other cribs; and for that reason there is usually more chlorine put in the water than at other cribs further to the north. There is some pollution that comes from the Indiana towns. Practically the only pollution I know of in the water supply is beyond the Indiana line.

3816 If we had the sewage going into the lake, if we had this purification of sewage referred to, to the amount that I say is practicable, and had a water filter, if the water supply were filtered, and we had chlorination, with the sewage going into the lake at times, the only barrier against the people getting contaminated water would be these artificial means; that is, the perfect operation of the chlorination system and the water filtered at all times.

In referring to the situation at Detroit, it seems to me that was within the last year. There were several hundred thousand cases of diarrhoreal diseases there.

3817 Detroit has a filter. It filters its water supply, and also chlorinates it. The pollution or contamination of that supply was traced to some sewage pollution above, or blown up by the wind on the surface of the water against the current, from the pollution in the water in Lake Erie, and it was claimed some backing up of Lake Erie there at the time, so that the Detroit River did not flow as rapidly as it had before.

In speaking of this diversion as serving the purpose in the Illinois River of diluting or oxidizing the sewage, that was not the only purpose. I referred to the necessity at all times of keeping the sewage or contamination out of the lake.

3819 When I said the Sanitary District had not done any-

thing in the way of taking solids out of the sewage, except to look after garbage and dead animals, etc., I referred to the time prior to 1914. I thought I made it clear that I did not want to be understood as covering any date later when they put in some purification works.

Cleveland and other cities around the lake have been letting their sewage go into the lake practically untreated, except Milwaukee, and that has been only within the last year that they have done any treatment there. I think back ten or twelve years they commenced to work
3820 on that, and they have been ten or twelve years developing plans and putting in the works. The sewage of these towns flows into the rivers and from there into the lakes, or goes directly into the lakes.

Along the Des Plaines and Illinois Rivers there are a number of towns of considerable size, Joliet, Marseilles, Ottawa, that discharge their sewage into the river. Joliet has a population of sixteen or seventeen thousand.
3821 They have always done that since they have had a sewage system. And Peoria with a population of ninety or one hundred thousand.

Re-cross Examination by Mr. Jackson.

In referring to an outbreak or epidemic in Detroit, my knowledge is just as a matter of engineering knowledge and opinion resting in things of that kind with people whom I have talked to and who have read to me. I have not seen it, of course. All I have heard is what I have had read to me from technical papers and from talking to sanitary and health officers. As I re-
3823 call it, there were somewhere around 200,000 cases.

In response to Mr. Adcock I said the Sanitary District had not taken any fecal matter out of the sewage prior to 1914.

3824 Since 1914 there is a pretty good size plant built at Des Plaines and Calumet. The Sanitary District in a way did remove solids by retaining them. They probably did not want to, but they did, due to sedimentation in the canal and river itself that did not find its way to the Illinois River. Sludge was so heavy that it showed in the canal in spots, but no works had been built prior to 1914.

3826 I said that 8,500 cubic feet per second through the Chicago Canal, plus the 1,200 for sewage, making a total flowing at Lockport of 9,700 when we can get that through, will practically keep the river flowing away from Lake Michigan all the time. In case of a severe storm we would shut the controlling works in the Sag Channel and it would take nothing from the Calumet River. That would reverse the Calumet Sag Channel and Calumet River and cause them to flow into the lake, but that is not as serious as the other. It is not quite as serious in the Indiana cities as it would be if practically all of the sewage of Chicago, which is in the Chicago River, goes into the lake. It is not a thing to be desired, but we choose the lesser of two evils, and this big flood occurs only occasionally and we have to make the best of it.

3827 We did not also take about one thousand cubic feet of our water through the North Shore pumping station and down through the North Channel. We shut that down in time of flood. We do not pump any lake water into the channel at all, except as it comes through the drinking supply in times of heavy flood.

3828 Assuming that the geographical situation of Chicago were such that the construction of a drainage canal, as is now in existence, were impossible, it is my opinion as a sanitary expert that the sewage and water supply problems of Chicago would be solved, but not as

well as they are now being solved. I would not say they would be solved so that the conditions in Chicago would be perfectly healthful. That is going pretty strong, as I understand the meaning of the word "perfect." As cities generally go, I assume that would be done, that they would do as well as they could. I think it would work out in the best way possible, and while the result might be satisfactory, it would not be as satisfactory as at present.

3829 If I were called upon now to design a sewage treatment proposition for Chicago to take care of its water supply, and there were no sanitary or drainage canal in existence or any of its works, I certainly would advise, in the present state of sanitary science, the installation of such a system, because it would improve conditions over what they would be without it.

If we could build the canal and dispose of the sewage as we are doing it, I would do that in preference to putting in artificial methods, except possibly to the extent of removing objectionable solids and keeping the sewage matter away from the drinking supply. Even if it were healthful to drink the effluent from a sewage disposal system, yet it is not a very delicious thought to think you are doing so. I suppose Milwaukee is now

3830 drinking the effluent coming from a sewage disposal station to some extent, and to some extent drinking the raw sewage, when being fixed up by chlorination. My testimony is that turning that sewage into the lake, and having the intake from that same lake, at least part of that sewage effluent is going to get to the water intake during the course of a year. It may not be every day, and some may every day, depending on how far apart they are, and the direction of the wind.

3831 I do not know whether it would be entirely purified by that time. It would depend on how long it was be-

fore it got to the intake and how far apart they were. I suppose there are some places on Lake Michigan at the lower end where the intake could be set fifteen miles from the shore. It would be very expensive.

Redirect Examination by Mr. Adcock.

This diversion plan by which this water is diverted from the lake works scientifically and automatically, and does not require the hand of man or artificial works.

Dr. William A. Evans, for defendants, January, 1927. Health Expert:

3855 *Direct Examination by Mr. Lewis.*

Live at 2319 Commonwealth Avenue, Chicago, Illinois. Am a physician and surgeon. Graduated in medicine in 1885 and am licensed to practice in the States of Mississippi and Illinois and do practice in Illinois. Have degrees of B. S. and M. S. from the Agricultural College of Mississippi, M. D. from Tulane University Medical School in Louisiana, Doctor of Public Health from the University of Michigan, Doctor of Laws from Tulane and the University of Mississippi and another M. D. from the University of Illinois.

Have been Professor of Public Health at Northwestern University Medical School since 1908, finishing my ninteenth session.

3857 Prior to that time for seventeen years was Professor of Pathology at the University of Illinois Medical School. Am a writer on the subject of health for the Chicago Tribune and the Tribune Syndicate and have been since 1911.

Am a member of the American Public Health Association and have been president thereof; of the Illinois

Health Society; the Illinois, Chicago and American Medical Associations, and various health societies such as the Chicago Tuberculosis Institute, the Illinois Social Hygiene, the Chicago Heart Society, Infant Welfare Societies, and perhaps others.

3858 Have lived in Chicago since 1891, and was Health Commissioner for the city from 1907 to 1911. Am at present on the State Board of Health of Illinois and on the Advisory Board of Health of Cook County and of Chicago. Began practicing medicine in Chicago in February, 1891, and had considerable opportunities for knowing of conditions as they were during the years preceding the opening of the canal in 1900.

3859 Since 1907 my opportunities to know conditions have been better still by reason of official connections which have been continuous or nearly so.

3860 In the nineties the water in the Chicago River was almost indescribably foul. The water was black and bubbling and sludge was floating here and there. It happened not infrequently that the river would catch on fire. The fire department was occasionally called out to extinguish a fire on the river. I once saw a fish start up the Chicago river and he was caught by hand at about the Adams Street bridge. The water flowed into Lake Michigan quite frequently whenever there was a storm and the currents carrying sewage out into the lake could be traced for considerable distances in the lake.

3861 I have seen streams of pollution extending out as far as the cribs or water intakes.

3862 The health of the city was very bad. The death rate was very high and the typhoid death rate was especially high. The maximum typhoid death rate was reached in 1891 or 1892 with a rate of 173.4 per 100,000. The death rate from diarrhoeal diseases was high, and, as I have stated, the general death rate was high. The sickness rate was correspondingly high.

The largest single factor, certainly in the high typhoid rate, was a polluted water supply. It was an important factor in the high diarrhoeal death rate, although not the most important.

The changes since the opening of the Sanitary Canal have been very marked and notable. The very high death
3863 rate of Chicago of the nineties has been succeeded by perhaps the lowest death rate of any large city in this country, so far as the general death rate is concerned. The death rate from typhoid fever has been reduced to 1 per 100,000 or thereabouts, which has been held for just ten years, showing that it is not an accident or temporary improvement.

No other city, I believe, in the civilized world has had so marked an improvement in its death rate and its typhoid death rates as the City of Chicago has experienced during the past 36 or 37 years. Starting from a position that was worse than the position of the other lake cities in the nineties, it has moved to a position which is better than that of the other lake cities at the present time.

3864 Typhoid is contracted practically exclusively by swallowing polluted articles. There may be a little typhoid contracted by inhalation, but that is altogether theoretical, and I think improbable. The articles that are commonly taken into the mouth, polluted, and are therefore responsible for typhoid fever, are water, milk, oysters, and vegetables, and of these water is infinitely the most important.

Typhoid is regarded as a yardstick by which not only health is measured but by which the works of health departments are measured. If a community has a high typhoid rate, it is accepted among health officers (and I claim to have been one) that the community has poor health conditions; that it has a health department that

is not functioning very well; that under certain circum-
3865 stances they have not much regard for the decencies of life.

It has been discovered that when we decrease the deaths from typhoid fever we incidentally decrease the deaths from other diseases. About that time there was developed what is frequently known as the Hazen phenomena or the Mills-Reinecke phenomena, described by those three gentlemen rather separately to the effect that when you save, let us say, a thousand lives that otherwise would have died from typhoid fever, by purifying the water supply, in some other unexplainable way you save three thousand lives from other causes.

3866 It was determined, and I think is now accepted by health officers, that a part of that improvement is the result of improvement in the death rate or sickness rate from diarrhoeal diseases among adults and among babies, but particularly among babies. I believe that demonstration was first made by McLaughlin of the Public Health Service.

3867 There are three barriers for protection of the water supply: Diversion of sewage from the supply, chlorination of water, and filtration. The great majority of places employ diversion of the sewage; chlorination is very generally used; filtration somewhat less generally; and I am aware of a few places at which both chlorination and filtration are employed.

Diversion of the sewage is far and away the most efficient of the three procedures. It is infinitely better to protect the water supply from pollution than it is to endeavor, by whatever means, or however scientific they may be, to purify it after it has once been polluted.

The custom is to employ at least two of these procedures; there are places that are employing three.

3868 There are comparatively few places now that are without some one of the three. There are some places, though not very many, that employ one, but no more than one.

Chicago employs diversion and chlorination. Diversion is our chief method of defense and it is responsible for 95 per cent of the results, for which we are proud. Those results are reduction of the typhoid death rate from about 174 to 1; reduction of the general death rate from about 28 to a little more than 11; reduction of the infant mortality rate to about 70 or 80. There are men who believe that we had an infant mortality rate as high as 300 back in the nineties.

3869 The facts have been studied carefully and the opinion is not ill considered. I have never thought it was as high as that, but it was certainly as high as 200.

Typhoid is by no means a local proposition. In the first place, a considerable part of the people who have typhoid in one place contract it in other places. The incubation period of typhoid fever is at least a week, sometimes two weeks, rarely three weeks. There is an interval of about three and occasionally seven days after a man begins to feel sick before he becomes bedfast. That gives between two and three weeks between the time when the man is infected and the time when he becomes bedfast.

During that time men can, of course, travel a great distance. In three weeks a man can go from one con-

3870 tinent to another. In fact, I have seen a man sick with typhod fever in Paris who was infected in New Jersey. I have seen men who were infected with typhoid fever in California who were sick in Chicago or at other points in Illinois.

Since about 1902 we have known the typhoid carrier, who is a person not sick with typhoid but who bears

typhoid germs in his body and is capable of infecting others. It is generally accepted now that of those who recover from typhoid about two per cent are chronic lifetime typhoid carriers, a large percentage of them capable of infecting people for the remainder of their lives. Different authorities give this figure differently, say from ½ of 1 per cent to 10, but the consensus of opinion is about two per cent.

3871 We are now of the opinion that that is the most important cause of typhoid fever in the United States. Pollution was the most important in the nineties but since the improvement of that situation the carrier has become more important. This is certainly true of the protected cities such as Chicago and New York. In many places they hold that the carrier is responsible for about 40 per cent of typhoid. Carriers have been known to infect several thousand people. Under former conditions, in all probability, we were making in Chicago something less than 600 typhoid carriers a year; at the present time perhaps two or three a year.

3872 Of course, Chicago is a railroad center. About 1,600 cars are watered in Chicago every day. About 250,000 suburbanites come into the city and go out every day, and something like 60,000 transients other than suburbanites. So that, according to calculations which I have made, people other than Chicago people undergo about 96,000,000 exposures in Chicago every year for a day's unit. That would mean 96,000,000 drinking water in one day, though of course the actual number who drink it is not so large as that. I do not know the number of people who travel on boats but I think it is only moderate.

3873 Boats and trains take on water at Chicago. Prior to 1910 there were a great many epidemics of typhoid fever and diarrhoeal diseases on vessels on the Great Lakes.

I have read and investigated the subject widely and I found that the typhoid rate among the crews was higher than the typhoid rate of the community from which they came. We began an agitation which resulted in the passing of rules by the Public Health Service relating to water supply and by the City Health Department of Chicago relating to the discharge of sewage.

Prior to 1910 the vessels frequently took their water from the harbor. At the present time they only take
3874 on water that conforms to the requirements of the service, or else they have means of purifying the water. As a result the death rates among the crews of Great Lakes vessels is now down to about the level of the typhoid death rate of rural communities; it has not yet reached the level of urban communities.

3875 In 1908 my attention was called to the fact a good deal of our typhoid fever was coming to us from Hammond, Gary, East Chicago, and Michigan City, cities located at the foot of Lake Michigan, taking their water out of the Lake, and discharging their sewage directly or indirectly into the Lake. Some of these cities are practically continuous with the City of Chicago. Chicago
3876 people were getting their typhoid in Hammond and in addition these cities were contributing to our typhoid by depositing their pollution where it could reach our crib intakes with a short flow.

Some of these places are protecting their water supply by chlorination, some of them by chlorination and filtration, and some of them by filtration without clhorination. In none of them is there complete diversion of the sewage.

I served as president of the Lake Michigan Sanitary Commission which spent several years in investigating the condition of the waters at the foot of Lake Michi-
3877 gan. As a result of chlorination or filtration, begin-

ning in some instances in 1915, they have had a very material improvement, but in no case has the improvement been satisfactory in my judgment. For instance Gary began chlorinating in 1915, since when they have had typhoid rates as high as 83, but immediately following the year in which they began chlorinating the rates were 23, 31, 10, and I find one rate as low as 1½. In contrast, however, Chicago has had 1 for about ten years.

3878 East Chicago began filtration in 1920, since when they have had the typhoid death rate as high as 25. They had one year in which they had no deaths and there were none the first ten months of this year; but the lowest rates they had were 4 and 7.

Whiting has been filtering since 1920 and has had a pretty good record, though in one year the rate was 18.

Hammond has been chlorinating since 1918, using about as much chlorine as the people will stand for; and in spite of that they have had rates as high as 51, 21, 41, 17, 26, although I find they did have a rate as low as 6 and 9, which again I compare with our 1. Michigan City has not had a rate anywhere comparable with ours.

I think we are entitled to the conclusion, therefore,
3879 that no method of purification of water by chlorination or filtration, alone or combined, has sufficed to protect water according to existing standards. By existing standards I mean that, under the conditions now prevalent in this country, a city with a typhoid death rate exceeding 20 is regarded as scarcely a decent place in which to live. Cities are in bad odor now if their typhoid death rate is over 5.

Filtration of water supply is an effective method of
3880 purification, but there are few places, if any, depend-

ing upon filtration which have not experienced breaks in their method of protection, for one reason or another. Literature is full of illustrations of typhoid outbreaks and diarrhoeal outbreaks as the result of breaks in operation, physical or otherwise, of filtration plants.

It is my professional opinion that without diversion we could not hold our typhoid death rate as low as it is, nor do I believe we could maintain our general death rate.

3881 If we were limited to taking from the lake such water as would be required for domestic purposes, say 1,000 cubic feet, my judgment is that we would have a very considerable increase in our typhoid rate.

3884 I do not believe it would be possible, by any method of purification of sewage and the protection of the water supply to maintain as good health conditions as we maintain in Chicago now by the method that we employ at present.

The present system of protection is, under the circumstances, the best that could be applied in Chicago. None of the other systems which have been suggested, even if they could have been put into effect, would have had so beneficial an effect upon conditions from the standpoint of public health.

3885 If we were to discharge the sewage into the lake untreated, we could probably hold the death rate from typhoid down to 50, or somewhere thereabouts. We might be able to hold the general death rate down to 20; the diarrhoeal death rate amongst babies down to, perhaps, 130. The things that we could do to compensate are more effective now than they were in the nineties. I do not believe we could maintain conditions that are regarded as conditions of decency amongst civilized people, although they would not be so bad as they were

3886 in the nineties.

Under such conditions we should have to discontinue beach-bathing. I used to go swimminng occasionally in Lake Michigan in the earlier days and I now swim daily in the summer. It was while I was Health Commissioner that our people began to use the beaches. Practically the foot of every street is now used as a bathing beach; there are several large public beaches. Bathing first came into vogue about 1909 or 1910. Occasionally we
3887 have to close a beach on account of pollution; the beaches around 80th street were closed most of last summer. The beach that I swim in, the Oak street beach, was polluted once or twice by ashes from the South Chicago Rolling Mill, but I do not believe there was any sewage pollution up there at any time. If raw sewage were discharged into the Lake in volume, I am quite certain that we should have to discontinue the use both of the public beaches and of the ends of the streets as bathing places.

Cross-Examination by Mr. Jackson.

3889 In 1891 the typhoid death rate was 174.2; in 1899 it was 27.2; that drop cannot be ascribed to the drain-
3890 age canal. Nevertheless, it was a fair statement to attribute the reduction in the typhoid death rate in its major proportions to the opening of the drainage canal. There was always epidemic typhoid in Chicago and in every other city. There is considerable fluctuation in the typhoid rate from year to year. The years 1891
3891 and 1892 were the maximum peak in Chicago. It is the history of typhoid that it will fluctuate considerably from time to time. It is natural that there should be a fluctuation in the year 1900. In addition thereto, we find that the people were doing a good deal to make water conditions tolerable. The Health Department was constantly advising the people to boil the water. The

newspapers were carrying statements to that effect every day. The people were expending large sums of money in boiling the water and otherwise purifying it. They were drinking large quantities of mineral water. The improvement between 1891 and 1900 was partly the result of the recession of the wave action customary in
3892 typhoid and partly the result of extensive health protection measures. A fairer way of making the contrast is by ten-year periods.

From 1892 to 1899 there was no year in which the typhoid rate exceeded 53.5 (the rate for 1896). In 1902, the third year of the opening of the drainage canal,
3893 the typhoid rate was 44.5, which was higher than four of the six years from 1892 to 1899, although 1898 was practically the same. 1898 was the Spanish-American War period, though its characterization by counsel as "the epidemic year of the Spanish-American War period" is new to me.

3894 From 1912 to 1916 there was a marked general improvement in the typhoid rate over preceding years; the
3895 figures were 1912, 7.6; 1913, 10.6; 1914, 6.9; 1915, 5.3; 1916, 5.1. The partial chlorination of water supply was begun in 1912; other things happened as well.

3896 I was Health Commissioner from 1907 to 1911, during which time we began the chlorination of the stock yard water. In 1912 the city began in a larger way at the Dunne crib. All the typhoid rates from 1912 to 1916 are under 10, except 1913, which is 10.6; and far
3897 lower than any rate ever had before.

In 1917 there was a drop in the typhoid rate from 5.1 to 1.6, being the commencement of the present low rate. I do not know whether this was the year when complete chlorination of the water supply was commenced, as suggested by counsel; I should say that the complete chlorination of water according to the present development of the art, began in 1926.

3898 It is true that on the exhibit of the Sanitary District on the easel there is the statement that complete chlorination of water was begun in December, 1916; but that is inaccurate, and there are some other minor inaccuracies in the chart. The statement as to the pasteurization of milk is not exactly accurate either; it began in January, 1909, and not in January, 1910.

3902 At this point counsel read into the record an offer in evidence from page 219 of Document No. 4, 69th Congress, first session, Committee on Rivers and Harbors, House of Representatives, which is Complainants' Exhibit No. 18 for identification, the following statement out of the table entitled, "Table 1—Comparison of Typhoid Fever with Total Mortalities in Chicago (Based on Chicago Department of Health Records)."

Year 1917. Death rate, all causes, per 100,000, 14.79. Total deaths from typhoid fever, 43. Deaths per 100,000 from typhoid fever, 1.6. Per cent total deaths, 0.11. Under the Heading "Remarks" Complete Chlorination of Water.

3903 Since 1891 there has been considerable advance in medical science; more advance, I should say, in public health than in medicine. There has been a great advance in sanitary measures other than the matter of water supply. It is to be expected that these advances will be reflected to some extent in death rates.

3905 There are other methods of contracting typhoid fever besides the drinking of polluted water, although the cause suggested by counsel, "Unsanitary conditions in the home" is too broad and indefinite. Small children might get typhoid occasionally by climbing about the floors, though that would not amount to very much.

Typhoid carriers have typhoid bacilli in the bowel movement and in the urine and those typhoid bacilli get into the water and milk and other articles of food. In

some instances they get on the body of flies and in that way indirectly get into the food. There may be other
3906 ways such as infected fingers. Much of it is milk infection; some is infection of food other than milk. Much of it is water infection. The carrier is now the principal source of typhoid fever in the large cities.

In smaller cities the typhoid rate is naturally subject to greater fluctuation than in large cities. A few cases influence the rate more in small cities.

3907 There has been marked improvement in health conditions in every modern city in the last thirty-five years.

3908 I think we have got about as good a water supply as anybody has, but I would not want to say that it was perfectly satisfactory.

3909 The Public Health Service standard for bacteriological quality is as follows:

"(1) Of all the standard (10 c.c.) portions examined in accordance with the procedure specified below, not more than 10 per cent shall show a presence of organisms of the B. coli group.

"(2) Occasionally three or more of the five equal (10 c.c) portions constituting a single standard sample may show the presence of B. coli. This shall not be allowable if it occurs in more than (a) 5 per cent of the standard samples when 20 or more samples have been examined; (b) one standard sample when less than 20 samples have been examined."

3910 "Note: It is to be understood that in the examination of any water supply the source of samples must conform to both of the above requirements (1) and (2). For example, where the total number of samples is less than six, the occurrence of positive tests in three or more of the five portions of any single sample, although it would be permitted under requirement (2), would constitute a failure to meet requirement (1).

"Definition: A B. coli group is defind, for the purpose of this test, as in Standard Methods of Water Analysis, American Public Health Association, New York, 1923, and the procedures for demonstration of organisms in this group shall conform to those of the 'completed test' as therein specified."

3911 In the report published on page 703 of Treasury Department Public Health Report, Volume 40, No. 15, April 10, 1925, the following comment may be used in explanation of the rule:

"In accordance with these principles the first requirement stated in the standard, namely, that not more than 10 per cent of all the 10 c.c. portions tested shall show the presence of B. coli may be interpreted as implying that the mean density of B. coli shall not exceed about one per 100 c.c."

3912 As a general proposition the water supply at Chicago complies with that requirement. According to the report of the Department of 1925 there were a moderate number of instances in which it did not conform. The Department believes at the present time that it is conforming practically 100 per cent.

Councel for complainants produced an official document of the United States Public Health Service, entitled "Report on an Investigation of the Pollution of Lake Michigan in the Vicinity of South Chicago and the Calument and Indiana Harbors, 1924 and 1925, prepared by H. R. Crohurst, Sanitary Engineer, and N. D. Veldee, Past Assistant Surgeon, United States Public Health Service, in Cooperation with the Sanitary District of Chicago and Others," which was marked Complainants' Exhibit 155 for identification.

3913 The table on page 57 shows that the B. coli reading (mean for 12 months) for 100 c.c. for the Chicago intake ran from a minimum of 4 to a maximum of 50 between

November, 1924, and October, 1925. The highest mean for the highest month showed the B. coli reading in one instance 380 and in another instance 362.

3914 In the instance of the two high yearly means and monthly mean there was excluded in each instance a single extraordinary result on one day. I believe the figures to
3915 be accurate. During this period chlorination was the only chemical treatment of the water supply.

Filtration, plus chlorination, plus diversion should have
3916 given us a better product than we had. A better opinion than mine can be obtained as to the operation of a purification plant. My experience is that with heavily polluted water the hazard of having a breakdown where both filtration and chlorination are employed is considerable.

3918 In Detroit, Michigan, in February, 1925, there was an epidemic of diarrhoea and dysentery involving about 200,000 people, according to the estimate of the Health Commissioner. The water supply was protected, I think, by chlorination, but protected.

3919 I do not think I have made personal observation of
3921 any breakdowns, except that I call attention to the break at Whiting, Indiana, where chlorination was begun in 1915, and where filtration was added in 1920. I do not know the type of plant. The filtration plant was built
3922 about six years ago and I should say it could be called a
3923 modern plant. I do not know what the B. coli index of the raw water was. I do not know what particular kind of break they had there.

Assuming that you had complete treatment of all the sewage of the City of Chicago, according to the best type of sewage treatment and purification known to sanitary science at this time, in my opinion there would be some danger of the drinking supply of the City of Chicago, if it had modern filtration and water purification plant,

supplemented with chlorination. I base my conclusion that cessation of diversion would create unhealthful conditions upon the assumption that untreated sewage would thereby be turned into Lake Michigan.

3925 If there is added as an additional condition that the effluent of this sewage plant is also chlorinated, there would still be some danger, although it would not be to the same degree.

Even with sewage purification—85 per cent complete purification—there still remains a certain amount of matter which is not purified. In addition thereto we would have shore wash and storm water, and the river flowing

3925-a into the lake, which is, in my judgment a condition necessary for the complete and proper protection of the public health.

3926 Assuming the removal of 95 per cent of these suspended solids, 98 per cent of the bacteria, a chlorination of the effluent, a reduction of the oxygen demand to 7 parts per million, and the location of intakes four miles and further out into the lake, with a water purification plant and chlorination, I do not believe that the water would be what we would like to have it, even under those circumstances. I have known of the outflow of the river going

3927 more than four to six miles into the lake. The various commissions on which I have sat, where bacterial and chemical examinations of the water at various parts of the lake have been made, have indicated that there is a moderate amount of pollution out that far. Under most conditions I think that chlorination and filtration would provide a satisfactory safe water. There would be conditions in which we would have breaks, even with all the safeguards.

3928 Assuming a diversion of 1,000 second feet through the drainage canal and a clear, non-putrefactive effluent of the kind and character I have heretofore described di-

verted through the drainage canal, assuming a modern
3929 purification works and chlorination, I think that the water would be better protected under those circumstances. There still would remain the existing condition of shore wash, and the periods in which we have had storm outflows into the lake. We will have chlorination and ultimate filtration in the course of time—a protection. I hope we will have it. I would still feel that there would be times when we would be subject to small epidemics, small breaks. I think under those circumstances we could hold the death rate for typhoid fever below 5 pretty much all the time.

3930 I do not think there would be a very great deal of difference between the water under the conditions you have predicated and the water we have now.

3933 I know a good deal about the milk sold in the cities of Whiting, Hammond, East Chicago, and the general sanitary conditions, as well as the sewage disposal and the water. They are, of course, conditions entering into the death rate.

It is not true that in the computation of the typhoid death rate for Chicago in recent years there have been excluded those typhoid deaths where it was believed that the disease had been contracted outside of Chicago.

Re-direct Examination by Mr. Lewis.

3950 Our sewers have not very much fall, and a good deal accumulates in them. With diversion limited to 1,000
3951 feet, this would wash out into the river and then into the lake at times of storm. When conditions of wind and weather were right it would reach the cribs. A modern purification plant would not fully relieve that condition.

3954 The method of chlorination that is now customary is the addition of enough chlorine to leave an amount of

free chlorine in the water after the organic pollution has used up a certain amount. We came to that method after the little typhoid epidemic of 1923 or 1924. We are now putting in about as much chlorine as our people will stand for. They will not tolerate the use of a considerably larger amount than now. The city has been experi-
3955 menting with super-chlorination, which I think is being used in Toronto, and which is a method in which they add to the water considerably more chlorine than the people will stand for and then attempt to neutralize the taste by adding other chemicals.

In the case of typhoid fever it is fairer and better to use a ten-year average than to use a short period.

3956 Beginning with the nineties the cribs were moved further out, which had an effect on health.

3957 The opening of the canal was not simultaneous with the diversion of sewage because the intercepting sewers were only gradually extended. When I was in the Health Department there was a good deal of sewage going directly into the lake from the district north of Fullerton Avenue and down as far south as 39th Street. At that
3958 time all of the sewage from south of 22d Street and from somewhere up about Fullerton or Belmont or Evanston was flowing directly into the lake. Not all of it is diverted yet. There is a little sewage going into the lake down at 80th Street now, and more that is going in through the Calumet River.

3963 Referring to the report of an investigation of the pollution of Lake Michigan by Crohurst and Veldee, U. S. Public Health Service, the following extract beginning on page 67 expresses my view:

"The pollution of Lake Michigan by sanitary sewage and industrial waste discharged from the Calumet district in Illinois and Indiana, especially from Indiana, is such as to render the sources of water supply now used

by Hammond, Whiting, and East Chicago unfit for that
3964 purpose, even with elaborate and efficiently operated purification plants. The source of water supply at Gary, Indiana, though lying outside of the zone of grossest pollution, is also seriously contaminated but not beyond the capacity of modern purification processes to safeguard it. The water supplies drawn by the City of Chicago from the 68th Street and Dunne cribs are also affected and at times may be seriously endangered by sewage pollution from the Calumet district. * * *

"If the use of the lake as a source of water supply for the urban population in the area south of the Chicago River is to be continued, as seems inevitable, it is necessary, in the interest of public health, that the water supply intakes be protected. To remove the intakes beyond
3965 the zone of at least occasional gross pollution would require their extension very far into the lake, to a distance which is probably not practicable. Moreover, in the absence of remedial measures it is to be anticipated that the existing zone of pollution would be extended, with increase in the population and development of the adjacent land area. Therefore, the obvious remedy for the present intolerable situation is abatement of the existing pollution of the lake. The choice of methods to achieve this end involves engineering and economic problems which it is not in the province of this report to discuss. There is no question, however, that abatement of the existing pollution is possible, notwithstanding the difficulty which it may present; and it is certain that the need is imperative."

3966 The bacteriological analysis in this report referred to raw water and not to chlorinated water.

3968 In February and March, 1926, Detroit had an epidemic of diarrhoea with an estimated number of cases of 200,000, which was ascribed by the officials in charge to a

break in their method of water protection which consisted of a modern mechanical filtration plant followed by chlorine in the water.

3969 In March and April, 1920, Mt. Vernon, New York, had an epidemic of typhoid due to a failure of the water supply. The water is coagulated with alum, filtered and disinfected with liquid chlorine.

An epidemic of typhoid fever occurred at Moline, Illinois, in 1917 and 1918, which resulted from a break in the operation of their filtration plant.

Re-cross Examination by Mr. Jackson.

3970 I have no information as to the size of Mt. Vernon or
3971 the nature of the filtration plant. The filtration plant at Moline was installed in 1902. The State Health Department was not satisfied with the operation of that plant. Sewage is put into the Mississippi River unpurified. I do not know what is done with the sewage at Mt. Vernon.

3972 Practically all of the sewage of the Indiana lake cities goes into Lake Michigan in a raw state; there is some purification other than dilution at Gary, although not
3973 very much. Abatement of the pollution is possible. This
3974 is a zone of growing population; some of it is dense.

3975 The year 1921 was used in Exhibit No. 1142 because the chart was made many years ago and used for teaching purposes. It was started about 1892 and the first year used was 1891; 1921 was the result of using every tenth year thereafter. Moreover, beginning with the year of the greatest typhoid fever epidemic that Chicago has had made the chart more effective for teaching purposes.

3980 If the chart had begun with the year 1888 or 1894 it would have shown a different picture as to the typhoid rate.

The data on which Exhibit 1143 was based were ob-

tained by inspectors of the Health Department who customarily record where the patient's first symptoms appeared. This information is tabulated by the Health Department.

3981 In 1926 the typhoid rate was .8; the increase in chlorine
3982 treatment was quite largely responsible for this low rate.
3984 The amount of chlorine used is more than would be used if the water were filtered.

Langdon Pearse, for Defendants. January, 1927:

4935 *Direct Examination by Mr. Adcock.*

Winnetka, Illinois; sanitary engineer for Sanitary District of Chicago; consulting engineer of the firm of Pearse, Greeley & Hansen; graduate of Harvard in 1889, A. B.; civil engineering course at Massachusetts Institute of Technology, B. S., and M. S. in civil engineering
4937 in 1902; since then municipal work; in 1901 and 1902 with Massachusetts Harbor Commission as level man; 1902 and 1903 assistant to John R. Freeman, Charles River Commission; in 1903 assistant engineer for Commission on Additional Water Supply New York City; 1904, investigation of water supply in Maine, Cleveland, Ohio, Jersey City; 1904 to 1907, assistant engineer on additional water and sewage works in Columbus, Ohio; 1907 and 1908, on the California coast in the vicinity of San Francisco, studying filtration for water supply of Oakland and bay cities; from 1909 to date continuously connected with the Sanitary District in various capacities, organizing sanitary work, studies on supplementing
4938 the dilution method; the work has been built up on the sanitary side under my direction, and I am in charge of sanitary work, comprising general supervision of design work, laboratory work, testing stations, water supply from Gary to Waukegan; have complete charge of design

and construction of intercepting sewers and critical work, some of which has been split off on account of magnitude of work; at present am largely consulting and critical on sanitary work after it has once started in the drafting room.

4939 In private work, am consultant to United States Public Health Service on stream pollution; have advised various communities on the subject of water supply and sewage treatment; consulting engineer for most of the Sanitary Districts of Illinois, for example, Decatur, Bloomington, Normal, Urbana, North Shore Sanitary District; also involved in the study of water supply conditions in Indiana; have built four filtration plants, one
4940 at Evanston, two at Whiting and Winnetka, and one at East Chicago; additional engagements in Oklahoma City, where am building sewage treatment works, and in other cities; am member of the American Society of Civil Engineers, Institute of Civil Engineers of London, England; Engineering Institute of Canada.

My duties in connection with the Sanitary District relate to sanitary problems of the District, discharge of sewage, protection of water supply, general technical supervision of operation of treatment works, contact with all problems developed in laboratory and drafting room. In connection with Sanitary District work have visited sewage plants since 1909 in the United States, England, France and Germany, for the purpose of ascertaining
4941 best and latest methods; have visited large plants in England, thus coming in contact with various men in prominence in the profession; have had occasion to report upon and study the situation along the Cook County frontage of Lake Michigan, North Shore Sanitary Dis-
4942 trict, Calumet region, including the industrial region to the Illinois State line, through the Lake Michigan Water Commission; also have come in contact with the

same problems; helped to carry on work of so-called Crohurst-Veldee investigation for the United States Public Health Service, through which the Sanitary Districts
4943 of the States of Illinois and Indiana carried on co-operative surveys of condition of water supply of Lake Michigan along the frontage of Lake County, Indiana, and the frontage of the State of Illinois up to Waukegan.

4944 My work has made it necessary for me to become familiar with the Illinois River country, and since 1909 have carried on continued investigations of the necessary work to be done to meet the conditions as now existing in the upper part of the river, involving cumulative collection of data which have become very much more exact in later years.

In 1922 and 1923 the Public Health Service desired to reinforce work done on the Ohio River, and asked the aid of the Sanitary District in supporting a co-operative survey of the Illinois River, covering data of the different surrounding states over a period of about 14 months. During the past two years have been making a complete and extended survey of the entire river from Lake Mich-
4945 igan to the Mississippi, with a view to determining by frequent sampling and specific local studies the specific condition that has to be met at the present time and in the future.

4946 The condition peculiar to Chicago is the location of a group of cities of large size extending from Waukegan on the north to Gary on the southeast along the southern and western shores of Lake Michigan, where there is practically no circulation. In a state of nature the two rivers, Chicago and Calumet, flowed into that lake, and are now surrounded by a large aggregation of population and industry.

4947 On account of the physical configuration, the peculiarities are unique, in that they present an opportunity to divert the sewage from the water supply of the city in a

way that other cities around the lakes, like Cleveland and Milwaukee have been unable to do through the lack of natural advantages.

Another peculiarity of the Chicago situation is the rate of growth of between six and seven hundred thousand population in each decade, a growth in itself that of a large city. In addition, there has been a remarkable growth in industry, due to the concentration in Chicago of the largest unit of packing house industry in the United States, large tannery and corn products industries, all of which complicate the situation.

Another peculiarity is the flatness of the country, necessitating flat grades in sewers, increased expense for sewage and pumping.

4948 The development of sewage treatment as supplementing dilution or diversion has been considered by the Sanitary District since 1909, to my personal knowledge, and from observation and contact with others since 1887. It has always been the policy to obtain supplementary methods to reinforce the dilution plan, since about the year 1910.

4949 Since the domestic situation was studied over a period of years, and it was found it would divide naturally into a number of projects, there have been developed the Calumet, Des Plaines River, North Side, West Side and Southwest Side projects. In addition to the domestic situation there was the importance of the industrial problem in the solution; the presence of the largest aggregation of packing houses in the world produced a waste which has a direct bearing; the packers dumped their waste into the channel, and in earlier years dumped in almost everything except the meat, until the by-products were recovered for business reasons; this produced a great deal of suspended matter and material in solution in the water.

4950 After a number of conferences, a survey was undertaken in 1911 and money appropriated for dredging and

for a testing station built in 1912 and operated until 1918, for the demonstration of devices for elimination of waste, various types of tanks, and biological treatment.

In 1915 the so-called activated sludge process was developed, which required a fresh series of experiments, which culminated in September, 1918; this extended effort terminated in an admission on the part of the packers that the activated sludge system could handle
4951 their sewage; in 1917 a program was outlined, but the war disturbed the basis of negotiations, and even though an agreement was drafted it was never put into effect; the studies showed that the packers' waste was equivalent to the sewage of about one million people, compared with the population in 1920 of about three million.

I next undertook a study of the tannery situation. There are 21 tanneries on the North Branch of the Chicago River of various sizes, and some wool-cleaning plants, all of which deposit solids in the river and create conditions, together with those produced by the solids of
4952 sewage, which are unpleasant. In the summer the river was black and full of gases above its junction with the main river. This required the installation of a testing station for treatment and a study of the effect of the various forms of treatment. These studies evaluated that the effect of the tannery group was equal to a population of seventy thousand people.

The packers themselves had given up the problem in disgust. In addition, a testing station on domestic sewage was started, and went into service in October, 1909. It operated with various types of tanks to determine the
4955 characteristics of the known apparatus experimenting with various sizes and types of trickling filters and other devices. It was learned that Chicago sewage was such that it required more extended apparatus than was commonly thought necessary in places on a smaller scale, partly because of volume and partly because of condi-

tions of climate. We learned how to provide for the sludge or solids deposited from the sewage, and studied the various ways of dealing with that. We worked out the data upon which later work and projects were predicated.

This testing station work has been a very important part of the development of sanitary science. In this country they have been visited by people from abroad, and it has been commented upon favorably by govern-
4956 ment officials. These studies led the Sanitary District to adopt for the treatment program of the District a general program of taking out the suspended solids, or the so-called "sludge banks," and decided on the adoption of the Imhoff tanks, a double-deck type of tank, the upper chamber for reception and the lower chamber for the deposit and digestion of solids. This type has been adopted in the Calumet works and installed in the West Side works.

Where the work required was more than could be done by settling out the solids in suspension, two methods were considered: One applying the liquid to beds of crushed stone, in so-called "trickling filters," with the prepared liquid spread on the stone, and around the stone are films of bacteria which work upon the material coming in. These beds have to be followed by secondary sedimentation.

4957 The local significance of the activated sludge process, which came into prominence in 1915, was worked out. It performed the same general functions as the trickling filters, but instead of having the films and bacteria around the stones in a bed, they are held in suspension and agitated by air in tanks full of sewage.

4969 The intercepting sewers will pick up as much as they can during storms or thaws and the excess liquid flowing into the sewers discharges directly into the river from all existing outlets. Such liquid may discharge

into the stream on as many as 115 days off and on during the year, which has the effect of putting into the stream deposits which have occurred through dry weather, so that the storm water for several hours may be even stronger than sewage flowing in dry weather.

The dilution method has been regarded as an ultimate means of disposal of sewage for years. The early works built for collecting sewage discharging into streams were partly because it was the easiest and cheapest way. As conditions went along such disposal was studied and found to be of suitable use, subject to limitations in many
4971 cases as to the removal of settling solids. The dilution ratio was expressed by engineers and voiced by Mr. Hering in his early reports and has been incorporated in the Enabling Act of the Sanitary District. This ratio has been studied from time to time and criticisms expressed towards increasing the ratio and requiring a greater flow of water per thousand population rather than decreasing it. Where industrial wastes are prominent more water has been found necessary.

Referring to bulletin of the United States Public Health Service, known as Reprint 580, January 16, 1920, "Treatment and Disposal of Sewage," which was introduced as **Exhibit 1163,** of which page 1 was read into the record. I quote that page to the effect that:

> "The disposal of sewage by dilution consists of its discharge into natural bodies of water, in some cases with and in others without preliminary treatment. In the former instances it constitutes a single and complete method of disposal. In the latter it may be regarded as the final step of a more or less elaborate system of treatment, in which it is employed in conjunction with one or more artificial processes. Wherever sewage or a sewage effluent is discharged into a natural watercourse, dilution constitutes an integral part of the disposal process.
>
> "Dilution has for a long time been the most common means of sewage disposal practiced in the

United States. Formerly it was regarded as a temporary and undesirable expedient, to be ultimately abandoned as soon as sewage purification became sufficiently developed. During recent years, however, the economic need for utilizing to the greatest possible extent the self-purification capacity of nat-
4973 ural watercourses has been apparent, with the result that the disposal of community wastes by natural dilution has become recognized as a legitimate and desirable process, where carried out in such a manner as not to endanger the public health.

"Where dilution is successfully applied it must, in general, accomplish one or both of the two following results, depending upon the uses to which the receiving body of water is to be subsequently devoted:

"1. The limitation of bacterial numbers present in the receiving watercourse to within boundaries safely consistent with the hygienic safety of whatever sources of water supply, bathing beaches, or shellfish areas may be dependent upon such a watercourse.

"2. The maintenance of a sufficient reserve supply of dissolved oxygen in the receiving watercourse to insure its freedom from objectionable odors or other conditions, either locally or at more distant points.

"In general, the degree of dilution necessary to satisfy the first of these requirements is much higher than that required for the second, although this principle may not necessarily hold if careful local precautions relative to the proper dispersion of sewage are neglected.

"The prescription of definite quantitative stand-
4974 ards with reference to the dilution of normal sewage has for a long time engaged the attention of sanitary engineers. The first authoritative standard of this sort proposed in the United States was that of Hering, Williams, and Artingstall in 1887, who concluded from a study of data for the design of the Chicago drainage canal that the minimum flow of the canal safely consistent with the avoidance of objectionable conditions should be 3.3 cubic feet per second per thousand of waste-contributing pop-

ulation. This standard was widely accepted for many years.

"More recently, however, a further knowledge of the variable part played by self-purification in determining the capacity of watercourses for pollution has resulted in a greater degree of caution in attempting to adopt and apply widely any fixed standard of dilution which must be met at the point of sewage outfall. On the contrary, the present tendency in the United States is in the direction of prescribing standards as to maximum bacterial loads impassable upon water purification plants at the intake, and as to the minimum permissible degree of dissolved oxygen saturation at critical points consistent with the avoidance of nuisance. An example
4975 of the former is the so-called International Joint Commission Standard which states that the maximum safe bacterial load impassable upon a modern efficient water purification plant should be such that no more than 50 per cent of 0.1 c.c. portions of the raw water, tested regularly throughout the year, should contain B. coli. In terms of the commonly employed B. coli index, this is equivalent to a yearly average bacterial load of not exceeding 500 B. coli per 100 c.c. An example of the second type of standard noted above is that which was proposed by Black and Phelps as governing the minimum permissible dissolved oxygen content of New York Harbor. This standard, which was given as not less than 70 per cent oxygen saturation, is not concurred in by Fuller, who states that 20 per cent for winter conditions and 30 per cent for summer (each equivalent to about 2.5 parts per million of dissolved oxygen) represent a more practical and generally accepted minimum.

"Still more recently the United States Public Health Service has conducted in the Ohio River basin probably the most intensive scientific study of stream pollution which has ever been carried out. The results obtained from this study, the publication of which is now under way, have thrown considerably new light upon the entire matter of standards of dilution as well as upon the fundamental principles un-
4976 derlying the disposal of community wastes by this

method. They have emphasized the great need for caution in applying any fixed standards of dilution to widely varying conditions. At the same time they have shown conclusively that the combined resources of natural dilution and self-purification represent a tremendous economic asset which, in a given case, may be evaluated in definite quantitative terms through properly planned preliminary studies. Such resources should be utilized to the fullest extent in connection with any proposed project of sewage treatment involving artificial processes in order that the cost of the latter may be minimized.

"A full description of the theory and practice of dilution processes is given by Metcalf and Eddy and by Fuller in the general reference (1 and 2) accompanying the present discussion."

4977 I have had occasion to follow the work carried on by the International Joint Commission with reference to pollution of the international boundary waters.

Progress Report of the International Joint Commission, On the Reference by the United States and Canada, on the question of pollution of boundary waters, and whether or not such pollution extended across the boundary in contravention of the treaty of January 11, 1909, and, if so, in what manner and by what means it was possible to prevent the same, **Defendants' Exhibit 1164.** Page 12 to page 15 as follows:

4978 "PRINCIPAL FACTORS IN THIS POLLUTION.

"The greatest single factor in this avoidable and remediable pollution is the sewage discharged without restriction or treatment of any kind by the municipalities situated on the boundary waters. The second factor in point of importance is the discharge of sewage by vessels. Vessels not only contribute their quota to the sewage pollution of these waterways, but they menace the public health in other ways. Vessels are supposed to fill their drinking water tanks from mid-lake, remote from sources of pollution. The distance pollution travels from shore in the lake, as shown in the report, demonstrates how difficult it may be to find an unpolluted area.

There is excellent evidence to show that vessels frequently fill their tanks from polluted sources.

"During the season of 1913 several epidemics caused by polluted water aboard vessels were investigated by the United States Public Health Service. In the laboratories of the Commission also samples from water tanks of vessels on the lakes were shown to be polluted. Another pernicious practice attributed to vessels is the taking on of water ballast from a polluted harbor and the discharge of the same in less polluted waters, frequently within a short distance of some waterworks intake.

"Effect of Pollution Upon Public Health.

"In the cities and towns upon the Great Lakes and their connecting rivers, sanitary and climatic conditions, exclusive of public water supplies, are much better than the average for the country as a whole. These sanitary conditions are infinitely better (with the exception of water supplies) than those which pertain in European cities. These Great Lakes cities lack the overcrowding, the filth and the poverty of less favored communities; yet the typhoid fever rate in these cities for many years has been excessive and punctuated at intervals by massive explosive epidemics which are without parallel in European countries. Typhoid fever death rates per 100,000 in the large cities of Northern Europe with safe water supplies have an average of less than 5. Without reverting to the appalling disasters of a decade ago, in the last three years a rate of over 300 was registered in Ashland, Wisconsin; of 109 in Marquette, Michigan; of 196 in Port Huron, Michigan; of 194 in Niagara Falls; of 190 in Erie, Pennsylvania, and above 50 in Alpena, Bay City, Sault Ste. Marie, Duluth and Sandusky; of 179 in Port Arthur, Ont.; of 330 in Sault Ste. Marie, Ont.; of 134 in Sarnia, Ont.; of 55 and 57 in Windsor and Walkerville, Ont.; of 86 in Niagara Falls, Ont.; of 63 in Brockville, Ont.

"Even in the more fortunate cities possessing intakes which are not so grossly polluted rates are attained for typhoid fever which would not be tolerated in European countries. Detroit has never reg-

istered a lower rate than 15, and in 1913 had a rate of above 30. In most instances these high typhoid fever rates were due to the use of sewage-polluted water without purification of any kind. In a number of cases, however, an alleged purification plant was in operation, but disasters have occurred in spite of these plants, either due to faulty construction or more frequently careless or unskilled operation.

"SECOND BRANCH OF INVESTIGATION.

"Having concluded the investigation of the question at what places, from what causes and to what extent these boundary waters are polluted on either side to the injury of health or property on the other side, and it having been established by the investigation that these waters are thus polluted, the Commission will now proceed as rapidly as possible with investigation of the second question, viz:

"'(2) In what way or manner, whether by the construction and operation of suitable drainage canals or plants at convenient points or otherwise, is it possible and advisable to remedy or prevent the pollution of these waters, and by what means or arrangement can the proper construction or operation of remedial or preventive works, or a system or method of rendering these waters sanitary and suitable for domestic and other uses, be best secured and maintained in order to secure the adequate protection and development of all interests involved on both sides of the boundary, and to fulfill the obligations undertaken in Article IV of the waterways treaty of January 11, 1909, between the United States and Great Britain, in which it is agreed that the waters therein defined as boundary waters and waters flowing across the boundary shall not be polluted on either side to the injury of health or property on the other?'

"In view of the magnitude of the interests involved, an adequate plan must be prepared by the Commission, with the aid of sanitary engineers qualified to give competent and intelligent advice, to the end that the investigation of this second question may proceed along proper lines and be concluded at the earliest time possible. It is

the intention of the Commission at its special session called to meet March 9, 1914, for the consideration of other matters pending before the Commission, to give this branch of the investigation consideration, and at that time to prepare and adopt a plan under which it shall be conducted and to outline the procedure that will be followed with respect to working out the sanitary engineering problems and affording the people and the municipalities affected on both sides of the line a full and complete opportunity to be heard regarding remedies where avoidable pollution has been found to exist."

4989 There was also offered in evidence the maps facing pages 18 and 41 of Exhibit 1164. The map facing page 18 shows the zones of pollution in the Great Lakes, and discloses serious pollution in the Rainy River from the outlet of the Rainy River to International Falls, serious pollution in Lake Superior in the vicinity of Port Arthur and Fort William, serious pollution in practically the entire St. Marys River, a good deal of boat pollution at the head of Lake Huron, serious pollution throughout the entire St. Clair River and about one-fifth of the entire area of Lake St. Clair, boat pollution along the principal vessel lanes in the St. Clair, serious pollution covering the whole head of Lake Erie, the whole of Niagara Falls, the whole head of Lake Ontario, the whole foot of Lake Ontario, and the whole St. Lawrence River from Kingston to Cornwall, and the St. John River from Grand Falls to Edmonston.

The serious pollution at the head of Lake Erie is shown in detail on the map facing page 41, by a statement of the B. coli average count, from samples taken at various areas in the lake, and shows B. coli counts running from a minimum of 11 to a maximum of 2620 distributed all over the area from Put-in-Bay in a line almost north by northwest to Bar Point.

4990 Mr. Pearse continuing: The conditions as shown on

the map on page 13 of Exhibit 1164 are substantially today as stated in the table. The major pollution, such as from Detroit, Buffalo and Toledo, are still being carried on to an even greater extent than at the time of the report, because of the growth of population, and, with the exception of a small plant in a suburb of Buffalo, there has been practically nothing done towards sewage treatment in the United States cities mentioned in that table. In other cities, as for example, Cleveland and Milwaukee, there has been an effort to carry on treatment.

4995 **Defendants' Exhibit 1166**, entitled "Final Report of the International Joint Commission on the Pollution of Boundary Waters, Washington-Ottawa, 1918," is in part as follows:

> Page 19. "Rainy River through its entire course has been rendered unfit for domestic uses owing to the unrestricted discharge of sewage and other wastes. * * * Thunder Bay is extensively polluted in the neighborhood of the towns of Port Arthur and Fort William, but not to such an extent as to affect Lake Superior. * * * Lake Superior at the head of the St. Marys River is practically pure. * * * The discharge of sewage from vessels was shown to seriously pollute the waters in the lanes of vessel travel. Especially does vessel pollution menace the water supplies of the towns of Sault Ste. Marie, Michigan and Ontario. * * * A serious condition of the river continues * * * down to Neebish Island. * * * Water examined in the Straits of Mackinac proved to be quite pure.
>
> "The waters of Lake Huron at the head of the river would be practically free from B. coli were it not for the pollution from vessel sewage. * * * Below the towns of Port Huron and Sarnia the waters of the St. Clair River for a stretch of about 34 miles are quite unfit for drinking purposes, unless extensively treated * * * The pollution below these towns is due to the combined effect of the discharge of untreated sewage from vessels and the towns along the shores. * * *
>
> "Lake St. Clair, which receives the discharge of

the river, showed less evidence of pollution. * * *

"The results of our analyses of samples taken above the intake for the Detroit city water supply showed this to be an unsafe source of supply without careful treatment. Samples taken along the several cross-sections from this point to the site of the Michigan Central tunnel showed a marked increase of pollution in the shore samples. The water intakes of Walkerville and Windsor are both located in dangerous situations, owing to the discharge of sewers above these intakes. * * * At times the pollution is so great that the quantity of chlorine required to overcome it gives an objectionable taste to the water. * * *

"Samples taken from a cross-section over the Michigan Central Railroad tunnel showed gross pollution at sample points near the Canadian and United States shores, and a considerable pollution extending across the entire river. Samples taken from several cross-sections showed gross pollution throughout the entire river from the Michigan Central Railroad tunnel to Fighting Island. From Fighting Island to the mouth of the river the water is grossly polluted. * * * Wyandotte, Trenton and Amherstberg are taking their water supplies from this part of the river. * * *

"The pollution in the Detroit River is occasioned by the discharge of raw sewage from its riparian communities, notably the City of Detroit, and by the sewage from vessels. * * *

"Lake Erie, outside of this polluted area and the polluted areas at the mouths of its tributaries and its littoral waters, affords a remarkable instance of self-purification. * * * Above Niagara Falls the great bulk of the pollution in the river, and due to the discharge of sewage therein, is confined to the marginal waters of the country in which it originates and that the sewage of Buffalo is polluting to a serious extent the available water supplies of the two Tonawandas and the City of Niagara Falls. The effect of the pollution of the lower Niagara is to render the river water totally unfit for domestic uses unless purified. * * *

"* * * The waters of Lake Ontario are comparatively free from B. coli, with the exception of

an 18-mile radius from the mouth of the Niagara River. * * *

"The St. Lawrence River is the only water supply available for the summer residents at the Thousand Islands and for the communities along its banks.

"During the period of examination it was observed that the present practice of unrestricted discharge of sewage renders certain areas unfit sources of drinking water. * * * Below the Thousand Islands the population is denser and considerable pollution exists * * *."

The report states that the pollution in the St. John River amounted to about 125 B. coli per 100 cubic centimeters in the late fall; that vessel pollution is confined to the vicinity of the traffic lanes, and consists of two kinds: raw sewage and water ballast discharged by vessels on approaching ports of destination; that this pollution is a serious menace to public health; that the grossly polluted condition of boundary waters is doubtless because of the abnormal prevalence of typhoid fever throughout the territory bordering thereon.

On page 32 of the report the statement is made that:

"SANITARY CONSIDERATION FIRST IN ORDER OF PROCEDURE.

"It must be admitted that the conservation of public health is of paramount importance under the treaty. This is evident from Article IV to which reference has been made. The significance of sanitary considerations is also evidenced by Article VIII of the treaty."

Part VI of the report refers to the "Limits of Permissible Pollution and Standards of Sewage Purification," and takes up the question of whether boundary waters are to be looked upon as open sewers for the reception of riparian pollution, and whether the policy should be to restore the purity of the boundary waters; in other words, whether the riparian right to discharge

sewage is stronger than the riparian right to receive water pure.

The Commission recommends that all sewage should, before being discharged into boundary waters, receive some purification treatment, and the limit of such treatment should depend upon the limit of safe loading of water for purification plants. It says that on the one hand, it is evident that the paramount importance of public health and the binding obligations of the treaty must be borne in mind; that on the other hand, sewage treatment requirement must not be made so excessive and unreasonable as to involve the cities and towns along these waters in an expenditure entirely unjustifiable.

As to the Detroit and Niagara Rivers, the Commission was of the opinion that the towns discharging sewage into them should purify it to such an extent that the resulting average cross-sectional pollution in each river will not exceed the limit of safe loading for a water purification plant.

The report says that the standard of sewage purification as to safe loading must be regarded as tentative; that in view of the difficulties and uncertainties of bacteriological technique, it is distinctly advantageous to have a working rule which is more accurate and readily determinable than the bacterial standard suggested. Reference is made to Professor Phelps in connection with the progress report, and his statement that if the sewage of the city be diluted in a stream flow of 4 cubic feet per second, per capita, the resulting water will contain approximately 500 B. coli per 100 c.c.; that if the dilution is proportionately less, a corresponding degree of purification of the sewage will be necessary; that in the light of accumulated knowledge it is considered that for all purposes of a present inquiry the practical equivalent of

the dilution of the bacteriological standards may be accepted.

The report further says that the fixing of standards for boundary waters, and the subsequent modifications of the standards from time to time, should be left as hereinafter recommended to some authority clothed with the necessary power to deal with the question.

Part VIII is "Conclusions and Recommendations," which are in effect that:

> "1. The Great Lakes beyond their shore waters and their polluted areas at the mouths of the rivers which flow into them are, except so far as they are affected by vessel pollution, in a state of almost absolute purity. With the exception of these pure areas, the entire stretch of boundary waters, including Rainy River, St. Marys River, St. Clair River, Detroit River, Niagara River, St. Lawrence River from Lake Ontario to Cornwall, and the St. John River from Grand Falls to Edmundston, New Brunswick, is polluted to an extent which renders the water in its unpurified state unfit for drinking purposes. This pollution has its origin chiefly in the sewage and storm flows from the riparian cities and towns and the sewage from vessels. It is very intense along the shores of the Detroit and Niagara Rivers and in the contaminated areas in the Lakes. Throughout the whole length of the boundary waters where sewage is discharged from the sewage works of cities and towns the pollution is most concentrated in the shore waters on the side of the boundary on which it originates. These shore waters, besides being in places unsightly, malodorous, and absolutely unfit for domestic purposes, are a source of serious danger to summer residents, bathers, and others who frequent the localities. So foul are they in many places that municipal ordinances have been passed prohibiting bathing in them.
>
> "2. In the Detroit and Niagara Rivers conditions exist which imperil the health and welfare of the citizens of both countries in direct contravention of the treaty. This is true, though in a less marked degree, of the Rainy and St. John Rivers.

"3. In the St. Marys, St. Clair, and St. Lawrence Rivers pollution exists which is in substantial contravention of the spirit of the treaty, and unless these conditions are improved, and the rivers placed under the control of competent authority, the resulting injury will be much more pronounced as population increases.

"4. Vessel pollution in certain parts of boundary waters exists to an extent which causes substantial injury to health and property. * * *

"6. It is feasible and practicable, without imposing an unreasonable burden upon the offending communities, to prevent or remedy pollution, both in the case of boundary waters and waters crossing the boundary. * * *"

4999 From **Defendants' Exhibit 1167,** Bulletin 83 of the Public Health and Marine Hospital Service, March 1912, on "Sewage Pollution of Interstate and International Waters," (page 133) the following appears:

5000 "The growth of the City of Chicago finds no parallel in history. From a population of 7,500 in 1843 it has grown to be the second city in the United States with a population in 1910 of more than 2,000,000. No argument is necessary to show the importance to the whole country of sanitary conditions in Chicago. Its vast commerce and giant industries make it the metropolis of an enormous territory and bring thousands of visitors daily from nearly every State in the Union. These visitors drink Chicago's milk and water and eat Chicago's food. Contamination of these articles of food or drink by typhoid fever germs means infection of transients as well as citizens—transients who go to their homes in other States to establish new foci of typhoid fever. These transients and interstate travelers are less able to protect themselves against contaminated food or drink than the citizen who heeds the warnings of Chicago's excellent department of health. Thousands of interstate travelers drink water on trains which is taken aboard cars in this great railway center, and the character of Chicago's water supply is of vital importance to these travelers and to the States to which they are destined."

5002 **Defendants' Exhibit 1169,** is a table showing the number of sewer outlets of the Sanitary District of Chicago in 1926. It shows in the North Branch of the Chicago River 96; in the main Chicago River 21; in the South Branch of the Chicago River 104; in the Calumet River and Calumet Sag Channel 34, and in the Des Plaines River and Salt Creek 59, making a total of 314.

5003 Mr. Pearse continuing: Outside the Sanitary District, there is a total of 479 outlets along the lower Des Plaines and Illinois Rivers from Lockport to Grafton. 131 are municipal and 348 are private. The greatest number, 134, is at Joliet; 76 at Ottawa and 64 at Peoria. The

5004 problem of the Illinois River is intimately related to the problem of disposal of Chicago sewage through the relationship of the diversion of flow to the amount of treatment required. With a high flow, slight treatment is required; with a low diversion or no diversion, a high degree of treatment would be required.

5005 **Defendants' Exhibit 1170,** summarizes the result of the survey of the industries of the Illinois River based upon work done partly by the United States Public Health Service in 1921, showing a total of 44 major industrial developments up and down the valley, and in 1925 a report made by me and engineering associates found 21 industries at Peoria in place of 11 in 1921.

The principal trade wastes found are at Joliet 11; beverage, chemical, paper, rendering, slaughtering, iron works and penitentiary; at Morris 2, paper mill and tannery; at Marseilles 3, paper mills; at Ottawa 2, brewery and packing house; at La Salle 3, smelting, chemical and plating; at Peru 6, plating, zinc refinery, clocks and brewery; at Depue 1, zinc; at Chillicothe 1, cannery; at Peoria 11, distilleries, milling, packing house, paper, refinery, tractor, steel, feed, stoves and syrup; and at Pekin 4, corn products, distillery, paper and yeast.

5006 The total equivalent load of the industries upon the Illinois River has been calculated in connection with the investigation made by the Sanitary District and the United States Public Health Service in 1921. The equivalent load is very close to that of a million people, the major portion of the load being concentrated at Peoria and Pekin. Since that time I have made an investigation leading to the conclusion that due to changes in industries at Peoria, the total effect would be nearer to that of a million and a half people, the principal elements in the load being distilleries and other similar waste-producing elements in Peoria and the Corn Products Refining Company plant at Pekin.

5007 **Defendants' Exhibit 1171,** Table 13, Part III, Engineering Board of Review, The Sewage Disposal Section, summarizes data obtained jointly by the Engineering Board of Review and the United States Public Health Service. This table is headed "Total Population Loads, Human plus Industrial equivalents, on Des Plaines-Illinois River from data of the United States Public Health Service, 1921-1922," and includes the Sanitary District of Chicago, the towns of Joliet, Morris, Marseilles, Ottawa, La Salle, Peru, Peoria, Pekin, Havana and Beardstown, showing for each of these communities the sewered human population and industrial equivalent population, total population and percentage of total. The total sewered human population is 3,240,460, of which 3,100,000 pertains to the Sanitary District of Chicago. The total industrial equivalent population is 2,590,490, of which 1,530,000 pertains to Chicago. The total population is 5,830,950, of which 4,630,000 pertains to Chicago, of which total population Chicago represents 79.4 per cent; cities from Joliet to La Salle, 3.4 per cent; Peoria and Pekin 17 per cent, and Beardstown .2 per cent.

5010 The flow of the tributaries of the Illinois enters into

the problem of the Illinois River through furnishing additional diluting water according to the stage of the river.

5011 I have been working upon the treatment problem for the sewage of the district in general since 1909 and in particular since 1919. The Engineering Board of Review for the Sanitary District laid out a program in 1924, which was substantially the program that our organization and myself had arrived at for purposes of treating the sewage of Chicago and supplementing the diversion from the lake as a means of disposing of our sewage. The program of the Sanitary District for sewage disposal was fixed by the permit of March 3, 1925, and the understanding in connection with it to the extent that the Sanitary District was going ahead on the program for treating the sewage, but after the permit was issued and subsequently through negotiations with the District Engineer of the United States Engineer Corps modifications were made from time to time, whereby because the treatment of the Packingtown waste was put back to a later date, the District Engineer requested that the West Side Treatment Works be shoved forward.

5020 With respect to the sewage of Chicago south of 87th St., the study of the Calumet region in 1907 recommended a separate sewer system for the Calumet region. The work was done under special assessment, the engineers' recommendation being disregarded, and it has been built as a combined system of sewers. Therefore, with the knowledge that the Calumet River could not be entirely reversed in times of storms, owing to run-off, interceptors there have been designed large enough to take up the flow of the other sewers intercepted and to carry that flow to the point of maximum storm behind the gates at the entrance to the Calumet Sag Channel. So that the sewage, as well as the effluent, picked up

from the operation of that treatment works can, with the exception of a very short period of the year, be taken into the Calumet Sag Channel and kept out of the lake.

5021 The Indiana situation is separated by a state line, separating South Chicago from the towns of Whiting, East Chicago, Hammond and Gary, an area that has developed remarkably in the last few years. The flow of sewage through the entire region enters either Lake Michigan directly or the Grand Calumet River and passes

5022 thus directly into the lake east of the State boundary, and at a point where, with favorable winds, the pollution, both bacterial and of taste, reaches the southern cribs of the City of Chicago. The pollution from those towns is very gross. Their water supply is grossly polluted, full of tastes and odors produced by phenol waste, oil waste, and other material of that type, and has to be dosed with chlorine to an extent which renders it very unpalatable.

Essentially, the sewage should be diverted from the

5023 lake and turned over to the Sanitary District. This has been discussed and the engineering department of the Sanitary District instructed to co-operate and receive effluents properly prepared within the channel.

Efforts have been made to form sanitary districts in Indiana. The water of Gary and Hammond has been chlorinated, and water filtration plants have been built at Whiting and East Chicago. But with all that the water has tastes, and is heavily chlorinated, and with the possible exception of Gary, is unable to meet the United States Treasury standards for sometimes one or two months at a time, and the whole situation is one explosive in character.

The Calumet region, through dual water supplies and the use of bad water through mains available to workers keeps alive a certain amount of typhoid as a reser-

voir adjacent to Chicago. It is not a pleasant situation for the community itself and is a source of apprehension to Chicago.

5025 The Crohurst-Veldee report in evidence, shows 123 industrial plants, 82 in Indiana and 41 in Illinois.

5027 A summary of the industrial wastes situation, as shown on page 27 of Exhibit No. 155 of said report was introduced in evidence. It shows the points of discharge of industrial wastes, the putrescible organic wastes, the taste-producing wastes and the ultimate point of disposal for the Calumet River, the Little Calumet River, the Grand Calumet River between Indiana Harbor Canal and Little Calumet River; Indiana Harbor Ship Canal and Grand Calumet River above entrance of Canal, and Lake Michigan.

In the Little Calumet River the putrescible organic wastes are beet wastes and canning wastes; in the Grand Calumet River, 517,000 gallons of fertilizer wastes and 1,300 gallons of glue wastes; in the Indiana Harbor 400,000 gallons dehairing wastes and Lake Michigan 1,500,000 gallons corn products wastes.

Of taste-producing wastes the Calumet River has 524,000 gallons of coke wastes, Indiana Harbor 1,800,000 gallons coke wastes and 582,000 gallons oil wastes, and Lake Michigan 4,500,000 gallons oil wastes and 672,000 gallons of coke wastes.

All these wastes are ultimately disposed of in the Calumet Sag Channel, except that of Indiana Harbor, and those into Lake Michigan near Whiting and at Indiana Harbor.

5028 **Defendants' Exhibit No. 1172,** a computation from the United States Census Report of 1920, shows past and estimated future populations of Indiana cities on Lake Michigan, including East Chicago, Hammond, Whiting, Gary and Michigan City. The totals are as follows:

1890	18,867
1900	34,620
1910	82,439
1920	156,951
1930	233,000
1940	308,000
1950	384,000
1960	458,000

5030 **Defendants' Exhibit No. 1173** is a computation made in the Engineering Department of the Sanitary District of Chicago for the years 1900 to 1927, showing population discharges into Lake Michigan by years for the Calumet district of Illinois and Indiana.

The report divides the Calumet district as between the Illinois portion and the Indiana portion and shows the total population in the Illinois portion discharging sewage into Lake Michigan at 397,555 (the maximum) in 1905, declining in an irregular but steady reduction to 174,019 in 1921, and then, because of the diversion in 1922 of several communities in Illinois suburbs to the City of Chicago, declining in that year to 67,460 and in 1925 to 35,534, by reason of other works intercepting this sewage from Lake Michigan, and in 1927 to zero, which estimate is based upon the work of dredging by the Sanitary District in the Calumet River.

The total Indiana population discharging into Lake Michigan begins in 1900 with a figure of 34,620 and increases on a steadily rising curve to 202,579 in 1926, or an estimated 210,185 in 1927.

5031 If this Indiana sewage could be treated, it is entirely practicable to take the effluent into the Calumet Sag Channel, but this has not yet been discussed, the suggestion having been made to the Indiana towns that they discharge treated sewage into the river and then by proper dredging open the waterway from Indiana into Illinois so that treated liquid could flow through the

Sanitary District channel and be kept out of the drinking water drawn from the lake by both States.

The program of the Sanitary District is to treat all the flow of sewage that passes through the sewers at time of dry weather and 50 per cent in addition thereto. The 50 per cent increase is possible with the hydraulic capacity provided in the plant and the raw sewage above that mixed with storm water would discharge into the water courses like the Chicago River and the Calumet River.

5032 As a general procedure, this amount of treatment appears to be good practice and as much as the District is justified in trying to take care of. There has been a procedure in England where a treatment of six times the dry flow has been considered, but inasmuch as it starts with a very much lower initial quantity, the net result of the final amount treated is about the same as the result of the present program of the Sanitary District. In England they are running from 35 to 50 gallons per capita. On a metered use of about 150 to 200 dry flow in the sewers, if the Sanitary District takes 50 per cent of the dry flow, it has 300 gallons per capita as a basis upon which to start.

In times of storms the untreated sewage in storm waters would flow into the rivers and canals which would ultimately carry the storm water. It has not yet been considered practicable to treat storm water on the scale of operation projected because the cost of works required for that purpose is as much as ten times the dry flow that would have to be taken care of.

5034 **Defendants' Exhibit 1174**, is an estimate of human population and population-equivalent of industrial wastes by treatment projects and shows itemized by districts the human population and the industrial population equivalent for the City of Chicago, and shows in 1920 a hu-

man population of 3,000,000 and a population-equivalent of 1,500,000; in 1925—3,355,000 human and 1,600,000 population-equivalent; in 1930—3,710,000 human and 1,700,000 equivalent; in 1935—4,070,000 human and 1,800,000 equivalent; in 1940—4,425,000 human and 1,900,000 equivalent; in 1945—4,785,000 human and 2,000,000 equivalent; in 1950—5,140,000 human and 2,100,000 equivalent; in 1955—5,500,000 human and 2,200,000 equivalent; in 1960—5,860,000 human and 2,300,000 equivalent, and in 1970—6,580,000 human and 2,500,000 equivalent.

Some industrial experts and one college professor have a much more exaggerated viewpoint on the increase of population in Chicago, but those responsible for expenditure have made a conservative estimate, because it is difficult to find where the money is coming from.

5036 There are about 55 storm overflows into the river in the course of a year, with about 360 overflow hours in varying amounts according to duration and extent of storms; and the storm overflow would carry that portion of the sewage at time of storm that did not get into the interceptors from the sewers and got out into the river past the devices for admitting the dry flow into the intercepting sewers.

The estimated treatment by tanks at the different plants testified about would be equivalent to the removal of 33⅓ per cent of the organic matter measured in biochemical oxygen demand. The treatment by tanks plus

5037 trickling filters or activated sludge process would remove 85 per cent on a similar basis of test. The removal of suspended solids is a different matter and on the tanks might run from 40 to 80 per cent, averaging possibly 60 per cent, and on the tanks and trickling filters from 85 to 95 per cent, averaging 90 per cent. The removal of settling suspended solids is higher, but that has never been determined gravimetrically.

I made a study of filtration of Lake Michigan as consulting engineer for the City of Evanston with George W. Fuller, with whom I built the first water filtration plant inside the Sanitary District, a plant of 12-million gallons capacity. Have been in touch with the operation of it since and recently I and engineering associates have enlarged this capacity to 24-million gallons per day and have operated it since.

5038 Had occasion to build, with associates, the plant in the Village of Winnetka which supplies Winnetka and Glencoe, and also a plant in the Calumet district. Have examined the situation in Chicago to determine what would be the cost of filtration in order to ascertain the costs and the funds necessary to be raised.

The program of the Sanitary District contemplates continued diversion of water from Lake Michigan. Have been unable to find any break in the program which would permit a reduction in the diversion, because even with the so-called complete 85 per cent treatment I do not see how the flow can be cut if at all until 1945. There is not sufficient treatment provided by the program prior to that time to permit it and after 1945 and even up to 1955, with modern knowledge and available equipment I do not know how the Illinois River can be kept in a proper condition without continued diversion of

5039 practically the same amount now permitted, assuming that everything goes to 85 per cent treatment. That is because of the presence of storm overflows and the carrying over of the sludge from the treatment works; that is, the finely divided suspended matter; the fact that the treatment does not produce 100 per cent treatment in the demand for oxygen in the stream receiving an effluent, and, further, from the fact that even with the storm overflows, as experienced on the Des Plaines River system, constantly patrolled, does not prevent raw sewage

from getting into the river at times, even with careful and continued operations in dry weather.

There is a further problem coming from the effect of nitrates produced by high degree of treatment and the possibility of an after effect produced by the rapid growth of organisms, which means that there is a necessity to flow, even with 85 per cent treatment, a definite diversion down the river.

The protection of water supply and sewage disposal problems has two aspects, one that of keeping the sewage out of the lake and the other to dispose of the sewage in such manner that it will not create a nuisance in the lower river system. The program of the
5040 Sanitary District was originally instituted to protect the water supply of the City of Chicago by diversion of sewage from the drinking water. That program went into effect actively in 1900 and has produced reduction in typhoid along with other causes which have been shown here in the record.

The program at first contemplated dilution of the sewage, but as time went on, as was foreseen by the planners of the work, the load reached the point where dilution would not alone suffice. Supplementary methods had to be planned and installed in the program to reduce the load upon the diluting water and so take care of the increments of population and industry. The capacity of the channel was planned for the purpose of keeping the flood discharge of the Chicago River out of the lake and required 10,000 second feet. In the present and near future at maximum flows as the city grows the flood discharge may get up as high as 12,000 second feet.

5041 The cost of filtering the water supply of the City of Chicago with the present intakes would run from about $50,000,000 to $55,000,000, and with the addition of a

cross-town tunnel which is necessary might run to from $58,000,000 to $65,000,000, based on a metered program as provided under the present permit.

5043 If the diversion were now cut to zero or 1,000 second feet the effect would be to produce a very disastrous condition. It would vastly increase the pollution in the intakes and put the city in a position where with the modern methods available in such an emergency it would be unable to cope with the situation at all adequately. It would be a calamity, as a waterworks engineer would see it, and the condition is unthinkable. There would undoubtedly result an increase in typhoid fever death rates and the cases appertaining thereto, and other disease rates, as has been outlined previously in the record, according to figures that are known in the art. The entire effect would result from the vast and sudden increase of pollution at the existing intakes.

5044 The Chicago River would become a stagnant cesspool or septic tank, with the flow of sewage into it. It would revert to the conditions in what was known as Bubbly Creek before remedial measures were taken to clean that out, with a scum formation and gas bubbles, a foul condition of odor and very unsightly. The flow would be very sluggish.

In the Illinois and Des Plaines Rivers there would be no flow, except what came from the Drainage Canal, so that those cities would have likewise a very difficult time, not only at the north end system but also in the vicinity of the industrial development further south, at La Salle and Peru and Peoria. The river has in a state of nature a dry flow, which is unable to cope with the organic pollution that would be delivered into it. The condition would be extremely foul and would become a great nuisance.

5045 I refer to Bubbly Creek because it stands in my mind

as a typical picture of a foul, noisome stream, grossly polluted, bubbling with gas from decomposition with an accumulated scum through which you could force a rowboat with difficulty, or even a small gasoline launch.

If the diversion were reduced to zero and an adequate time were available and funds were also available in the amount required, the works that might be installed to try to offset the situation would include a line of complete treatment of all sewage, carrying the program forward to the point hoped for in 1955, involving 85 per cent treatment of all works, not only of human population but of industry. It would involve the chlorination of the effluent from those works.

5046 For the protection of the water supply from the discharge of sewage at times of storm overflow it would be necessary to treat the chlorinated effluent, and the city would have to install filtration works in addition to chlorination. To arrive at a suitable result it would be necessary to abandon the present intakes and go to a point north twenty miles from the Chicago River and construct a new intake and feed tunnel to the present tunnels, in order to reach water that would be reasonably safe. That would cost in the neighborhood of $300,000,000, including some of the present program.

5047 If diversion were reduced to 1,000 second feet the conditions would be practically the same from the standpoint of the public health and the desirability of a safe water supply. Assuming that funds were provided, it would take from 20 to 30 years to install the works, depending on the difficulty of getting started right away and other matters that have to be overcome in such undertakings.

Assuming that new works were installed and the diversion were reduced to zero or 1,000 cubic second feet, from a public health standpoint I would regard that con-

dition as being almost as good as it would be with the program of the Sanitary District carried out with reference to sewage disposal and a diversion of 8,500 second feet, but the present situation would be better. It would be hard to choose, but the balance is in favor of the present situation with 8,500 second feet and the Sanitary District sewage disposal program.

The principal reason why the present situation would be better is that I regard it as important to keep sew-
5048 age out of the drinking water in any form. There is an opportunity here. The situation is complicated by the presence of two rivers and the possibility of storm water discharges and the like, so that it is highly advisable to keep the sewage out of the water supply. The machinery exists for doing it and it would have to be abandoned in favor of something not quite so good.

5049 During the period of construction of works under the present program as regards the protection of water supply, it is necessary and desirable to have 8,500 second feet, because the 10,000 second-feet capacity of the Canal prevents the discharge of the Chicago River, except at most infrequent intervals.

Even with 85 per cent treatment of all sewage as the program requires by 1955, the continued flow in the Chicago River would be necessary for the cleanliness and freedom from nuisance in the Illinois River Valley. The flow in general can be taken roughly as one cubic foot per second per thousand of total population, including the industries, which is roughly 7,700,000, and that means, roughly speaking, 7,700 or practically the 8,500 now permitted.

5050 A study of this subject is being undertaken at the present time by a two-year investigation of the river. The condition in the Canal and rivers is now bad. It constitutes a condition of nuisance and has been going

on for a number of years; in fact, ever since I have been connected with the District there has been a passage of solids from the Canal down the rivers lodging behind dams and creating consequent nuisance in the water pools, and the water behind the dams can be smelled for a distance of half a mile. Fish have been driven out of the upper river as far down as Chillicothe, and conditions of odor are noticeable at Chillicothe, a distance, roughly, of 110 miles from Lockport. By the time Peoria is reached the condition has cleared up somewhat, but the solids are sometimes down in the river to points considerably below Peoria, obstructing the natural flow of clean water and interfering with conditions that ought to obtain there. The problem of the lower river with the present diversion hinges on Peoria and its metropolitan area and the industries, rather than on Chicago.

If diversion were cut down to 1,000 second feet now, and if the sewage of Chicago went down there untreated, there would be a nuisance and obstruction to navigation on the Illinois River. The objectionable condition
5052 on the upper river would extend down to Peoria, with a reduction of flow. The amount of flow at present is of value to the valley as well as to Chicago. A reduction in flow would tend to make conditions worse.

I have studied the quality of water from Gary as far as Waukegan in association with my chemist and director of laboratory. Daily from the various cities have been collected intake samples of the raw water along the frontage, received each day for six days a week, resulting in knowledge of the raw water conditions as well as the water supplied in the cities and villages in the Sanitary District; that is, the North Shore District and also in Indiana. Reports are not received from all villages but from the more important ones, and there are available studies of their water supply and from the various cribs of the City of Chicago.

5053 In general the water supply of the City of Chicago is good. It meets the Treasury standard. The pollution reaching the cribs in the raw water is slight, and the cribs of the Chicago Waterworks, taking the South Side crib at 68th Street and extending north to the northern boundary of the Sanitary District, the water supply is taken from the lake quite free from pollution. Proceeding into Lake County, Illinois, the water gets worse. At Waukegan there is a condition of extereme local pollution due to the discharge of the sewage in that city into its own drinking water.

South from the 68th Street crib toward Indiana the condition of pollution gets worse. Off the Indiana shore, in the vicinity of the intakes of Whiting, East Chicago, and Hammond, there is gross pollution, making a load upon water filtration and chlorination plants that they ought not to be called upon to bear. They are near the breaking point all the time.

The water supplied in that locality cannot meet the Treasury standard at all times.

5054 The Treasury Standard is one B. coli per 100 c.c. That is approximately one-tenth of a quart. In the study of water supply the significance of B. coli is the known relation to the human being, indicating fecal pollution; so that water chemists and sanitary engineers of late years have used the presence of B. coli as indicating a bad state of pollution. The Treasury Department has done good work in laying out those standards for water used by interstate carriers and on lakes and trains on the shore. If there are more than 1 B. coli in about a 5055 glass of water, the water is dangerous.

In the City of Milwaukee they drink water with many B. coli per hundred c.c. and they seem to survive, but it is expected that if the Treasury standard is exceeded an area of trouble is entered, and if the B. coli are numer-

ous enough there is a degree of pollution that might become dangerous, depending on typhoid bacilli and other bacilli that might produce intestinal disturbance. The presence of the bacilli is taken as an index, because they are ready of determination.

There are many other bacteria in sewage besides B. coli. Thirty-five kinds have been isolated. Many more have been found in sewage, but they have not much significance in the sewage treatment art unless the protection of the water supply is being considered with the discharge of sewage into it. The number of B. coli found in sew-
5056 age runs into the millions per cubic centimeter, between five and ten million in raw sewage.

5064 **Defendants' Exhibit No. 1178,** shows for the principal cities of the United States their population in 1920, the typhoid fever death rate per 100,000 for the years 1900 to 1926, inclusive, the source of their water supply and the method of purification thereof.

5065 **Defendants' Exhibit No. 1179,** is a map of Chicago and the Sanitary District, on which had been marked by heavy black lines those beaches in Chicago under the direction of the municipal department having to do with bathing beaches. The beaches are operated under local park departments by park boards, and there are certain private beaches. The nearest beach to the mouth of the Chicago River is the Oak Street Beach, about three-quarters of a mile north. Over five million people use the available beaches in the summer time during the warmer months for bathing purposes. The Oak Street Beach is along the Lake Shore Drive, Park Drive or Boulevard, with an esplanade along the lake front. There is a clean sandy beach there and in hot weather it is black with humanity along a frontage of nearly a mile. Bathing beaches are scattered all along the North Shore at almost every street intersection with the lake.

5068 The pollution of Lake Michigan will materially affect the condition of bathing beaches. If the sewage were allowed to go into the lake, the beaches would not be fit to bathe in, and even with a treated effluent going into the lake, there is a serious question as to whether bathing should be permitted within a number of miles of the mouth of the Chicago River.

5073 The operation and maintenance costs for 1945 on the Sanitary District program, leaving out any interest or sinking fund allowances for the retirement of bonds or the depreciation fund, would amount to $4,300,000, and that is exclusive of the cost of chlorination of the sewage.

The program in 1955, adding complete treatment, 85 per cent on all plants, would increase the cost to a little less than $5,000,000. In estimating costs exact estimates cannot be made because of the restrictions imposed by union labor in adding men that in a private plant might not be used. So that operating costs are higher than would obtain in the absence of restrictions.

5074 The additional cost for chlorinating effluents would be around $2,000,000 to $2,200,000, and the operation of water filtration plants would probably run about $1,500,000 to $1,700,000.

5077 Practically all the sewers in the Sanitary District are on a combined system. Two small villages on the North Shore have separate systems. An estimate for Chicago alone has been made and it has been found that it would cost between $250,000,000 and $300,000,000 to build an additional system for the purpose of separating storm water from human sewage. The streets and alleys would have to be torn up and there are something like 2,970 miles
5078 of existing sewers that would have to be duplicated. This estimate includes not only the cost of the sewers, but the cost of making connections to buildings, and the

like, which of necessity must be arrived at roughly. It would be more expensive on the big down town office buildings than on the smaller outlying apartments and individual houses.

In building works to purify storm water as well as dry weather flow great expense would be occasioned by the greatly increased quantity of liquid that would have to be handled. The unprecedented nature of such an attempt would increase the cost of interceptors and pumping stations and treatment works. Such a system must be regarded as highly impracticable, and I have no knowledge of its being practiced in any other large place.

With reference to the work that might be installed to compensate for cutting off of the diversion to a thousand second feet or to zero, the amount of annual operating cost in excess of the amount of operating cost under the present program would be $4,800,000 for operation exclusive of interest and other charges.

Cross-Examination by Mr. Jackson.

5422 I am referred to my testimony given before the Rivers and Harbors Committee of the House of Representatives between March 17 and 20, 1924, as follows:

> "The development of the sprinkling filter, or trickling filter, in which sewage is spread over beds of crushed stone, marked a great advance in the intensive treatment. With this process from 10,000 to 25,000 people could be handled per acre, according to the strength of the sewage and the depth of the filter. A well-nitrified effluent was produced. The stones furnished a workshop for the bacteria, which attacked the material coming in the sewage and converted it into humus, nitrifying the organic matter and delivering an effluent, which, after settling, was fit to run down the stream without dilution. A sprinkling filter, unlike a water filter, manufactures solids. These must be settled out."

I made the statement for the purpose of outlining, in a popular manner, to nontechnical men, the process that would occur in general, and not in particular.

5423 Referring to a paragraph on page 1640 of the same hearing, the following:

> "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."

I made the foregoing statement before the Committee subject to the same qualification as I have stated before, to explain, in a purely general brief way, to nontechnical men, and in general, not in particular. The statement is correct in that fish were living in the effluent of the Sani-

5425 tary District trickling filters right at the filters. Young carp were living in the effluent, some shiners from Lake Michigan, and some others.

6645 LANGDON PEARSE recalled for further examination:

Direct Examination by Mr. Adcock.

6646 Defendants' Exhibit 1310 is four tables marked A, B, C and D, and B, C and D are as follows:

"DEFENDANTS' EXHIBIT 1310.

(B)

TOTAL CONSTRUCTION COSTS AND CAPITALIZED ANNUAL COSTS OF ADDITIONAL SANITARY DISTRICT AND CITY WORKS TOGETHER WITH CAPITALIZED PUBLIC UTILITIES COST AS OF THE YEAR 1955 ASSUMING LAKE MICHIGAN DIVERSION AT CHICAGO LIMITED TO 1,000 C.F.S.

Construction Cost		
Sanitary District		
Chlorination	$ 2,100,000	
City		
Sanitary Sewers	335,125,000	
Water Filtration	53,000,000	
Super Tunnel and Crib	70,000,000	
Total Construction Cost	$460,225,000	
Interest during construction	53,522,000	
Total		$513,747,000
Capitalized Annual Costs—as of year 1955		
Operating	$107,653,000	
Depreciation and obsolescence	83,127,000	
Overhead	28,593,000	
		219,373,000
Total Municipal Costs		$733,120,000
Public Utility Damage as of year 1955		186,900,000
Grand Total		$920,020,000

(C)

SUMMARY OF ANNUAL COSTS AS OF 1955 FOR ADDITIONAL SANITARY DISTRICT AND CITY WORKS.

Based on Diversion at Chicago Limited to 1,000 c.f.s.

Sanitary District and City		
Interest on Capital Cost	$ 21,834,000	
Depreciation and obsolescence	3,532,900	
Operating Expense	4,575,250	
Overhead (and interest on expended overhead during construction period)	1,215,220	
	$31,157,370	
Public Utility		
Mean Borrowing Rate (6%)	11,214,000	
Grand Total		$ 42,371,370

(D)

ANNUAL COSTS AS OF 1955 FOR ADDITIONAL SANITARY DISTRICT AND CITY WORKS.

Based on Diversion at Chicago Limited to 1,000 c.f.s.

Sanitary District		
Interest at 4¼% on $2,145,000*		$ 91,000
Depreciation and obsolescence		171,600
Operating Expense		2,220,000
Overhead		111,000
		$ 2,593,600
Municipal		
Interest at 4¼% on $511,602,000*	$21,743,080	
Depreciation and obsolescence	3,361,300	
Operating Expense	2,355,250	
Overhead and interest on expended overhead	1,104,220	
	$28,563,850	
Public Utility		
Mean borrowing rate of 6% on $186,900,000	$11,214,000	
Illinois Valley		
Interest at 4¼% on $15,395,000*		$ 654,290
Depreciation and obsolescence		474,306
Operating Expense		1,131,450
		$ 2,260,046

6647 These tables were prepared by me from testimony given by me, Mr. Eddy and Mr. Fuller, to show the cost of additional works up to 1955 and probable operating costs, with allowances for depreciation, obsolescence and overhead.

*Including interest during construction on principal sum."

Referring to Defendants' Exhibit 1310-B, the figures therein given for sewers are in addition to my original statement of $250,000,000 because I have allowed an additional 750 miles to be built. These are built at a lower rate per mile, assuming they are to be built in new territory, making a total of $335,000,000 as compared with the original $250,000,000. However, Mr. Fuller testified to $300,000,000, so the figure in Exhibit 1310-B is lower than if I used his figure.

6648 With other figures as previously given, the total construction cost is $460,225,000. I have computed the interest at 4¼ per cent, which is the average rate experienced by the Sanitary District over a long period of years. The capitalized annual costs are based on operating costs as testified to by Mr. Fuller and myself, with allowance for depreciation and obsolescence on the filtration plant of 1¾ per cent; on the super-tunnel, crib and sewers, ½ per cent; and on the chlorination, 8 per cent. The figure also includes an allowance of $350,000 for the maintenance of the sewer system. The overhead is at the rate of 5 per cent. Operating expense is taken as of the year 1955, and includes the capitalization of the operating cost, both capital expenditures and operation in that year for the water filtration, sanitary sewers and chlorination.

6649 To that total municipal cost as distinct from the public utility I have added a public utility damage as of 1955, which I believe was testified to by Mr. Fuller. It was obtained in the same way that he obtained it, by taking information from Exhibit 18. It shows a figure for 1950 for damage to the Commonwealth Edison Company which I have extended to 1955 at the same rate. That makes a grand total of $19,925,020.

6650 **Defendants' Exhibit 1310-C** is a summary of 1310-D, and shows the total for the year for the Sanitary District

and City as distinct from the Public Utility, giving a grand total of $42,371,370.

I included an estimate of the annual cost of the Illinois Valley, because of the additional cost of works for a flow of 1,000 c. f. s. over and above that for 8,500 c. f. s. diversion.

6688 *Recross Examination by Mr. Jackson.*

6691 The cost for the water purification plant was $53,000,000, based on 720 m.g.d. as of 1945. This esti-
6693 mated cost covered recovery of land from the lakes, connections to existing tunnels, cost of cross-town tunnel, low-lift pumping station, and the connections to the tunnels to cover a working addition to the present water works plant.

6694 The computations are built up from different unit prices for different parts of the plant, but if averaged they are roughly $40,000 a millon gallons. We have assumed that there would be four plants, with an average initial installation of 275 m.g.d. at each. Thus the initial cost for each is $14,100,000, and in 1950 there is to be additional capacity added. The total ultimate cost for 375 m.g.d. as of 1950 is $17,550,000. The cost per million gallons over all is $46,000. That is split. Exclusive of
6695 low service that would be $44,000, and we have allowed $2,000 for the million gallons of low service, which means the pumping from tunnels to plant.

The figures include the completion of purification plants, connections to tunnels and water mains, and the necessary piling and other connections. That is a single stage filtration plant with a single stage coagulation basis. If the installation were built as one plant the cost would be practically the same. It might be a little
6696 higher or a little lower. My estimates are based on what work has cost in the last three or four years, and

what we would consider a reasonable price could be obtained by letting contracts in the open Chicago market under the municipal conditions.

6697 The item of chlorination, $2,100,000, in Exhibit 1310-B, is for chlorinating the sewage effluents. It is a construction allowance for the additional equipment and housing of the same at the different main plants, based upon the capacity on a metered basis of flow through our treatment plants as of 1955. The total estimated flow is 998 m.g.d. and the first cost is estimated at $2,109,000, some of the apparatus being put in in accordance with the theory of this table at years successive from 1930 to 1955. Roughly, the unit cost is $2,100 per million gallons, but the total cost was built up from assumed costs of apparatus and housing, and not from unit costs.

6698 In the estimate for the water purification plants I did not use the cost of pumping a million gallons a foot high. I took an allowance for chargeable head and power in kilowatt hours, using actual assumed operating conditions. The figure of chlorination assumed 10 parts per million of chlorine at all plants except the North Side, and at the latter 5 parts per million. I allowed a base figure of $1,500 a machine for chlorinating, and I think

6699 a rate of 720 pounds per day per machine as a maximum, to which was added, of course, an allowance of 15 per cent for contingencies and engineering.

As to how I arrived at my figure of $2,100 per million gallons ,if a machine costs $1,500 and the application is 83 pounds per million gallons of chlorine, there are other incidentals required in such a plant. I allowed for chlorine storage, scales, heaters, switches, centrifugal pumps, piping, booths, wiring and building housing apparatus. The cost of the chlorination is a comparatively small proportion of the total cost.

6700 One of these machines furnishes chlorine for a little

less than 9,000,000 gallons, but you must recall that spare machines are required. The difference between the cost per machine of $140 per million gallons and the estimated cost of $2,100 per million gallons is overhead, if you include in that term housing, chlorine storage and other appurtenances. The overhead constitutes a large portion of the expense. As I recall, we allow a floor
6701 space of 7 by 14 for each machine. The actual floor space for each machine is 3 by 3, but there has to be space to go around it.

The super-tunnel was based on a diameter of 35 feet, or else two tunnels 24 feet in diameter for the main line from the intake in shore. The size becomes less as we go south. My computation does not show the distance off shore. The location chosen is 20 miles northwesterly from the mouth of the Chicago River approximately in 60 feet depth, and is about 7 miles off the mouth of the North Shore Channel.

6702 I figured on 14 miles from the intake to Lawrence Avenue, 5 miles from Lawrence Avenue to Chicago Avenue, 2½ miles from Chicago Avenue to 14th Street, 7 miles from 14th Street to Western Avenue, in order to reach existing connections. At the furthermost point south the tunnel is reduced to the equivalent of a 20-foot circle. I cannot say offhand whether it connects with a present tunnel that is only 12 feet, but the estimate was
6703 made to furnish the capacity which we felt was needed.
6704 The relative capacity of a 20 foot and a 12 foot tunnel would be as 400 to 144. For the unit cost of a 35-foot tunnel we used $500 a foot; for 32 feet, $350; for 24 feet $250; for 20 feet, $200. The cost was based on our
6705 judgment of what such work would cost. I do not recall that I have ever seen any actual figures of the cost of water tunnels in Chicago, though I have asked for them from time to time. I did not have the advantage of such figures in making this estimate.

The sanitary sewers are to be a separate system built alongside the present existing sewer system, the assumption being that the old system would be left for storm water. As a matter of fact, the sewers in the loop are very old and inefficient to carry off sewage and storm water at the present time. The construction of a new
6706 system is required in that district, on which there have been various estimates. I do not know of any estimate that a new system could be constructed for approximately $28,000,000. As to whether the loop is the most expensive place in which to construct a system, it depends upon what you mean. It may take the highest rate per mile, but there is a low mileage in the loop. It is the additional mileage that will build up the cost in the outlying territory. The cost per mile would be the highest in the loop.

6707 I am told that under present conditions in the loop the capacity is so small that sewage and storm water frequently backs up into basements which, of course, is not a desirable condition.

My estimate of miles of sewers was originally 2,970, based, as I recall, on mileage which existed in 1926, but in making up the present estimate I added 750 miles to take care of the additional separate system that would be required if the policy went into effect in a period of
6708 years up to 1955. The added mileage was in outlying districts which I anticipated would be built up in the next period of years. I would not as a sanitary engineer recommend that separate sewer systems be constructed in such districts under present conditions. Theoretically that would be a desirable policy, but not practically.

6709 In determining the diameter of sewers we considered a range of diameters based on typical layouts in different
6710 sections of the city. The cost was built up from costs

on different sizes, so that I cannot state a unit cost on all the sewers. I have not the costs with me. I have costs here which average from $81,000 to $121,000 a mile, exclusive of engineering and contingencies. The largest amount per mile is in the loop district. There is a difference made in our estimates for location, the amount of work that would have to be done in going into other buildings, pavement allowances and other incidental work.

6711 It is true that the cost of construction between buildings and sewers was paid by the owners of the property when the sewers were originally built, but in adopting a program of this sort I included that item in the estimated cost of the project. We allowed approximately $100 per building, and cross-connections for every 30 feet on each side of the street. The estimate of $250,000,000 is an average cost of about $84,000 a mile. That comes out lower because we made deductions for certain sewers in unpaved streets, and certain adjustments. The 750 miles of new work was added at a reduced price, because they would be in new territory and built alongside

6712 of other sewers; but in view of the fact that there would be two sets of connections required in the houses, I have assumed that the estimates made include the cost for the sanitary connection. The size of the sewers for the outlying districts would average probably less than 30 inches. I could not say offhand what proportion are less than 30 inches. Probably none are greater than 30 inches,

6713 but that might be depending on the distance they run to connect with the interceptors.

My estimate of $250,000,000 for 2,970 miles did not include engineering and contingencies. I added 15 per cent for those items. As I recall, the estimated cost for the 750 miles of additional sewers was $66,000 a mile.

6715 As to counsel's question whether 12-inch sewers in Chi-

cago did not cost $2 a foot or $10,000 a mile for ordinary depths, it depends on what you are estimating. This is not an estimate of new sewers. It is an estimate of going in and tearing up streets and pavements and rebuilding. That is not the case with the additional 750 miles, but the figures include house connections, and certain contingent items of uncertainty as to design.

As to counsel's question whether 30-inch sewers in Chicago did not cost about $7 or $8 a foot or about $40,-
6716 000 a mile, there may have been some let by the city at or around that price. I would not care to say there have not been. I would not say that there has been a marked difference between the cost of sewers built by the city and those built by the Sanitary District, because our sewers in general have been so much bigger that there is no comparison, except on a few shorter lengths and smaller sizes.

The 35-foot tunnel is assumed to have a capacity of 2400 c.f.s. and a velocity of 2.4 feet per second. That
6717 would be 1,560 m.g.d. The cross-sectional area of the tunnel is approximately 1,000 square feet. I cannot say offhand what is the combined cross-sectional area of all Chicago's present intakes. I would not be surprised to know that it is less than 1,000 square feet, but this is a longer tunnel and therefore the slope conditions are not the same. I cannot say offhand what would be the frictional loss in the 35-foot tunnel at an average pumpage in 1955. I never estimated that, because the figure was built up to give approximately the same drop on our line that now exists.

6718 It is true that four or five tunnels with a combined cross section of 1,000 square feet would have greater frictional loss than one tunnel of the same dimensions, if they were the same length, but they are not. I would not say offhand that the present intakes are figured on

a 4 to 5 foot velocity. I have stated the data on which I have figured this tunnel and the velocity. It would be smaller in bore if it had a higher velocity. I am not denying that.

6719 I cannot say whether the velocity is greater in the present intakes.

6720 I have no comparison of the aggregate size of the present intakes or their proportions, and I can only say that there is a total average water consumption now of 888 m.g.d. which would be about 1200 second feet, according to my notes, or a maximum demand of 1,450 m.g.d. As to whether this maximum capacity is met by pulling in at a higher velocity and reducing the level, it is, of course, up to the capacity of the works. The same process followed with the proposed tunnel would, of course, materially increase its capacity.

6721 The proposed tunnel provides for some enlargement of the intakes. As to whether I would consider it fair to charge that expansion of the waterworks to a cessation of diversion, I would not care to answer that question without a detailed examination of the capacity of exist-

6722 ing tunnels, which I have not got here. If the proposed tunnel more than replaces the present facilities, that portion should not be charged.

An extension of the intakes, such as the Dunne crib and the 68th Street crib, would be an addition, and it would be somewhat of an improvement in a general way.

I cannot agree in general that many of our existing tunnels are leaky and permit the entrance of polluted water. I have heard that one tunnel, the old 68th Street tunnel, might be slightly leaky through some connections that were improperly blocked when they were abandoned, but I would not care to say that the tunnels are leaky and obsolescent. I have never examined them personally and they are not within my supervision.

I am not familiar with the report made by Mr. Gorman on the condition of the tunnels. He is an employee of the City of Chicago, and his reports go to the city. I would not necessarily feel that I should consider and investigate these questions before determining what the loss occasioned by replacing the present intakes would be.

6724 It is likely that the useful life of the proposed tunnel will be longer than the useful life of the tunnels replaced. No allowance for that is made in the estimate.

6725 In my estimate I used 10 parts per million of chlorine for the trickling filter effluent, and 5 parts for the activated sludge. This consumption of chlorine is based on complete treatment.

6726 As to whether the item of water filtration included in Exhibit 1310 is an expenditure which must be sustained by Chicago in any event, I believe that the water will be eventually filtered, but I do not feel that the filtration works will proceed as summarily as will be undertaken in this estimate. I believe that filtration will come from the standpoint of esthetic improvement of the water to get rid of the turbidity and to give another bulwark against chance pollution. It would also somewhat lessen the quantity of chlorine used. Nevertheless, I think it is proper under the conditions of this inquiry to include the cost of a filtration plant as a loss attributable to a cessation of diversion.

6727 The estimate for the filtration plant has been based on the reduction in the per capita use of water, but making allowance for the increase over the average daily consumption in the chosen capacity of the plant. In other words, I have assumed that the water supply will go on a metered basis and that after a certain period of years the consumption will begin to increase again in a slight amount, but taking account of the maximum over the average for the year in allowing the size of the plant.

6728 My estimate of $14,104,000 for each of the filter plants makes a total of $56,000,000 for the four. That is prac-
6729 tically the same as the figure of $53,000,000 given in my original testimony for 1,100 m.g.d. That is slightly more than the present consumption.

6730 I would not say that the installation of metering would cut water consumption one half. My figures show a per capita consumption considerably reduced by 1945, and somewhat increased again by 1955 to 160 gallons per capita, as compared with the present consumption of 274. I am not informed that the metering in the Calumet district has reduced the per capita consumption from 400 to a little over 80.

6731 I made no investigation of the effect of such metering as has been done in Chicago in arriving at these estimates. For the water filtration plants we took a maximum loading of 125 m.g.d.

6732 As to whether in computing the loss from abandoning present intakes, it is fair to determine the value of the intakes in their present obsolescence rather than taking the cost of a new piece of construction, my thought was that this is an additional expenditure upon the community to replace existing plants and therefore we have used a reasonable expense to estimate. I would not be surprised if the 65 miles of tunnel now existing cost only $18,000,000. It was built over a period of years and under much cheaper construction costs, and much of it was built by the city itself.

6733 My figure of operating costs capitalized, $107,000,000, in Exhibit 1310-B, is derived from the $4,575,000 operating expense in 1310-C by capitalization at 4 per cent. That figure in Exhibit 1310-C is a summary of 1310-D, in which the operating expenses are detailed. The item of operating expense in the Sanitary District of $2,220,-000 is an annual expense for additional chlorination of

6734 effluents on the basis of 10 and 5 parts per million, depending on the type of treatment. The item of $2,255,250 under the head of "Municipal Operating Expense" includes the cost of operating the filter plant with a low-lift pumping station, and the additional cost because of this super-tunnel, and an allowance for the operation of the additional sanitary sewers.

6735 I did not make any allowance to offset the present cost of operation of tunnels and cribs. Six tunnels would
6736 cost more than one. However, operation of cribs and tunnels is a very small proportion of the whole cost.

I cannot state the unit cost for operating the filtration plant, because that was built up. The total cost was $1,700,000 for an average load of 720 m.g.d. The low-lift head in the allowance for pumping was 25 feet. The allowance made for low-lift pumping was $388,000 plus 5 per cent for general overhead.

6737 The figures in Exhibit 1310 on public utilities were taken from Exhibit No. 18. Mr. Fuller used that figure of $186,900,000 derived from the table on page 244 by taking the 1950 figure given there and adding to it the difference between the 1945 and 1950 figures. I have used his testimony that $186,900,000 is a fair allowance for 1955, and also his testimony that 6 per cent was a fair mean borrowing rate.

6738 As to counsel's question whether in arriving at the capitalized annual cost of operating expenses in Exhibit 1310-B I gave any consideration to the fact that operating expenses would be increased by 1955 regardless of diversion, I made no allowance for such assumption, because I understand that this table fits in with the sewage treatment program up to 1955, and I made no allowance for increases that might come if the filter plant were built anyway. There is nothing in the exhibit relating to the present sewage program.

6739 There might be a saving in waterworks expense resulting from metering and water filtration already contemplated, but my examination has not given me the data to say how much that saving would be. There would not be a very substantial saving for the sewage disposal plant.

6741 Assuming that metering cuts the consumption of water in half, it would have caused a substantial saving, if it could have been made before our work was planned and put under construction; but, unfortunately, that does not obtain today, because part of our work has been built up on a partly metered basis, and future work taking into consideration the effect of metering. An allowance has been made in the estimates for the effect of metering on the plants which were designed without considering such effect.

I am referred to page 435 of the official reports for 1923, 1924 and 1925 of the Department of Health of the City of Chicago, in which it is stated that in July and November, 1925 there was a sharp rise for short periods in the bacterial contamination of water in the Clarendon Ave-

6742 nue tunnel; that the tunnel system was promptly investigated, but the cause was not determined; that it might be that water from the old Lakeview land tunnel surges across the station to the Clarendon Avenue system; that the tunnel gate at Wilson and Clarendon Avenues was found jammed, that the results of a sampling pump installed September 11, 1925, indicated serious contamination of the tunnel shaft just east of the station; that the contamination persisted throughout the remainder of 1925, and it was necessary to use quite heavy doses of chlorine.

That statement indicates that it is a point that requires investigation by the proper authorities.

6743 I am referred to page 142 of the same bulletin, in which it is stated that on November 16th salt was dumped into

shore shaft No. 13 on the abandoned section of the 68th Street tunnel, and that tests for salt in the South Branch tunnel were positive and showed that the bulkhead between the two systems was leaking; that a diver was sent down into shaft 13 to inspect conditions, and found a serious break in the brick bulkhead, which was plugged by bags of sand during the latter part of November; that on December 1st another test on the 68th Street tunnel from the shore side was conducted and the leakage was found to be greatly reduced; that on dewatering the tunnel the leak was found to be around the cast-iron bulkhead between shaft 13 of the abandoned tunnel and shaft 11 of the 5-foot branch tunnel to the 68th Street Pumping Station.

That is the particular place I had in mind when I told you my knowledge of the situation. It is a local place, as your description indicates.

My attention is directed to page 445 of the same bulletin, where it is stated that as the result of an unusually high contamination at the Green Street shaft an investigation was made showing visual evidences of sewage seepage through the west wall.

That indicates an unsatisfactory condition at that particular point, in the manhole. It is just a local situation.

6745 The same bulletin states that samples of water in the shaft showed gross contamination by sewage organisms; that further investigation showed there was a 24-inch brick sewer passing within one foot of the shaft wall; that the invert of this sewer was about the elevation of the seepage through the wall; that the sewer was exposed in August, 1924, and found to be in fair condition, but three house drains, one of which was within 10 feet of the shaft wall, were found leaking; that probably following heavy rainfall periods this sewer flowed full and even under considerable pressure; that grossly contaminated seepage water undoubtedly entered the tunnel shaft.

It indicates an unsatisfactory condition locally, that the authorities are curing to the best of their ability and speed. I do not see that that invalidates the entire tunnel system or destroys its usefulness.

6746 The estimates of dry weather flow in the new interceptors are based upon an adjusted flow from the new work reflecting the effect of metering. The old interceptors are those under contract up to the time when the permit was issued by the Secretary of War requiring metering. Those are based on a capacity which is somewhat under what would have been the pushed ahead figuring from existing conditions. We made slight allowance, assuming that there might be a slight effect if meters were considered; but the effect of that has been, in general, to give us structures that will have a longer life, depending on the conditions of actual flow. That is, the earlier structures were able to take care of existing conditions at that time, but since the Secretary of War's permit we are taking account of the effect of metering.

6747 If the water consumption should be reduced, you will have a greater provision for storm water in the sewers originally built, but the treatment plants are designed to take care of a definite proportion of the dry flow, so that that proportion of the sewage will not necessarily be treated, unless it proved that on the North Side plant, for instance, we have additional capacity because of lower flow and, therefore, can take that through. I cannot make an estimate of the increased capacity of storm water flow in the sewers designed before metering was taken into consideration, in the event that metering should be effective. Offhand I cannot give the figure of water consumption on which the interceptors are based.

6748 Referring to the figures of flow shown in Table 54 of the
6750 report of the Board of Review, Part 3, Appendix 1, page 88, if you are talking about capacities, this table with ref-

erence to the Calumet area is based on some allowance of flow other than what your question asks me for that particular area, because, if I remember rightly, somebody testified to 700 c.f.s., capacity at the Calumet Pumping Station.

If the population be taken from Table 52 of the same report that you are quoting as 350,000 people as of 1950, and the 700 c.f.s., be translated into million gallons per day, that is about 455 m. g. d., for 350,000 people. That is about 1,300 gallons per capita, and I think that is likely correct, because that sewer was designed purposely years ago to keep out of the Calumet River or out of the lake as much of the sewage as possible, and to put it behind the controlling works at Blue Island. It is on an entire different basis of design from that adopted afterwards with our treatment program on the North Side, West Side and Southwest Side.

6751 I would not say that that interceptor was designed to carry all the storm water, because there is a double hookup in there. A certain part of the area goes through the 95th Street pumping station. That pumps again into an interceptor going to the Calumet pumping station. In an extraordinary rainfall, if the capacity is taxed at the Calumet pumping station, we can divert the flow at 95th Street direct into the river. We have not yet found, and probably will not for many years find, it necessary to do that, but it is possible. It is also possible to discharge direct at the Calumet station.

6908 In my computation of the cost of low-lift pumping I made no credit as such for the saving in high-lift pumping due to the heads being increased, because I assumed that over the whole program the heads would be practically the same. In so far as there is any change and if there is a saving, I am willing to admit that it should be deducted.

6909 The original Calumet interceptor was laid out without

any thought of metering, because it was built about twelve years ago.

6911 To the best of my recollection, we did the designing for a flow of 1,300 gallons, as previously explained. As to whether it was built to last until 1970, I can only say that we put it in without regard to the exact design on
6912 the basis of the question you have asked me of dry flow. I cannot say what dry flow the North Side interceptor was designed for, because our method of designing was not based on that factor. I have had a man working a year and a half with proper assistance developing the flow in the different areas. I cannot answer your question as you have asked it. I can tell you what flow we would expect to get at the treatment works.

6913 In 1955 we expect an average flow at the North Side works of 202 m. g. d.; at the West Side plant, 354 m. g. d.; at the Southwest Side plant, 366 m. g. d. There are two intercepting sewers running to the North Side plant, one from the territory north to the Cook County line, which is comparatively small, about 5½ feet in diameter; and one from the south, which I think is 15 feet in diameter. The North Side sewer, as I remember,
6914 was designed for between 1960 and 1970. I have not with me information on its capacity.

6915 The south sewer was built for between 1960 and 1970.

6916 The West Side sewer is estimated at the plant to be 17 feet. It is not exactly circular. A horseshoe would describe it generally. What I have stated is the horizontal diameter.

The West Side interceptor is designed for 1970, at which period the population given in Table 52 of the report of the Board of Review is 1,920,000 humans, plus
6917 an allowance of Loop population of 300,000, a total of 2,220,000 people.

The Southwest Side interceptor is laid out for a size

coming to the works of 17½ feet horizontal diameter. It is designed for 1970 with a population at that date of 2,200,000 and the sewage from the stockyards.

6918 As to sewers designed without reference to the effect of metering, they will be available to take storm water to the end of the sewer, but if the treatment facilities are not provided it does not do us any good to take it there. I will endeavor to furnish the percentage of increase of capacity for excess storm water by reason of metering.

6919 In saying that sewers are designed at one and one-half times the dry weather flow, I mean in a general way one and one-half times the average dry weather flow. However, we allow for a factor of safety, and for an air space, so that the sizes are not capable of being computed without knowledge of those data.

6920 Regarding my testimony on page 5032, I did not say anything about interceptors being designed for a specific
6921 flow. I stated as a general proposition what the procedure was, and referred to the practice in England. Then I stated that estimating on a metered use of 150 to 200 gallons dry flow in the sewers and 50 per cent of that would give 300 gallons per capita as a basis on which to start.

That was not given as a basis of design, but was given because during some of the periods of operation we have estimated that on some of the old sewers we would get as low as 100 gallons per capita, and on others we would get as high as 200 gallons per capita of flow. We have in mind ultimately that when these systems are to be tested out, in 1970 or thereabouts, we are hoping to arrive at an amount of 50 per cent more than the flow; but these figures are given for the purpose of illustration and were not stated otherwise.

6922 In the case of the West Side interceptor, we estimated

so much for domestic sewage, but it was built up from the different areas tributary.

6923 On the West Side there is an allowance for industrial waste, including a large portion of the tanneries on the North Branch and such additional allowances for industrial water as are shown by our survey of the territory to be required. In building up the West Side interceptor there was an allowance for infiltration of ground water, which varied according to our estimates of the character of the areas. Our computation was on the basis of acres.

6924 We allowed a 50 per cent overage for storm surplus, and then as I have explained, an additional percentage for a factor of safety, an air space. The additional capacity for storm surplus was based on dry weather flow, because, as we regard it, that total capacity is limited by the size of the treatment works.

6925 If that additional provision for ventilation was used for taking care of storm water it would defeat its pur-
6926 pose. It may fill up in time of storm, but the intention is to keep the air space there. The sewer may run nine-tenths. The interceptor capacity is not based on the capacity of the sewage plant, except in so far as the interceptor is laid out, and then the amount in excess of the dry flow that we expect to take care of is limited by the capacity of the treatment plant, because we do not build our treatment works so far ahead in capacity as we build our sewers. The interceptors were designed so that any excess of storm water would go directly into the South Branch or the Main Channel.

6929 The capacity of the interceptor is not affected by the capacity of the sewage treatment plant. There will be a difference between these two capacities until they become equal. Until they are equal the excess can be carried down to the plant, if you are willing to pay for the pumping, but it is cheaper to spill it into the river as we have

designed at each of the present outlets of the existing sewers.

6932 In estimating the population equivalent of industrial waste there is no bacterial comparison made. I may be mistaken as to packing house waste, but I know we have done very little in the other wastes from a bacterial standpoint. The basis is the oxygen demand.

6933 I would not want to say offhand whether the bacterial equivalent of industrial waste would be very much less than the bacterial equivalent of domestic sewage of a population of a million and a half people. I believe that on account of the packing house problem industrial waste is a greater problem in Chicago than elsewhere.

6934 I have no information on the proportion of packing house waste occurring in Madison, Wisconsin, or Cudahy or Milwaukee. I do not see that the proportion cuts any figure, because it is the total aggregate. The seriousness in the case of tannery wastes comes from accumulated solids. I have no information on the proportional industrial load of tannery waste in Milwaukee, though I am ready to believe that they have more than Chicago.

6935 I know it has been a source of worry to those operating the plant there. My opinion as to the problem of industrial waste in Chicago was expressed without consideration of the situation elsewhere, because I believe the aggregate is the important thing.

6936 The total rainfall going into sewers may vary from as low as 10 or 20 per cent up to practically 100 per cent. We have assumed there would be from 50 to 60 per cent for certain years, which refers to the main treatment

6937 works, and in so far as the Loop is contained in that it is averaged up. It might go as high as 90 or 100 per cent in the Loop, and other points might run as low as 20 per cent. We consider the average to be 50 or 60 per cent.

6938 In so far as an average of our best judgment is hypothet-

ical, I suppose the average may be so termed. The esti-
6939 mate of 50 to 60 per cent is based on my own judgment and that of another man, from our experience of 6 to 17 years.

The storm run-off might equal 10,000 c.f.s. once in 2 years. I cannot say how many inches in rainfall per hour that would be. How long it would continue would
6940 depend on a good many factors. As to specific instances of such a flow, I am informed that one occurred in 1923 or 1924 when I was out of the city. I think it was August 11, 1923, and I think you will find it in a memorandum to the Chief of Engineers that is in evidence.

6942 I am unable to state what percentage of the total storm overflow is stronger than sewage. I have made some observations in connection with pumping station operations and in connection with the operation of treatment works and the drainage canal which indicate that storm water overflow is frequently stronger than ordinary sewage.

One of the purposes of the 50 per cent excess in design of sewers is to take care of that storm sewage. One of
6943 the effects of overflow discharge is to put into the stream deposits of organic and mineral matter which have occurred in the sewers. These are not necessarily largely
6944 grit or substances of that character. There is slightly more mineral in relation to the volatile than ordinarily, but it is a difficult matter to decide just what does happen. I do not say it is all gritty material or that it is inoffensive. It may be very offensive. I am not giving an opinion as to the bacterial comparison, but it undoubtedly does contain bacteria.

6945 The muddy appearance of the overflow is due to grit and dirt, with a proportion of human sewage and industrial waste or whatever may be coming. My understanding is that Chicago sewers were designed with a

minimum flow of 2 feet a second, and in some tight places the design is less than 1½ feet per second. I believe the 2 feet per second was on the basis of a sewer flowing half full or slightly under. 1½, I believe, is the minimum velocity of dry weather flow. These are the
6946 Chicago sewers, and not the intercepting sewers of the Sanitary District. On the interceptors we have worked to a minimum velocity of 2 feet per second. I think in our Des Plaines River interceptor, on account of the presence of rock, we used in a certain critical section a minimum velocity of 1½ feet per second on the dry flow.

As to counsel's suggestion that the Chicago sewers were designed for an average flow of 3 feet per second, my recollection is that as to critical velocities the minimum velocity is as low as 2 feet per second, and that is as
6947 far as I can go in expressing an opinion of work done by the city over a period from 1854 to date. A velocity of 2 feet per second or better is considered a cleaning velocity. In tanks for the settling of sewage solids we allow a velocity of ½ foot per second on an average, or a maximum of 1 foot a second for settling grit or min-
6948 eral matter, and for the balance of the plant the velocities are much more, depending on the type of structure and design. That is where the major portion of the work is done.

6950 Chicago sewers are provided with catch basins to entrap street dirt. I cannot say how often they are cleaned. I believe some, particularly in the Loop district, are cleaned fairly frequently. I believe some are not cleaned more than once a year. That is not under the control of the Sanitary District.

Each of the 314 sewer outlets in the Sanitary District represents a possible storm overflow. Under present working conditions none of these overflows can go into
6951 Lake Michigan, though if the canal were shut off there

is a possibility that at high flood water from the Des Plaines River, it would find its way into Lake Michigan by reason of the overflow near Willow Springs. The dam constructed in 1909 allows excessive peaks to go over, as I have personally seen, though it rarely hap-
6952 pens. That would occur if the gate at Lockport is raised and there is no diversion. The Des Plaines River has no connections with the Drainage Canal above Lockport, except in so far as the excess flood at Willow Springs can spill over into the canal.

I do not recall whether the Hering report of 1887 recommended a separation of storm water from sewage. I believe some recommendation was made in 1907 for the Calumet region.

Referring to the report of the Drainage and Water Supply Commission, dated Chicago, January 1887, signed
6953 by Rudolph Hering and others, stating that it is practicable to exclude the storm water from the sewers over a large portion of the future city by adopting a separate system of sewerage, and that the area north of the town of Jefferson and of the middle of Lakeview may be treated to advantage in this way, and also a large portion of Hyde Park, Lake Calumet and other adjoining towns, I do not question that Mr. Hering said that, though it was written in 1887 and not in 1927.

6954 As to what portion of the city would have had separate sewers if that report had been adopted, I cannot answer, because I have no information at hand as to the sewer system of the city at the time the report was
6955 made. As to whether the report would include all the south part of Chicago south of the 39th Street station, I know there were some sewers around 39th Street in existence at that time, and some I believe in the town of Pullman, and some in the town of Lake, but I do not have any exact knowledge on that so as to give a definite

opinion. I cannot say that three-fourths of the area of the present city would have had separate sewers if the report had been followed.

6956 There are separate sewer systems in Glencoe and Winnetka, and there is a portion of Pullman that was originally built up on a separate sewer system discharging into Lake Calumet. To my knowledge, there is no separate system contemplated in the City of Chicago. Whether such would be built in the suburbs is difficult to ascertain, because the selection of sewer types so far has been largely in the hands of village authorities, boards of local improvement and village councils.

6958 The testimony I gave on page 4969 is correct, to the effect that as we built interceptors up along the sides of the River we were able to pick up by suitable devices to a total flow of 1½ times the dry flow; that after that the liquid discharges directely into the river from practically all the existing outlets, and that such liquid may discharge into the stream for as many as 115 days off and on during the year, but the major overflows probably occur 55 times a year. I will explain, however, that that is based on a theoretical relation between the time when the interceptors would fill up and the overflow, and assumes the kind of storms. That relation would occur on an average perhaps 94 times a year, and the maximum, so far as we can determine, would be perhaps 115 times. There are, however, so-called major overflows in 55 instances. So I see nothing inconsistent in that statement.

6959 By "major overflow" I mean a decided outfall to the river, and not merely a balancing in the interceptor between the rainfall coming in and the capacity of the interceptor and what the treatment plant will take away. It is a rather difficult hydraulic question to give an exact opinion on. The filling up of the intercepting

sewers was taken at a rate of rainfall of .03 inch run-off in one hour, .035 in two hours, and .04 in three hours. The .04 corresponds to between 71 and 115 storms, depending on the year analyzed. It would average 94.

6960 As I testified before, the amount of run-off was assumed to be between 50 and 60 per cent of the rainfall. As to counsel's suggestion that if the rainfall merely reached the rate taken as a basis and then immediately subsided, it would not produce an overflow, that is why I stated that is a delicate computation.

6961 To say what is the average run-off in inches per hour required for the 55 major overflows, you have to pick out the storms for a considerable period of time, and I cannot answer the question definitely. We tried to analyze the number of storms in the years from 1920 to 1924, where the data were available and it was on this that I arrived at the average result of 55 as major, which would not be balancing or just a slight spewing over for a few minutes.

6962 A major overflow results from a rainfall materially exceeding the rates I have given, and the degree depends on the extent of the actual storm. As to how long a period of time the rainfall would have to continue to produce a major overflow, that is a difficult proposition to answer. I find on this list a so-called major overflow that a storm of .92 inches produced. I also find another storm of 3 to 4 inches. I have not the exact statement of the rates in those storms.

6963 A tabulation of 56 storms in 1920 shows 332 hours of overflow. You can draw your own average. In 1921 there were 55 storms with 364 hours of overflow; in 1922, 48 storms with 329 hours of overflow; in 1923, 54 storms with 333 hours of overflow; in 1924, 9 months only, 51 storms with 291 hours of overflow. The difference between the total of 115 overflows and 55 major

overflows is slight in quantity, but I would not say it is practically negligible.

Redirect Examination by Mr. Adcock.

6976 I find that the capacity of our present intakes is 1,670 m.g.d., which would be 2,500 c.f.s. as compared with 6977 2,400 c.f.s. for the proposed new tunnel. I believe that only one of the tunnels which counsel for complainants referred to as defective was from the Lake, and that the others were what are called land tunnels.

George W. Fuller, for Defendants. January, 1927:

Sanitary and Water Supply Engineering Expert.

5091 *Direct Examination by Mr. Adcock.*

New York City, engineer; member of the firm of Fuller & McClintock; graduate of the Massachusetts Institute of Technology; student in Berlin at the Hygienic Institute and in the office of the Berlin Waterworks; nine years in research work connected with the purification of water and sewage; from 1890 to 1895 attached to the Technical Staff of the Massachusetts State Board of Health; most of that time at Lawrence, where the board conducted an experiment station for study- 5092 ing methods of purifying water and sewage; from 1895 to 1899 four years at Louisville, Kentucky, and Cincinnati, studying means of purifying muddy sewage-polluted waters; went to New York and have been in private practice since 1899, making a specialty of matters of water supply, water purification, sewage and sewage disposal.

In 1906, in association with Dr. Hering, made a report to the International Waterways Commission in respect to alternate methods for treating sewage as con-

trasted with the dilution method for certain outlying areas, notably in the Calumet area of the Chicago Sanitary District and the adjacent area in the State of Indiana.

Employed by the International Waterways Commission to find out alternate methods for treating sewage beyond the capacity or ability of 10,000 second feet to
5094 dispose of through dilution and diversion, which in their instructions were accepted as a fixed fact. This was on top of what was to be done with that particular stated volume. In 1914 was one of the advisory engineers to the International Joint Commission in their inquiries concerning some of the terms of their reference under the treaty between Great Britain and the United States concerning the pollution of boundary waters. During the war I was in Washington as a member of a sub-committee under the Council of National Defense, concerned with engineering and sanitation.

5097 I have had occasion, beginning in 1893, to have personal knowledge of matters pertaining to water supply and sewage disposal in the Chicago area, going back to the time of the World's Fair, when I had charge of the Massachusetts State Board of Health exhibit at the Columbian Exposition.

Next I came in contact with this enterprise in 1901, when I was retained by the City of St. Louis to advise concerning the securing of an improved water supply. This involved consideration of matters at Chicago.

In 1903 I was retained by the State of Missouri in injunction proceedings before the United States Supreme Court, whereby Missouri sought to enjoin the State of Illinois from continuing the use of the canal.

5100 In 1921 and 1922 I was on a board with Mr. Eddy and Mr. Hatton as to the best means of treating the sewage for the North Side treatment works district.

In 1924 and 1925 I spent several months on the activities of the Chicago District, and was chairman of the Engineering Board of Review of 28 engineers.

The Board of Review divided into groups of ten committees, of which perhaps seven were the most important, each committee having from three to five members of the board, some relating to lake lowering levels, some relating to the Illinois waterway, some to the water supply aspect, which happened to be the sub-committee of which I was chairman, the sewage disposal committee, power aspect, etc.

The board considered the program already laid out by
5103 the Sanitary District, so far as sewage disposal is concerned. In my opinion, the program for sewage disposal at Chicago was suitable. It equals in the aggregate the performance of all cities in matters of sewage treatment.

5106 The means available for taking care of the water supply problem at Chicago are related to the five items which are generally available in getting a fairly suitable water supply. One of those barriers against pollution is to start out with pure water which does not need any purification or which is particularly protected by diversion from becoming polluted. Secondly, there is the question of taking advantage of means of purification which are natural agencies, self-purification, which is taking place in lakes and reservoirs and streams within certain conditions. Then there is the sewage treatment method of preventing disastrous effects of a pollution by treating the sewage before pollution gets into the source of water supply. Then there is water filtration, and, finally, there is chlorination. There are five different steps or lines of defense available in different cities and under different conditions.

5109 The storm overflow into the Chicago River and

into the Calumet River is a very important item in the solution of the problem of water supply, because that method of disposition of sewage in the area of the Chicago Sanitary District, as well as from Lake Michigan is intricately tied up to the question of water supply and the flow away from the Lake down the Drainage Canal.
5111 That overflow comes about when the interceptors are built, and when the sewers are discharging through the outlet. The overflow comes around about once a week on the average, depending on the frequency and intensity of rainfall, and aggregates in time during a year perhaps five per cent, roughly measured, and will equal about two per cent of the total volume of sewage which goes through the sewer outlets in the course of a year. For a long time these outlets are going to discharge this sewage under certain rainfall conditions. Sometimes that volume, as with the Chicago River outlets will equal about 11,000 cubic feet. I mention that to indicate in the first place that it is roughly the carrying capacity of the sewers of Chicago when they are all running full. It also happens to be roughly what the carrying capacity of the drainage canal is, which is roughly 10,000 cubic feet per second. That is why Mr. Hering and his commission recommended that the canal be built at a certain depth and width, so that under the Act of the Illinois legislature in 1889 they should be receiving 10,000 cubic feet per second of diversion to prevent the polluted water of
5112 the Chicago River from going into the lake. That 11,000 second feet is larger than the flow would have been under the former conditions in 1887 and 1889, when the Act of the legislature was passed.

If this storm flow cannot be diverted, it is necessary to consider what can be done to minimize or lessen the evil coming into a water course which is a source of water supply. That brings in the question of chlorination and

what is spoken of as sterilization, the attempt being to apply liquod chlorine to that storm flow in order to destroy the bacteria or the germs which would cause typhoid fever and other diseases of an intestinal order. This particular chlorination has for its efficiency a very important prerequisite; it is necessary to add 150 pounds to a million gallons of that storm flow, and it is neces-
5114 sary to provide that there shall be a certain excess, say, for illustration, 10 pounds to a million gallons. So that if they would add 130 or 140 pounds the efficiency could not be relied upon. It is necessary to add that excess to get a good sterilizing method which can be relied upon.

There is a rapid variation of flow as to quantity and a rapid variation in the quality of these storm flows. That is sufficient to prove to those who have had experience in recent years that it is simply unmanageable to get that excess flow effectively adjusted so as to destroy the bacteria in these storm flows. That being so in general, it is more than so in Chicago, where they have more than 250 of these sewer outlets that are discharging into the water courses. So the treatment of these storm flows, in the absence of adequate means of diversion, means a very serious health problem in relation to the water supply.

In the event of the diversion being decreased to zero or 1,000 second feet, assuming that funds were available, there would have to be added to the Sanitary District's project to protect the water supply and to dispose of sewage a sterilization item; that is, arrangements to put chlorine in the majority of the sewage. As the dry weather flow goes through these treatment works, there is 50 per cent of additional quantity, being in part a mixture of storm flow and dry weather flow and sewage.
5115 This could be subjected to sterilization. Then there could be built water filters for the water supply of the

City of Chicago, and intakes could be extended by additional new tunnels so as to get the water at the most distant point from the shore.

I have studied for some time the question of costs of these additional works. The cost of the sewage treat-
5116 ment program to 1945, as recommended by the Board of Review, and on the basis that all water is to be metered, would be $145,000,000 in round numbers; that is, $25,000,000 more than the Board of Review estimated.
5117 Referring to Table 17 on page 62 of Defendants' Exhibit 1157, the sum of $115,000,000 expenditure for the program of sewage treatment to the year 1945 does not include the last three items shown on Table 17. I estimated that for additional works to complete the program up to the year 1955, that is, so that all the dry weather flow of sewage can be subjected to so-called complete purification, would bring the total item up to $187,000,000 in round numbers, including an item of $30,000,000 which I have taken as the cost of sewage treatment works put through December 31, 1924, which was the period when the Engineering Board of Review was actively considering these questions two years ago.

In addition to the sewage treatment works, I have looked into the question of water filtering plants and apparatus, and find that amounts to an item for the city, but not for the Sanitary District, of $53,500,000. That involves only a sufficient installation to connect the filter-
5118 ing plant with the existing water system, and does not make for any general benefit to the city waterworks, except as it relates to water filtration.

I have looked into the question of water tunnels, and in summing up the figures it provides for an item of $20,000,000 for the extension of the three principal tunnels of the city to go about 20,000 feet additional distance out into the lake and connect with the intake cribs.

5121 I have noted also in a rough way what would be the cost of providing a super-tunnel, getting one tunnel off Wilmette at the northerly limits of the Sanitary District for a distance of, perhaps, 8 miles into a 60-foot depth of water, which location would be 20 miles from the mouth of the Chicago River. That would cost $70,000,000 for a tunnel under the lake and the land tunnels which would be required in order to bring the water down north and south through the city and make available the existing waterworks and pumping stations, and making arrangements for supplying water to the southerly limits. The sum of these different items would assume substantial proportions; the full sewage treatment program up to the so-called 85 per cent of purification, and with the extensions of plants as required through to the year 1955, with the water filters, the total sum in round numbers
5122 would be $240,000,000. Adding 20,000 feet of extensions to the three major tunnels of the city would bring that $20,000,000 higher, or to $260,000,000. If, instead of building tunnel extensions, there would be built this so-called super-tunnel at Wilmette, the total item would be $310,000,000. The operating cost of the water filtering plant and the pumping which would be necessary to get the lake water to the filters would amount, in round numbers, to $1,620,000 a year on the basis of an average consumption of 720 m.g.d. The cost of operating the sewage works would be about $4,300,000 in 1945 and $4,900,000 in 1955.

Miscellaneous work required, such as bridges, highways, settlement of Illinois Valley overflow claims, contingent projects, including the Sanitary District's share of cost of lake level regulating works, and a small item
5123 for discount, which is apparently a balancing figure to give a rounded figure of $125,000,000 on page 62 of Defendants' Exhibit 1157, has been excluded from my tes-

timony of a total of $310,000,000, $260,000,000 and $240,000,000.

Assuming a reduction of the present diversion to zero or 1,000 second feet, the installation of complete sewage and water purification works as I have outlined, from a public health standpoint the conditions resulting would not be so good as would exist with a diversion of 8,500 second feet or substantially that amount, and the installation of sewage purification works such as the Board of Review has recommended. The reason is there would be a pollution reaching the intakes of the City of Chicago water supply. During dry weather periods if there were no diversion there would be all the sewage from this large population which would get into the intakes, controlled largely by temporary currents which are induced by wind and weather conditions.

5132 The extent to which those currents would bring the pollution from the mouth of the Chicago River in dry weather is very difficult to estimate. It would probably vary with the different intakes very markedly on the same day. During the storms there are indications that the water can be driven by currents for 12 or 15 or 18 miles, or even farther distances, and that is the essentially weak link for all of this polluted material, perhaps infected material.

5133 In times of storm, winds will drive this pollution to the intake, and it is then that the element of danger comes in, with all filter plants in service by overloading them to a point where with any mishap there would be some of the objectionable bacteria pass on through the filters and also a chlorination process.

In addition, if the tunnels are to be moved roughly four miles out it would lessen the frequency of the times when currents would drive the water from the mouth of the Chicago River to the re-established intakes. Even

in the case of the super-tunnel off Wilmette, twenty miles from the mouth of the Chicago River, I do not doubt that there would be currents which would carry the polluted water to such intakes.

The question of efficiency of operation comprises the question of lapses in performance and the weak links in the chain of purification works subject to human control. The whole question comes back to the question of pure water being really better than purified water. Innocence
5134 is better than repentance. The more I have seen of the frailties of human nature particularly in municipal works, the more convinced I am that pure water is better than purified water.

During the period of construction of the alternative method of a complete replacement of the present sewage and water projects a diversion from Lake Michigan would be required unless all risks of pollution of water supply be taken. If diversion is cut down there would certainly be serious trouble in the Chicago River.

During the ten years required for building these water-works there should be diversion to prevent the discharge of storm flows out into the lake. If the diversion were cut down, the public health would be affected through the pollution that would come at times through the intakes and it would overtax the ability of chlorination devices regularly to produce a water which would meet the United States Public Health Service tests, which limit the B. coli content in water which may properly be used in interstate commerce.

As to the effect on the Chicago-Des Plaines-Illinois River, if there should be a diversion of, say, zero or a thousand second feet, there would be a large accumulation of organic matter sent into the branches of the Chicago River so as to make a set of open sewers or cess-pools or septic tanks, from which would emanate serious

odors, and there would accumulate at places on the bottom of these water courses banks of sewage mud. These accumulate during the colder season and in the summer time when the weather is warmer they putrefy and cause a gas-lifting scum and objectionable odors. It would menace property interests and cause some kinds of property devoted to certain purposes to be abandoned, as far as those particular uses are concerned.

5136 Going down the Canal, these conditions would continue in substantial form. If there were 1,000 second feet diversion the situation would differ from the zero diversion. Below Lockport, if you had zero diversion, that would end it, so far as the Illinois Valley is concerned. With 1,000 second feet diversion it would produce worse conditions in the Illinois Valley than now exist, by which I mean there would be foul odors; the sewage solids would move on down the waterway, and conditions would be very unsatisfactory from the standpoint of riparian owners. I do not see how fish life could be restored or how there could be any freedom from objectionable conditions. They would become worse.

Respecting the setting up of a canalized river with more locks, I think that would tend to accentuate the objectionable conditions in the upper stretches of the lower river system below Lockport. It would cause solids to be deposited and they would putrify there, and it is quite likely that at times would be better conditions down toward Peoria, but at times of storms in the Des Plaines River all those solids would be moved on down. They would not go towards making a betterment of these conditions, but they would grow worse. There would also be in these lower basins quite a tendency for growths of what is called aquatic or microscopic life, so that with a clear sewage you might get

quite a line of objectionable conditions in that respect. It would create a very serious overburdened water course.

5139 Assuming that the diversion continues as authorized at present during a period of construction of the alternative methods of handling the water and sewage problem as described by me, the diversion from Lake Michigan from a public health standpoint could never be reduced to 1,000 second feet without affecting the water supply of the District because of the storm flow. I do not believe it could ever be reduced on account of the storm flow. I am aware that filtration and extension of intakes would handle reasonable loadings as regards pollution, but after installation there are elements coming from flood flows where winds will carry dirty water fifteen or twenty miles and adding to that the question of failures and weaknesses and breaks and lapses incident to operating filtration plants. I am familiar with these faults of operation and know that there are times when the efficiency of filtering falls off materially.

5140 Storms bring to a filtering plant water which needs a change in the amount of chemical treatment. This may happen at three o'clock in the morning with a sleepy attendant, to whom that line of work is an old story. They do not make the adjustment. The pollution gets away and goes into the water supply of the city. They do not know it. The citizens do not know it. They drink it. There are unfortunate results, dependent on whether the water or its bacterial content happens to carry disease germs.

There is another fault that comes from breaks in pipes and connections and arangements which cannot be immediately corrected and sometimes are not detected.

5141 There is the question of efficient maintenance. After a long period of use filters get out of condition. Failure

to make current repairs as needed causes a portion of the sand bed to become entirely impervious. Wash and the water fails to clean that sand or disturb that mass, causing the filters to get out of condition. It becomes larger and larger. The water does not penetrate it. The time comes when if the water should go down at the average rate of two gallons per square foot there is a falling off of efficiency.

The people to whom the operator in charge reports do not realize the importance of such conditions, and that raises the fourth weakness, the failure of administrative or executive authority to support the operator. There is also delay in making extensions. A good many plants in this country after the armistice being operated in this country got far beyond their limits. They ought to have been extended and were not. These things are
5142 constantly being encountered in the line of my work as a sanitary engineer. After ninety days of operation they may need thorough cleaning, but it almost always comes within five or six years. As to the competition for funds, it is a perfectly normal and natural outgrowth of our type of administration. Sometimes a health department checking the bacterial content is more enthusiastic about getting money for a hospital, or for establishing a larger laboratory in its own department or in supporting a friend in some other branch who is interested in the park department or in some other department of the city, than in a water filter or sewage dis-
5143 posal plant. I have encountered in the last few weeks specific instances where it was impossible to get extensions at the time when it was of the greatest importance from the public health standpoint.

5146 Referring to the five barriers or lines of defense against infection of water supply, the most nearly practicable one is that one which provides naturally pure

water protected against pollution, which is better than any line of defense in securing a hygienically safe water supply. Pure water does not carry hazards or lapses due to errors or unavoidable mistakes which occur in the operation of purification plants.

5151 *Cross Examination by Mr. Jackson.*

5159 The activated sludge process will behave in a generally similiar maner to the trickling filters, but be slightly more efficient, depending upon operating conditions. That would apply to the consideration of all the various tests which have been discussed in relation to the trickling waters.

5160 Modern activated sludge plants have removed 98 per cent of the bacteria. That is the Milwaukee standard, and is the standard they seek to obtain.

5161 I have no information that at Milwaukee they have ever failed to obtain 98 per cent removal, but my information is that while they have been running this plant at half capacity, as they have been for a year and a half, they have been making that standard.

Chlorination of the effluent of any one of these processes of sewage purification would remove objectionable bacteria, if applied in a careful way. With an activated sludge plant operated with an efficiency of 98 per cent removal of the bacteria, followed with complete chlorination of the effluent so as to have some residual chlorine in there, there would be a removal of over 99 per cent on all occasions when there is a real excess of chlorine in the effluent; and would have no other marked effect on the effluent than the reduction of the bacteria content. The remaining organic matter would be slightly affected by this powerful oxidizing agent, but I do not believe it would measure in units of organic pollution. The amount of chlorine added is too small. I do not

know that it has been established that chlorination of such an effluent does substantially and materially reduce the B. O. D. demand of that effluent. There is a tendency in that direction, but it has never come within my range of observation.

5163 Chlorination of the effluent has not been recommended by me to be added to the sewage program of the Sanitary District, because that sewage program is also related to the question of diversion to keep storm flows out of the lakes, and from that angle this program would be developing through a period of ten or twenty years and there would be no occasion for it, because the effluent would go down the Canal and down the Illinois Valley.

5164 The diversion of the sewage away from the lake and into the Illinois Valley is a function of the program to protect Chicago's water supply, and if the diversion were stopped or reduced to very low quantities, sterilization or chlorination of the effluent of the works which were built under this program would be a thing to be done, or desirable.

If the sewage from a population of 10,000,000 people were treated by the activated sludge process to the highest degree of treatment which is practicably possible, followed by chlorination of the effluent so as to obtain a removal of 99 per cent or more of the bacteria from that effluent, the polluting effect of the effluent from 10,000,000 people upon the public water supply would not be any greater than the discharge of untreated sewage for a population of 100,000 people, mathematically, but the question has to be considered in the light of the lapses.

5165 It is a fact that the City of Cleveland turns practically all of its sewage in a raw state into Lake Erie opposite the intake of the city water supply at the present time. They seek to remove some of the settleable solids to a limited extent, but there is no removal of any of the

settleable solids from the sewage which is discharged from the Cuyahoga River opposite the intake of the
5166 Cleveland waterworks. It would surprise me if 65 per cent of the sewage of Cleveland comes down the Cuyahoga River.

5167 Whether the City of Cleveland, taking its water supply from the Lake about 4½ miles off shore, from the outlet of the principal sewer of the City of Cleveland, having at the same time water purification, has met the Treasury's standard for pure water supply for the last two years I do not know; but I do know that the over-
5168 loading is only following floods. The trouble in 1925 or 1926 was only when heavy floods came. I do not know whether they came in those years or not.

In October, 1925, the B. coil index for the water at the Division Avenue filtration plant was not within the limit of 1 to 100 c.c., and there is a note that the filters were down and out of service for two days; that the effluent was 25 for 100 c.c., and the chlorinated water averaged for that month 15 for 100 c.c., at Division Avenue, the older of the two filtering plants. The situation at Cleveland, with reference to sewage disposal and water purification plants is worse than was indicated on the basis of 99 per cent bacterial removal of a population of 10,000,000 people, providing purification of the water supply, in the sense that Cleveland does not get the removal from the treatment arrangement they have, but they do get into the same trouble I have been trying to make plain, and that is overloading. The Cleveland sewage system handles the sewage of approximately 1,000,000 people.

5183 In comparison with the conditions that now exist in Illinois River treatment of all the sewage of the Sanitary District, so as to remove 95 per cent of the settleable solids, would improve materially the formation of sludge

banks and would eliminate future increments of such sludge banks, but would not remove present accumulations.

5199 Generally speaking, it is true that water purification is based upon well-known and well-established principles. For example, I designed or advised the designing and the installation of water purification works at Cincinnati, dealing with the Ohio River, which was badly polluted, and ever since that plant was placed in operation in 1907 it has constantly turned out an effluent that has met the Treasury's standard, and that performance has been equalled in other parts of the country.

5200 Breaks and inefficiences in such plants come through failure to have variations in chemicals—speaking of coagulation—necessary in order to get efficiency of the so-called rapid filters. With sudden changes in the quality of the water, it is necessary to add 25 per cent more chemicals, sometimes at three o'clock in the morning, and sometimes the best of instructions on the part of the technical supervisors are not carried out.

5201 Physical breaks will also come in, and they are, of course, a danger, especially if there is any very sudden increase in the amount of pollution, and there is need of instantaneous adjustment of the chemicals and the whole treatment process of the water. If that is not adjusted it is unfortunate and sometimes there will be lapses which are serious. The change in the lake water would be as great as that in the case of the Ohio River, or greater, because it would depend in large measure upon the effect of these variable currents introduced by wind.

5202 The opportunity for taking the operating personnel of a filter plant by surprise would be markedly greater in a plant operating with lake water than it would be for the Cincinnati plant on the Ohio River. Of course,

5203 wind shifts can be observed, and they do not affect currents in the Lake for several hours, although pollution at the mouth of the Chicago River could be taken to the filtration plant in a very few hours. The current of the Lake has a definite mathematical ratio to wind velocity, sometimes several miles an hour.

5205 At times, although the figures of the test that I made years ago have escaped my memory, it is as much as four miles an hour. The wind moves a mass of this polluted matter along the surface of the lake in a certain direction. With shifting winds, it breaks up that mass of polluted water and sends prongs out in different directions. There would be no advantage in determining the probable change in degree of pollution in Lake Michigan over the conditions in the Ohio River, unless it be assumed that the water is always going to be polluted at a certain wind velocity. Real benefit could be gotten, of course, from readings of wind movement in advance of the effect on current.

5206 Three or four filtration plants would be necessary in Chicago, if the existing tunnels be used. If extra units are provided, (and it is usual to so provide), it is feasible to shut down each filter unit or more than one and go forward with the balance of the filter units.

5208 During the early life of the plant, probably no large percentage of the 250 units would go out of commission at the same time, but after a while, after wear and tear, these plants deteriorate, there comes a time when it is necessary to thoroughly overhaul them. There is also the question of funds, which is a very serious difficulty. Deferred maintenance is a very common experience in municipal undertakings.

5209 The use of chlorination is a factor of safety, rather than a bigger part of the normal process of removing objectionable bacteria. The testing of the chlorine con-

tent and proper amount is simple, but when the quality of water is considered it is sometimes difficult to do it adequately, and unless there is excess chlorine in an amount so that it will be in excess for ten or fifteen minutes or longer, the benefits of that chlorination are not what may be expected from scheduled performances, if there is a sudden load of bacterial pollution or infection that gets by the earlier lines of defense and goes through the filters.

5211 Water filtration plants are successful, generally speaking, and are a great help where it is necessary to deal with polluted water. They are ordinarily constructed on a single stage, that is, just a single filter, one unit and only one. They have coagulating and settling basins in which, after the chemical is applied the water is prepared for filtration. After the water passes through the filter it is usually chlorinated and goes through a basis holding several hours' flow, the purpose of which is to equalize irregularities of pumping. It is possible to put water through a filter twice, and it is done in some places, which gives a better effluent.

5212 With a large water purification plant of suitable size under competent technical supervision, there is practically no danger, except in the unusual period of the weak links in the chain, such as times when storm flow will get out into the lake and be carried fifteen or twenty miles, and the volume of pollution per unit volume of water will overload the capacity.

5213 If an intake were located twenty miles from the mouth of the Chicago River, pollution at the river mouth would be greatly purified by the time it reached the purification works. Ordinarily, the resultant wind would have to be in the direction of the intake, although the wind may have been variable. There would have to be a wind for a sufficient period of time to create an appreciable cur-

rent, so that in the first instance the difficulty would only arise in the case of a storm reversing the Chicago River, and the frequency of that would depend upon the diversion. These storms come on the average about once a week, and vary in intensity. Once a year the run-off would equal 10,000 second feet, if my recollection is right. Six or eight times a year it gets up to 4167 c.f.s.

5214 In such conditions, to have pollution carried toward the water purification plant off of Wilmette, it would be necessary that the wind should be blowing at the time of that storm substantially from the south. That would be relatively infrequent, but when the volume of storm flow is less than 4,000 second feet there would still get out into the lake a very great deal of very polluted water. In dry weather, if there were no diversion and all the sewage would go into the lake, there would be zones of polluted water some distance out, and the wind would drive it as far as twenty miles. This is true both with raw sewage, as well as the case during the next ten or fifteen years. Assuming the treatment works and chlorination, there still would be in times of storm real quantities of pollution going out, and there would be some pollution in the lake shore water at all times.

5216 With complete treatment of all of the sewage of Chicago, followed by a chlorination of the effluent, so as to remove over 99 per cent of the bacteria, there would be at times pollution at the intake off Wilmette in dry weather, but it would be very infrequent, and it relates to the storm or flood periods.

Ordinarily there would be 250,000 B. coli per cubic centimeter in raw sewage. 99 per cent would be removed, which is a maximum more or less theoretical, and that effluent that came out of the Chicago River would be diluted, and would also be polluted with storm flow and sediments. By the time that pollution had proceeded twenty miles in the lake it would be still further diluted.

5222 Assuming the removal of 95 per cent of the bacteria, the installation of controlling works at the mouth of the Chicago River, the location of the water intake off Wilmette twenty miles from the mouth of the Chicago River, the installation of a water purification plant coupled with chlorination of the effluent of that plant, I think safe water would be gotten, because pollution would be kept out of Lake Michigan. Without the existence of the controlling works and with a diversion of 1,000 second feet, the City of Chicago would in general have a safe water supply, subject, however, to the storm flow situation, which is serious at times.

5223 Assuming the same conditions, without any controlling works, except that the regulation of the flow through the Sanitary Canal is at the junction with the Chicago River instead of at Lockport; and assuming the opening of that control to permit a large flow in time of storm, I believe
5225 that the water supply would be safe, except from flood conditions. There would be more water coming from the North Branch of the Chicago River and from that end of the Chicago River system out into the Lake, and it would make more frequent and probably more intense the weak links referred to. The assumption as to the condition in normal seasons, with an effluent from which bacteria have been removed to the extent of 99 per cent in all the cases that have heretofore been assumed, is the same so far as
5226 the condition of the effluent discharged into the Lake is concerned; but the storm flows, which occur in the aggregate of about five or six per cent of the time in the course of a year, are going into the Lake, if they are not barricaded at the mouth of the Chicago River, and that is the time when there will be practically no sewage treatment at all.

5227 Even with controlling works at the entrance of the canal and a movable gate at Robey street, the entrance

to the Drainage Canal, then, the North Branch of the Chicago River is like the stem of the letter Y. One arm would be through the end of the Chicago River into the Lake, and the other arm of that Y would be five miles away at Robey Street. Without entering into precise hydraulics, it seems easier for that flow of the North Branch to go relatively a short distance, less than one mile, out to the Lake, than to go a distance of some five miles to Robey Street, even with the gates open at Robey Street, on account of the inertia of the water in that five-mile stretch.

5229 Assuming a complete treatment and chlorination removing 99 per cent of the bacteria in the effluent, the construction of a separate storm sewer system, no diversion of water from Lake Michigan whatever, location of an intake off Wilmette twenty miles from the mouth of the Chicago River, the water supply of Chicago would be safe, based on a separate system of sewers which would convey all household wastes to a sewage treatment plant to be subjected to these degrees of purification, and eliminating storm flows going through existing sewers, and having no mixtures of household wastes or discharges of a fecal nature in them. Theoretically, under those conditions, you could get a treatment of all of Chicago's sewage in the way assumed, and that would eliminate the storm flows, because the existing sewers then would have no household waste in them, and that would stop the pollution of the Lake. I do not believe that under those circumstances there would be enough objectionable bacteria in that effluent to move twenty miles to be an overloading on a modern purification plant that would take water from that source.

5231 Having in mind the above assumption, and the fact that in 1924 there were under present conditions seven or eight reversals of the Chicago River, present condi-

tions otherwise to be the same with respect to the treatment of Chicago sewage and the location of the intakes and whatever treatment there is of the water supply today, as it now actually exists, with water supplies furnished under the conditions suggested, they would come in the same general class, and it would then be a question of measuring the freedom from the pollution on the one hand as against the adequacy of filtration with a not excessive loading on the filters on the other.

5232 Assuming the completion of the sewage treatment projects recommended by the Board of Review, with a diversion of 1,000 second feet, the construction of the supertunnel and the relocation of the intake off Wilmette, chlorination of the water supply thus secured, hygienically, the water supply would not be as good or better than the present supply, because one-fourth of the sewage at all times during dry weather would be going out into the Lake, and storm flows going out there, which would throw at times more of a load on the filter plant and purification plant. The effect on the possibility of pollution or severity of any pollution which might occur on the changing or removal of the intake to the position of 4½ miles off Wilmette and twenty miles from the Chicago River, would result in lessening the effect of the pollution greatly. I took that factor into consideration, and with that in mind, my opinion is still the same.

5233 Assuming that the storm flows are a burden to a purification system even with the intake from this supertunnel, with a diversion of 1,000 feet, a completion of the sewage program recommended by the Board of Review, filtration and chlorination of the water supply at the suggested Wilmette intake, the burden of the pollu-
5234 tion from storm flows would still obtain in these slugs of sewage going out into the Lake fifteen or twenty miles, not with any degree of frequency, but still existing. With

a filter plant in operation it would take care of the pollution under ordinary circumstances, but I still believe that under those circumstances the water supply would not be as good or better than the present.

The reversal of the Calumet River in storms in the vicinity of the 68th street crib is one of the things I am relying upon for the travel of sewage in time of storms. It is my opinion that there can be and have been effects of sewage pollution of Indiana Harbor at the Carter Harrison crib twenty miles away.

5235 Assuming the foregoing conditions, except the complete treatment of all the sewage of the Sanitary District of Chicago, the only way in which the change in assumptions would bear on this question is that more chlorine would have to be used, assuming that all the sewage would be put through Imhoff tanks or activated sludge and settled. It would not be 85 per cent complete treatment, but somewhere about 33, as far as removal of solids is concerned. You could chlorinate such an effluent and it would not change my opinion It would simply change the amount of chlorine to be added, and would still leave the weak link of the storm flow periods and the ability under certain unusual conditions to cause or permit the flow of pollution to go as much as twenty miles. The assumption of 85 per cent treatment of all sewage in connection with other conditions is not a factor in affecting my conclusion, because it simply affects the amount

5236 of chlorine. It is, of course, a little easier and a little cheaper, and a little more satisfactory to apply chlorine to a sewage that has been well treated up to 85 per cent, but it is practicable to apply chlorine to a sewage that has been treated only to a 33 per cent stage and settled. The bacteria removal would not be as great, but that relates to the dry weather period. It does not direct itself to the weak link, which is the storm flow period, except where a separate system of sewers is built.

5237 At times the water supply of Chicago, under present conditions, is turbid with silt that comes from the silt deposit on the bottom of the lake. It is not clear water for several months each year. Chlorine does not improve the appearance of it, although treatment by chlorination tends to remove the objectionable bacteria. The recommended program of sewage treatment does not improve the appearance. If you remove the intake further away you have sixty feet in depth, instead of forty, and the winds that would stir up the bottom of the lake would
5238 be very much less frequent in occurrence; 55 to 60 feet is the depth at which the wind most severe in intensity ceases to have an influence in causing turbidity, but the water has become turbid nearer shore, and it would be possible to avoid the turbid water and get an entirely clear water eight or ten miles from the shore. Filtering would take out that turbidity, under ordinary circumstances. Regardless of sewage disposal, I believe that water ought to be filtered from the standpoint of getting a good, clear, satisfactory, palatable water. It would also improve the condition under which a safe water hygienically could be had.

5240 Any city located on the Great Lakes, the sewage effluent of which must be returned into the lake from which the water supply is taken, is sure to encounter real difficulties if it does not get its financial program on a proper basis. Whether such cities will encounter real difficulties, or limitation in growth on account of these difficulties, I feel puzzled as to how to answer. From an engineering standpoint these things can be managed, but the thing that is most serious is whether plans are set in motion sufficiently early to avoid serious pollution. That is probably the situation at Cleveland. I have been studying the Toledo situation for the last year. The day has gone by when a city of less than 1,000,000 people can put

sewage partly treated into a lake and take water out of it, and get it of satisfactory quality. The people have been thrown off their guard by putting the burden of work onto chlorination devices. That is why the United States Public Health Service has jacked up its loading for B. coli in these waterways from 500 B. coil, to which I testified in 1914, to a statement that it should be 100 B. coli with filters alone, 600 with the two together. There are times when you can get from these records 10,000, 50,000, and even 100,000. The day is coming when the weak links are going to get away in a manner that will be very prejudicial to the public health. While these things can be built in a reasonable period of time, the administrative and financial difficulties get to be real burdensome.

5241 It is perhaps true, from an engineering point of view, that the growth of cities may not be limited by difficulties of sewage treatment, but it means separate systems of sewers that may cost $300,000,000. It would tax the patience of the people in ripping up every street in the City of Chicago and the replacement of the sewer system. It would mean changing the connections from the street sewer into the house, in some cases a shifting of the household plumbing in the household or office building. $300,000,000 is not a sum at all extravagant for that particular purpose. The question of how long it would take to do it is the thing the people would not stand for. I am asked academically if that can be done, I will say yes, but in my judgment it is not practical.

5243 If you start early enough with the assumption that there were no Drainage Canal in Chicago and no possibility of constructing one, the sewage question of Chicago could be handled with safety to the Chicago water supply, but it would still leave the question of purified supply as against the pure water supply, which no doubt would develop and would be prolonged for a term of years.

5244 The City of Cleveland has a combined sewer system. I am not of the opinion that the future growth and development of Cleveland is either limited by the sewage question or contingent upon the construction of a separate sewer system. While I would not attempt to give an offhand opinion, I know they are coming to a point where their water filter is subject to very serious overloading, with practically no treatment at all at Cleveland, except they are putting in chlorine for about three months of the year to protect bathing beaches.

5250 I have never taken the position that sewage pollution reaching the intakes must necessarily have traveled in a bee-line from the mouth of the Chicago River. With an intake north of Chicago the sewage might go directly east from the Chicago River and then be carried by shifting winds to the southeast of the intake. Engineers who have studied this question have not been able to get the weakest link in the chain, because it is not practicable in severe storms to go out and collect samples. In a study made for the City of Buffalo, in regard to locating a new intake, it was thought that water coming from practically the middle of Lake Erie would go down there without the effect of the pollution at shore.

5256 **Harrison P. Eddy,** for Defendants. January, 1927:

Sanitary Engineering Expert.

Direct Examination by Mr. Adcock.

5262 The Chicago problems of sewage disposal and protection of water supply are peculiar, due to the proximity of Lake Michigan and the large amount of water available for dilution of sewage. The opportunity of diverting the sewage away from Lake Michigan is a very unusual condition. The low divide made it feasible to build the Canal

and divert the sewage away from the city. The flatness of the country tends to reduce the rate of run-off during storms, and the size of the Chicago River made it feasible to divert the entire flow of the River through the Canal away from Lake Michigan. Another peculiarity is the size of the District, with a population of some 2,500,000, which is a very important factor with reference to the pollution of the Lake and the disposal of the sewage.

5263 The small run-off of the Chicago River makes it possible to divert it away from the Lake. The amount of diversion from Lake Michigan is measured by the maximum run-off necessary to keep the sewage out of the Lake. Taking the conditions as found in 1887 and 1889 and as they have been since, and in the light of the accumulated knowledge and experience, the program the Sanitary District has put into effect has resulted in an efficient diversion of a major part of the sewage from Lake Michigan, and has been a very important factor in protecting the water supply from pollution. It has also been an important factor in protecting the shore water so that it is suitable and satisfactory for recreational purposes, and in protecting bathing waters so that they are used with comparative safety by a great number of bathers.

The system of dilution which was adopted in 1889 is scientifically sound as a method of disposing of or purifying the sewage. It is the best example of a natural method of purifying sewage. In my judgment the system adopted and that which has been adopted for the future is the best method which was available at the time the sewage portion of the program was adopted and which is available at the present time, for carrying out the project for the disposal of the sewage and the protection of the purity of the water of Lake Michigan.

5266 As a result of the growth of Chicago and the great industries located there, the dilution works have become

outgrown and seriously overloaded, so that they have been unable to function as well with respect to purification of the sewage before it is discharged into the lower Illinois River as would be desired. As a result of that overloading of the Canal and River system the District undertook studies, investigation and research, and during the past twenty years has carried out a very extensive program with respect to such research, with which I am personally familiar. In my judgment the work done by the District has been an important factor in the advance of knowledge and in the advance of the art of sewage treatment during the last twenty years.

The program recommended by the Board of Review, which includes the Canal and River system which was in use and is now in use, in my judgment, will protect the water supply better than any other method, and will also protect the shore waters and bathing waters as well as they can be protected. The program recommended by the Board of Review will result in far better conditions down the River, and the improvement will be progressive. It will take time to accomplish the result, but when the program shall have been carried to completion, the conditions down the Des Plaines-Illinois Rivers will be satisfactory. In that program I am including the diversion of such water as may be necessary to supplement the purification of the sewage by artificial means, as a part of the program.

5267 In my judgment, there is no other plan which is practicable to adopt, or with which it is possible to secure the same degree of protection, coupling the two words "practicability" and "possibility." The system which has been adopted, coupled with the program, will continue to efficiently divert the sewage and storm water and protect the water supply and the shore water. To abandon the system which has been built and which is capable of

performing the functions stated, in my judgment, would be a serious backward step from the point of view of sanitary engineering and public health. Failure to take advantage of these natural opportunities, in my judgment, is not justified.

5268 From an engineering standpoint it is necessary, for the protection of the health of the community, to keep the sewage away from the Lake, and it is highly desirable for the protection of the shore waters for recreation and other purposes.

5276 The term "Complete Treatment," is applied to the dry weather flow, plus a percentage of the storm flow in times of storm; that is, all of the dry weather flow is to be treated, and in times of storm a small percentage in excess. This percentage of excess varies with the different plants, from 50 per cent in excess of the dry weather flow, in some cases of storm flow, and in others it has at times been double the dry weather flow.

5277 The storm overflow enters into the solution of the Chicago problem, both with respect to the Chicago River and the Calumet River, in that it is not practically possible to treat the storm flow which, under Chicago conditions, may be as much as 10 times the dry weather flow. It is not possible to build intercepting sewers and pumping stations to carry those flows to treatment plants, and after they arrive, if they do arrive, at the treatment plant, the cost of providing for their treatment would be prohibitive. For that reason, the storm flow must be discharged without treatment. Those storm flows contain the sewage, as well as the storm water, and the storm water itself, if there were no sewage in it, is seriously polluted and contaminated. In addition to that load of pollution, the sewage escapes with its contribution of contamination and pollution.

5278 When there are small overflows the proportion of sew-

age in that storm overflow discharge is very large; it may be from almost all of the sewage to 50 per cent thereof. In times of great storm the proportion of sewage may be relatively low, perhaps 10 per cent or even lower. On the other hand, in times of low or small overflows, the proportion of the total volume of sewage produced, which is discharged into the canal system, is small, whereas, in times of great overflow the proportion of the sewage escaping is very large, and may be as much as 90 or 95 per cent of the total dry weather flow escaping with the storm flow.

These discharges of storm pollution, whether it be from the surface of the streets or from the sewers, are a serious menace to the purity of the waters along the water front. If allowed to be discharged into Lake Michigan they would seriously pollute and contaminate bathing beaches, and would render offensive and objectionable the waters along the parks and in the enclosures at the water front, and seriously pollute the water supply.

5279 The conditions which I have mentioned with reference to the Chicago River, primarily, are applicable in the same general way to discharges from the Calumet River. There are something over 300 storm outlets at the present time which must continue. In my judgment, it is not practicable from any point of view to discontinue them. These storm outlets are located in the Sanitary District on different rivers and channels of the canal system.

5280 If this program that has been under consideration by the Board of Review and recommended and adopted by the Sanitary District were carried out as planned, the conditions of the Des Plaines and Illinois Rivers will tend to improve gradually with a reduction in load resulting from the gradual putting into operation of the sewage treatment plants. The present conditions in the

River are such that no immediate change to inoffensive conditions will result. In other words, the River is so seriously overburdened that there will not be an immediately noticeable improvement in offensive conditions. By 1945, when all the sewage is treated, in accordance with the program laid down by the Board of Review, there will be a noticeable improvement in conditions after that work has been completed. If there is a diversion of water amounting to about 10,000 second feet, including the sewage flow, the conditions down the River will be satisfactory from the point of view of nuisance or offensive conditions.

5281 It is a question whether fish life can thrive or exist at all points in the River even under those conditions, but so far as nuisance is concerned it is believed that a 10,000 second feet flow at Lockport will prevent any nuisance at any point. It is a possible that a somewhat smaller volume might result in that condition, but as nearly as we can predict, 10,000 second feet is indicated.

5282 With respect to the water supply, with the flow contemplated in the program approved by the Board of Review, the water supply would be efficiently protected. There would be some contamination in the vicinity of the Calumet River outlet coming primarily from the River outside the District, but taking it in general the water supply would be protected by that program. With respect to bathing beaches, they would be protected as they are now. There would not be material storm discharges or sewage discharges from the Sanitary District into the Lake.

With the diversion reduced now to 1,000 second feet there would be a continuous discharge of sewage into Lage Michigan from the Sanitary District. In addition to that continuous discharge of dry weather flow, there would be discharges of storm flow varying from rela-

tively small quantities to perhaps 10,000 or 11,000 second feet. Such discharges would subject the raw water supply to almost continuous serious contamination.

5283 Taking the intakes as a whole, under certain conditions of wind and lake currents, certain of the intakes might be relatively free from contamination, but others would be certain to be seriously contaminated. In times of large storm, discharges of great quantities of the solids which have settled out in the sewers and in the canal system would be flushed into the Lake. These would add to the pollution already described and would settle on the bed of the Lake and along the shores to be later stirred up by currents, and in that way furnish a continuous potential source of contamination of the water supply.

5284 With the diversion reduced to zero or 1,000 second feet, by which I assume is meant the maximum discharge of 1,000 second feet, the works which should be installed would comprise the filtration works for filtering and purifying the water supply, and works for the complete treatment of the sewage. Such equipment as would be necessary for the treatment of the sewage effluent with chlorine would probably be advisable, although their efficacy is a subject of doubt, because of the discharges of sewage and storm flows and the accumulation of sewage solids and deposits in the Canal System which would in a measure offset the benefits derived from the disinfection with chlorine. The best thing that could be done with respect to the intake would be the construction of the so-called super-tunnel to a point perhaps off Wilmette to get as far away from the pollution as practicable.

5286 After all these works have been installed and are in operation, and the diversion has been reduced to 1,000 cubic feet per second, the water supply would not be as good as under the program laid down by the Board of

Review, because with zero diversion the treated sewage and the storm flows and other contamination would at all times be discharged into Lake Michigan. In addition to the storm flows there will be more or less continuous discharge of untreated sewage through regulating devices which cannot be kept 100 per cent perfect. For a number of years I had charge of some thirty such regulating devices, and it is not humanly possible to prevent their becoming clogged and allowing sewage to pass them at times. This is a serious source of more or less continuous pollution.

5287 The sewage and storm water discharged into the lake would at times—how often it is impossible to predict—in my judgment reach the intake, even if it were carried as far north and east as off Wilmette, and I do not think the water supply would be as good as it would be under the system proposed by the Board of Review.

I had a very direct experience with breaks in the operation of water filters, particularly last summer in connection with my investigation of the storm water problem of the city of Detroit. I made a careful study of the effect of the discharge of storm water and sewage into the Detroit River which has a velocity opposite the waterworks intake of from $1\frac{1}{2}$ to $2\frac{1}{2}$ feet per second. The current of the river is such that it prevents the sewage and storm water discharged on the Detroit side of the river from crossing the stream to the intake under all ordinary conditions, but on this occasion there was a severe storm and an intense wind reaching a velocity as high as 56 miles an hour. The result of that was to pile up the water in the River at the down-stream end and stop the velocity, stop the flow, in a measure. It is just possible that the water flowed back toward Lake St. Clair. I was not able to prove it, but at any rate, the water was nearly quiescent, if it did not actually reverse the flow towards the east into Lake St. Clair.

5288 As a result of that condition the sewage did get across the River to the intake, and there was a very large number of cases of intenstinal disorder or diarrhea. I investigated that subject to the extent of discussing it with Dr. Vaughn of the local health department and put into one of my reports that as nearly as I could tell there were 200,000 cases. The water was filtered and chlorinated, and got by these barriers of protection. Just what the cause was I do not know, other than those I have mentioned, but that is a fact to the best of my knowledge.

5289 The problem of Chicago has to do with two aspects, the protection of the water supply and taking care of conditions in the lower river. There is also an exceedingly important additional condition, the protection of the shore waters and the bathing beaches which, while not perhaps as directly connected with the public health as the water supply, are certainly worthy of a very serious consideration from the public health point of view.

Referring to page 26 of Complainants' Exhibit No. 18, there is found a standard for the condition of the flow discharged at Lockport after the treatment of the sewage.

This standard is somewhat ambiguous. It provides that the liquid discharged into the Drainage Canal, as evidenced by the average of representative samples taken for any 30 consecutive days, "shall (a) be practically free from solids deposited in 2 hours."

That, I think, is a reasonable standard. It is not as definite as it might be, but it is helpful.

It further provides:

> "(b) shall contain not less than three parts per million of oxygen and enough to equal or exceed the biochemical oxygen demand of said liquid for five days when incubated at 20 degrees C."

The ambiguity comes in the word "and", because it states two things; it shall contain not less than three

parts per million of oxygen; and then it says, "and enough to equal or exceed the biochemical oxygen demand of said liquid for five days when incubated at 20 degrees C." If they are to be taken as cumulative; that is, three parts in addition to the five-day demand, I think it is quite likely that the standard would be satisfactory, as nearly as can be predicted at this time. My impression is that that is not the interpretation that was intended, but I am not certain.

The last sentence in paragraph 35 reads as follows:

> "It so happens that the adoption of a standard that no appreciable nuisance will result carries with it the restoration of conditions which will permit fish life to thrive."

That is going further than the Board of Review went. There is no question but that that is a tendency of the popular demand with reference to the cleaning up of streams, and I am in accord with that general principle. I think possibly I had better read some that goes before that.

"Whether adherence to this standard"—which is the standard I have read—"will produce exactly the results desired or not is unknown."

I agree with that, that it cannot be definitely determined at the present time.

> "but in view of the present extremely unsatisfactory conditions prevailing with upward of 4,000 cubic yards of settleable solids, being dumped into the Illinois each day, and with series of several months each year with no oxygen whatever present in the effluent, there is no question but what conditions will be improved materially."

On the interpretation that Section (b) of the standard is to be taken as cumulative, I think that that is a correct statement.

> "It should be understood that other sources of pollution are contributory to the Illinois River, and

that with no contamination whatever from the Sanitary District of Chicago, conditions in the Illinois will not be satisfactory until the rest of the communities now discharging their sewage into the system carry out satisfactory sewage treatment programs of their own."

That with the limited dilution is certainly true.

5303 The works recommended by the Board of Review contemplated so-called complete treatment of all sewage, that is, all sewage must be treated finally by trickling filters or by the activated sludge method. The effluent from that would flow into the Canal System and then down the Des Plaines and Illinois Rivers. The effluent from that treatment still has a residual demand for oxygen. If the conditions in the River are to be maintained satisfactorily it will be necessary to satisfy that demand. In addition there are large volumes of storm water and sewage passing regularly, sewage getting in accidentally or through surreptitious connection, which cannot be kept out, which will go down the River and add suspended solids to the flow and cause deposits in the stream. These solids will decompose and use up the available oxygen.

In addition to those sources of oxygen demand, the effluent from activated sludge or trickling filter plants contain fertilizing ingredients which result in prolific growth of microscopic plants, of large plants like duck weed, which float on the surface of the water, of grass and of other vegetation. Some of the micro-plants produce oxygen in their life process, and they add to the supply of dissolved oxygen and help to make conditions free from offense.

5304 On the other hand, the increase in the number of those organisms, due to the fertilizing effect of the effluent, is enormous. At Marlboro, Massachusetts, the number increased from two to three hundred to over 20,000 per

c.c., while the oxygen in the surface water—and that is where the plants live chiefly, on the surface of the pond or stream—was more than 100 per cent of the normal amount of oxygen present in water at that temperature. It contains so much of the organic matter of the dead plants that oxygen did not remain for much more than 24 hours. At Brockton, Massachusetts, there is a dilution ratio of in the neighborhood of $\frac{1}{4}$ of a second foot per 1,000 persons, and there the conditions are exceedingly offensive.

When the Chicago sewage shall have been treated as indicated and the effluents turned into the River System, there will be a prolific growth of these organisms. It is not possible to know in advance just how much water will be required or just what the conditions will be, but after giving that the best study that we could, we felt that 1 cubic foot per second per 1,000 persons would be satisfactory, possibly somewhat less, which would mean in 1955 a flow of about 7,700 cubic feet per second, plus the flow of sewage.

Defendants' Exhibit 1166, Rec. 4995-99—Final Report of International Joint Commission dated September 10, 1918:

Page 6-7:

> "Any conclusions the commission may reach and any recommendations it may make, may, if acted upon, affect the physical health of millions of people who dwell along these waters, as well as the financial and other interests of eight States of the United States and three Provinces of the Dominion."

* * *

Page 7:

> "The boundary waters are the natural channels of interstate and international commerce."

* * *

Page 8:

> "In working out the enormous possibilities of this

vast section of the continent the proper observance of international sanitary requirements will be a most essential factor."

* * *

Page 23:

"The grossly polluted condition of boundary waters is doubtless the cause of the abnormal prevalence of typhoid fever throughout the territory bordering thereon."

* * *

Page 24:

"Notwithstanding the general improvement, violent outbreaks of typhoid fever have occurred, and the potential danger must continue to exist in view of the extensive pollution of these waters and the limitations and inefficient operation of water-purification plants. Not only have the border communities suffered from this condition, but the navigation interests have also been injured very severely from the disastrous outbreaks consequent on the use of polluted boundary water."

* * *

Page 25:

"The City of Detroit discharges into the former all the raw sewage from its estimated population of 850,000. On the United States side opposite Amherstburg the pollution of the river reaches the enormour figure of 10,392 B. coli per 100 c.c., and its waters from that point to Lake Erie and the waters of that lake within a radius of about 4 miles from the mouth of the river are very greatly polluted."

* * *

Page 29:

"The pollution of drinking water supplies and of bathing waters at Bois Blanc Island, on the lower Niagara, at the Thousand Islands, or at other summer resorts, or of the waters navigated by vessels and yachts, might not only be an injury to the immense number of citizens of both countries who would be brought immediately in contact with the pollution, but would indirectly be a source of great peril to hundreds of thousands more. To illustrate the danger the following citation is made from the

United States Public Health Service Report for 1914, volume 29, page 393:

> It is stated that during one short period of the summer's cruise (referring to the voyage of a lake boat) 77 cases of typhoid fever developed as the result of the use of impure drinking water taken from the Detroit River. * * * Investigations by this service of similar outbreaks on three Great Lakes vessels during the summer of 1913 showed that out of a total of 750 people there were over 300 cases of diarrhea and 52 cases of typhoid with 7 deaths.

The lamentable prevalence of typhoid fever referred to previously calls for consideration in this broad international view of the question of pollution of boundary waters."

* * *

Page 32:

"It must be admitted that the conservation of public health is of paramount importance under the treaty."

* * *

Page 33:

"The harm done by existing pollution to bathing resorts cannot be remedied except by preventing the discharge of sewage into the waters which flow to them. Contamination of the sources of the drinking supplies of these classes of people is a most serious matter. The millions whom it affects or may affect are more exposed to danger than are the urban inhabitants who draw their water supplies from public water systems."

* * *

Page 40:

"Sewage-polluted drinking water constitutes an actual or potential menace to health, so much so that the presence of the bacterial organisms of water-borne diseases in the sewage of an urban community should always be assumed. While bacterial pollution is most serious in the case of waters used as sources of drinking-water supply, it is also serious in the case of waters used for bathing, boating, and other pleasurable exercise, and also, although to a

less degree, in the case of shore waters on account of possible indirect infection through cattle and insects."

Defendants' Exhibit 1167, Rec. 5000—Bulletin No. 83, Treasury Department, entitled "Sewage Pollution of Interstate and International Waters with Special Reference to the Spread of Typhoid Fever":

"CHICAGO.

The growth of the City of Chicago finds no parallel in history. From a population of 7,500 in 1843 it has grown to be the second city in the United States with a population in 1910 of more than 2,000,000. No argument is necessary to show the importance to the whole country of sanitary conditions in Chicago. Its vast commerce and giant industries make it the metropolis of an enormous territory and bring thousands of visitors daily from nearly every State in the Union. These visitors drink Chicago's milk and water and eat Chicago's food. Contamination of these articles of food or drink by typhoid fever germs means infection of the transients as well as citizens—transients who go to their homes in other states to establish new foci of typhoid fever. These transients and interstate travelers are less able to protect themselves against contaminated food or drink than the citizen who heeds the warnings of Chicago's excellent department of health. Thousands of interstate travelers drink water on trains which is taken aboard cars in this great railway center, and the character of Chicago's water supply is of vital importance to these travelers and to the States to which they are destined."

Abstract of Evidence Relied Upon by Complainants Offered at 1926-27 Hearings.

Dr. Harry L. Rockwood, for Complainants. March, 1927. Public Health Expert:

8168 *Direct Examination by Mr. Jackson.*

Am Health Commissioner of the City of Cleveland. My high school education was in Olean, New York, where I was born, subsequent to which I had academic and pre-medical training at Cornell University, and graduated in medicine from Western Reserve University in 1909. After graduation I became House Officer at Lakeside Hospital, Cleveland, and served there for practically two years.

In 1911 I became a medical examiner for the Pennsylvania Railroad, and in 1912 I entered private practice
8169 and practiced until the close of 1913. At that time I became medical director of the Cleveland Municipal Tuberculosis Sanitarium, and still hold that position, but in addition I became Health Commissioner of the city in 1918.

The responsibility for the quality of the public water supply and supervision of swimming pools and bathing beaches from a public health point of view is charged to the Health Division, of which I am Health Commissioner. It is one of our very urgent duties to watch the relationship of typhoid fever to water supply.

I am a member of the American Public Health Association, American Medical Association, Ohio State Medical
8170 Society, Cleveland Academy of Medicine, and President of the Ohio Society of Sanitarians. I have a certificate of Public Health of the Ohio State Department of Health, Rockefeller Foundation course.

I have read and studied the testimony of Dr. Evans, 8171 and Exhibits 1140 to 1144, which were offered by him.

There was received in evidence as Complainants' Exhibit 187 a photostatic copy of a table entitled "Table 1, Comparison of Typhoid Fever with Total Mortalities in Chicago," taken from Exhibit 18 which is as follows:

"COMPLAINANTS' EXHIBIT 187.

TABLE 1.—COMPARISON OF TYPHOID FEVER WITH TOTAL MORTALITIES IN CHICAGO (BASED ON CHICAGO DEPARTMENT OF HEALTH RECORDS.)

Years	Death rate, all causes per 1,000	Typhoid fever			Remarks
		Total deaths	Deaths per 100,000	Per cent total deaths	
1867....	21.21	165	73.3	3.45	
1868....	23.74	200	79.3	3.34	
1869....	23.17	183	65.3	2.82	
1870....	23.88	268	87.4	3.66	
1871....	20.87	204	61.0	2.92	
1872....	27.64	524	142.6	5.16	
1873....	25.15	272	71.6	2.85	
1874....	20.30	211	53.4	2.63	
1875....	19.72	207	51.7	2.62	
1876....	21.03	168	41.2	1.96	
1877....	18.67	159	37.0	1.98	
1878....	16.99	146	33.4	1.97	
1879....	17.53	208	42.3	2.41	
1880....	20.79	171	34.0	1.63	
1881....	26.11	568	105.2	4.03	
1882....	23.60	462	82.4	3.49	
1883....	19.92	361	62.2	3.12	
1884....	19.80	354	56.2	2.84	
1885....	18.76	496	74.6	3.98	
1886....	19.47	483	68.6	3.53	
1887....	20.27	382	50.3	2.48	
1888....	19.65	375	46.7	2.38	
1889....	18.12	453	48.4	2.67	
1890....	19.87	1,008	91.6	4.61	
1891....	24.16	1,997	173.8	7.20	
1892....	21.85	1,489	124.1	5.68	
1893....	21.61	670	53.5	2.47	
1894....	18.26	491	37.5	2.06	
1895....	17.72	518	37.9	2.14	
1896....	16.29	751	52.6	3.23	
1897....	14.63	437	29.3	2.00	
1898....	14.64	636	40.8	2.79	
1899....	15.68	442	27.2	1.73	
1900....	14.68	337	19.8	1.35	Opening of Drainage Canal.
1901....	13.93	509	29.1	2.09	
1902....	14.69	801	44.5	3.03	
1903....	15.62	588	31.8	2.03	

Years	Death rate, all causes per 1,000	Typhoid fever			Remarks
		Total deaths	Deaths per 100,000	Per cent total deaths	
1904....	13.85	373	19.6	1.42	
1905....	13.96	329	16.9	1.21	
1906....	14.54	370	18.5	1.27	Opening south side interceptors.
1907....	15.72	372	18.2	1.16	Completion south side interceptors.
1908....	14.49	332	15.8	1.09	Opening north side interceptors.
1909....	14.58	271	12.6	0.87	
1910....	15.13	300	13.7	0.90	Pasteurization of milk.
1911....	14.48	241	10.7	0.74	Completion north shore interceptors.
1912....	14.78	175	7.6	0.51	Chlorination of water started.
1913....	14.99	249	10.6	0.71	
1914....	13.93	167	6.9	0.49	
1915....	14.16	132	5.3	0.37	
1916....	14.42	128	5.1	0.35	
1917....	14.79	43	1.6	0.11	Complete chlorination of water.
1918....	17.01	38	1.4	0.08	
1919....	12.52	31	1.2	0.09	Completion Evanston interceptors.
1920....	12.77	30	1.1	0.09	
1921....	11.08	30	1.1	0.09	Completion Calumet interceptors.
1922....	11.18	31	1.1	0.10	Opening of Calumet Sag Channel.
1923....	11.7	57	1.9	0.17	
1924....	11.2	45	1.5	0.14"	

I am familiar in a general way with the method of sewage disposal by dilution and diversion for the protection of the water supply that has prevailed during a part
8172 of the period covered by that exhibit; and also in a general way with the conditions prevailing prior to the opening of the Drainage Canal in 1900.

8173 The greatest reduction in the typhoid rate in Chicago came before the opening of the Drainage Canal. Previous to the opening of the Canal there was a rate averaging 50 deaths per 100,000. At the time of the opening of the Canal the rate was 20 per 100,000. Since that time it has fallen to 1.5. This would indicate that the fall in rate was greater previous to the opening of the
8174 canal than since, and since that time a large number of factors have contributed to the rate reduction in typhoid fever, particularly the chlorination of water, which was instituted in 1912, and became complete in 1917 and the pasteurization of milk, which coincided with these years.

Some credit must also be given to the general improvement in public sanitation and development of the science of public health in the last 20 years.

No chart could be constructed from Defendants' Exhibit 1142 which would show a reduction in death rate from typhoid fever, with the selection of any other year than 1891, because the year 1891 which was selected was the peak year in typhoid for the city of Chicago, as far as all available records show.

Assuming the complete treatment of all sewage of the
8175 Sanitary District of Chicago, by the activated sludge process, or by Imhoff tanks, or trickling filters, and final sedimentation; no diversion of water through the Drainage Canal; and the present location of the water intakes, water purification plants could be so constructed that the public health conditions in Chicago, with special reference to the public water supply, would be as well safeguarded, as under present conditions.

I would assume the type of water purification works, in the operation of which the water entering the distribution system would comply with the standards for potable water set up by the American Public Health Association and the United States Treasury Department.

Assuming the complete treatment of all of the sewage of the Sanitary District of Chicago, as described, with reference to the activated sludge and the trickling filter processes; no diversion of water through the Chicago Drainage Canal; the replacement of the present water intakes, by a super-tunnel, located four and one-half miles off shore, in the vicinity of Wilmette, and twenty miles from the mouth of the Chicago River; with chlorination of the water supply only; the public health conditions in Chicago, with special reference to the public water supply, would be as well safeguarded as under the conditions now obtaining.

8176 I am basing my opinion on the underlying principle in the prevention of water-borne diseases, of a wide separation of susceptible individuals from these infecting organisms which cause these water-borne diseases.

In our Cleveland experience, as long as the source of the water supply was from a point in Lake Erie, near the city, and in an area where water pollution from these infecting organisms causing water-borne diseases was heavy, our typhoid fever rates, and rates in other water-borne diseases, were exceedingly higher than when the source of our water supply was placed at a distance more remote from the city, at a point 4½ miles, as compared with a point slightly over a mile from shore previously. Under these conditions, our typhoid rates showed an immediate reduction, with subsequent steps taken to safeguard the water supply in Cleveland, which are substantially the same as referred to. With regard to chlorination our typhoid rate showed a still greater reduction. With the changes contemplated in Chicago, as outlined, of the complete treatment of all of the sewage, the location of the water intakes as remotely as twenty miles from the mouth of the Chicago River, the water supply would be still increasingly safeguarded. If water filtra-
8177 tion or purification works were installed, in connection with such relocation of the intakes, that would still fur-
8178 ther improve the water supply. It would protect the entire water supply from the standpoint of public health.

Assuming complete treatment of all the sewage of the Sanitary District of Chicago, with the definition of complete treatment that has heretofore been adopted, with no normal or dry weather diversion of water from Lake Michigan, but with diversion of all the sewage and storm water by means of proper control works, the present location of the water intake and filtration and chlorination of the water supply, the public health conditions in

the City of Chicago, with special reference to the water supply, would be safeguarded as well as under present conditions.

8180 My opinion is based on the maximum pollution of the lake water occurring from the overflow produced by storm water, and with some diversion of this greater source of pollution by proper control works that factor would be eliminated.

Assuming complete treatment of all the sewage with no normal or dry weather diversion of water but with diversion of all the storm water by means of proper control works, relocation of the water intake and chlorination only of the water supply, the public health conditions in the City of Chicago, with special reference to the water supply, would be better safeguarded than under present conditions and for the same reasons, substantially.

8181 The water supply of Chicago should be filtered, regardless of the method of sewage disposal. In the conditions which have been assumed regarding sewage treatment there would be further protection to the public health by 8182 chlorination or sterilization of the effluents, the result of which is to reduce the pathogenic or disease-causing bacteria which may be present.

8184 Defendants' Exhibits 1178, 1140, 1142 and 187 do not show any unique or unusual experience in the typhoid fever death rate in Chicago not common to other cities mentioned therein during the last forty years.

Complainants' Exhibit 188 is a chart entitled "Cleveland and Chicago Typhoid Mortality Rates per 100,000 Population, Years 1878-1926, 1870-1925."

Complainants' Exhibit 189 being a chart entitled "Deaths Due to Typhoid Fever with Population Estimates and Total Deaths Years 1878-1926", is as follows:

"COMPLAINANTS' EXHIBIT 189.

DEATHS DUE TO TYPHOID FEVER WITH POPULATION ESTIMATES AND TOTAL DEATHS YEARS 1878-1926 INCLUSIVE. CLEVELAND, OHIO. H. L. ROCKWOOD, M. D.

Year	Typhoid Deaths	Typhoid Death Rate per 100,000 Pop.		Total Deaths	Total Death Rate per 100,000 Pop.	% Total deaths due to Typhoid Fever	Population
1926....	14	1.46		10,636	1107.5	.13%	960,468
1925....	14	1.50		9,706	1036.4	.14	936,485
1924....	11	1.20		9,287	1017.7	.12	912,502
1923....	16	1.80		9,618	1082.4	.17	888,519
1922....	19	2.22		8,743	1023.1	.22	854,565
1921....	29	3.49		8,705	1047.3	.33	831,138
1920....	26	3.22		9,997	1236.8	.26	808,273
1919....	21	2.67		9,932	1264.5	.21	785,408
1918....	37	4.85		13,061	1712.8	.28	762,543
1917....	53	7.20		10,848	1473.0	.49	736,452
1916....	36	5.05		9,987	1402.3	.36	712,187
1915....	54	7.83		8,841	1282.5	.61	689,322
1914....	54	8.12		8,266	1242.4	.65	665,327
1913....	88	13.69		8,842	1376.2	1.00	642,462
1912....	38	6.22		8,149	1332.8	.47	611,397
1911....	85	14.45		7,967	1354.2	1.07	588,292
1910....	105	18.57		8,034	1420.8	1.03	565,427
1909....	67	12.26		7,032	1286.6	.95	546,503
1908....	64	12.10		7,177	1357.7	.89	528,613
1907....	84	16.44		7,678	1503.3	1.09	510,723
1906....	93	18.87		7,353	1492.0	1.24	492,833
1905....	67	14.11	34.5	6,424	1352.5	1.04	474,943
1904....	203	44.41		6,476	1416.9	3.14	457,053
1903....	472	107.47		6,799	1548.2	6.94	439,163
1902....	133	31.57		6,134	1456.0	2.17	421,273
1901....	140	34.70		5,834	1446.2	2.40	403,383
1900....	205	53.18		6,104	1583.4	3.35	385,493
1899....	119	31.97		5,556	1492.5	2.15	372,241
1898....	121	33.59		5,040	1399.2	2.40	360,199
1897....	73	20.97		5,007	1438.1	1.46	348,157
1896....	142	42.24		4,959	1475.3	2.86	336,115
1895....	117	36.10		5,167	1594.3	2.26	324,073
1894....	89	28.52		5,663	1814.8	1.57	312,031
1893....	153	51.00		5,261	1753.6	2.90	299,999
1892....	166	57.64		5,227	1815.2	3.17	287,947
1891....	155	56.18		5,204	1886.1	2.97	275,905
1890....	182	68.97		5,058	1916.9	3.59	263,863
1889....	185	73.02		4,414	1742.3	4.19	253,345
1888....	113	46.45		4,415	1815.1	2.55	243,224
1887....	120	51.47		4,139	1775.6	2.89	233,103
1886....	113	50.67		3,525	1580.8	3.21	222,982
1885....	71	33.35		3,574	1679.3	1.99	212,861
1884....	121	59.68		3,730	1839.8	3.25	202,740
1883....	105	54.51		3,399	1764.6	3.09	192,619
1882....	122	66.85		3,563	1952.3	3.42	182,498
1881....	168	97.46		3,727	2162.1	4.51	172,377
1880....	70	43.14		3,156	1945.0	2.25	154,820
1879....	46	29.71		3,038	1962.3	1.52	162,256
1878....	55	37.14		2,710	1829.9	2.03	148,088"

8186 As shown by these charts, the mortality rate in both Cleveland and Chicago shows a marked decline during the period of 1880 and previous years to the present time, the rate in both cities having been in the neighborhood of 50 per 100,000 on an average in the early part of the period, and having now reached a rate which is almost identical in each city of 1 per 100,000.

8187 In addition, the chart also shows years of unsual prevalence of typhoid fever when it reached the epidemic stage, the highest year of its prevalence being in Chicago the year 1891, when the mortality exceeded 170 per 100,000, and the year of greatest prevalence in Cleveland having been the year 1903, when the mortality rate reached 108. The Cleveland peak is some 40 per cent lower than the Chicago peak, nevertheless. With respect to the last few years, the significant point is the practically identical rates for both cities.

Cleveland has no complete sewage treatment up to the present time. Only a small portion is treated. The sewage passes into the Lake in a raw state, with the exception of a small portion.

8188 There are two intakes. One is 4½ miles out, and the other is only a few hundred feet nearer the shore.

Complainants' Exhibit 190 is a chart entitled "Typhoid Fever Death Rates per 100,000 population, Cleveland."

8189 The statement regarding the opening of the new tunnel comes from a public document of the Cleveland Division of Water. The statement with reference to complete chlorination is from the Cleveland Department of Health records, and from the statement of city officials at the present time.

8190 The records I examined with reference to chlorination were the annual reports of the Division of Health for the years in the neighborhood of 1911. The data are repeated in several reports. The statement with reference

to the pasteurization of milk came from my own knowl-
8191 edge as a member of the Division of Health in 1916, when I was medical director of the Cleveland Tuberculosis Sanitarium and chief of the Cleveland Division of Tuberculosis. When I say "pasteurization of milk instituted," I mean that an ordinance was passed requiring all milk of a grade commonly known as market milk to be pasteurized before being offered for sale, and that the enforcement of that ordinance was immediately begun. I canot state the date in 1916 when the ordinance was passed. It was so that the pasteurization of milk began
8192 early in the year.

8193 The ordinance became 100 per cent effective within 2 years from the date of its passage. I don't know how effective in 1916, but it was considerably more than 5 or 10 per cent.

8195 Exhibit 190 is prepared on a larger scale than 188, showing the years from a point previous to 1880 in Cleveland, as regards the typhoid fever mortality rate per hundred thousand population for each year up to the present time and, in addition, there are shown changes in the sources of the water supply or other changes in the operation of the distribution system of water which were made for the purpose of reducing the water borne diseases.

It also shows certain other steps taken in Cleveland relating to the subject of preventing water-borne or other diseases of an infectious nature.

In brief, the Cleveland chart shows previous to the year 1904 a period of greatest prevalence of typhoid fever, the rate averaging between 40 and 50.

Reference to the Chicago data shows that similar conditions prevailed in Chicago with a slightly higher rate, between 50 and 60 per hundred thousand throughout the same period with the exception of epidemic years as stated.

8196 The Cleveland chart shows 1903 as the year of greatest prevalence and also shows that in the following year, 1904, both a new tunnel 26,048 feet long and an intake 4 miles from shore were opened and an old tunnel and intake 2 miles or less from shore abandoned; that subsequent to that step the typhoid fever mortality rate fell, never again to exceed 20; that in 1911 complete chlorination of the water began, and following that the decline in typhoid death rate continued until 1916 or 1918, in which years pasteurization of milk became practically 100 per cent, and filtration of the water 60 per cent, 100 per cent of the water having been chlorinated since 1911. Immediately after 1918 a still further drop occurred in the typhoid mortality rate, and that favorable typhoid mortality rate has continued up to the present time.

The chart also shows that in 1925 the Cleveland water supply was 100 per cent filtered.

8197 On Exhibit 188 the Cleveland mortality rate is represented by the dark blue solid line. Exhibit 187 shows the opening of the Drainage Canal in 1900. Exhibit 188 shows that the typhoid rate previous to 1900 averaged between 50 and 60. Exhibit 187 shows that pasteurization of milk in Chicago began in 1910, and that chlorination of water began in 1912. The Chicago rate shows a general and gradual decline until 1910 or 1912, but a more radical drop after those dates when chlorination and pasteurization was begun. Complete chlorination occurred in 1917, and since that date a rate almost identical with Cleveland has continued.

8198 Complainants' Exhibit 191 is a chart entitled "Cleveland Typhoid Actual Deaths by Months, Years 1912-1926."

8206 With reference to the alleged break in the water purification plant at Cleveland in October, 1925, the typhoid deaths in October were two and in November two. Ref-

erence to Exhibit 191 for previous years will show that this number of deaths was not in excess, but, in fact, was below the deaths in former years.

8207 Exhibit 192 shows that in October, 1925 there were 36 deaths from diarrhoea and enteritis in children under 2 years of age, whereas during the period shown on the chart there are three other years in the total number of 7 where the deaths from these causes were in excess of that in October, 1925. In November, 1925, there were 11 deaths, and in each of the other years except one the number was in excess of 11.

There is no significance of the statistics shown on Defendants' Exhibit 1178 with reference to the Chicago situation and particularly in regard to the safety of the public water supply as compared with the public water supplies of the other cities included in the chart.

In order to draw comparisons between various cities it is necessary to analyze the conditions prevailing in each as regards location, general sanitation, safeguards respecting milk, general food supply, character of the population and the private water supply, such as wells and springs. Comparison from a set of statistics without giving weight to any of these other factors is of no significance.

The following statement by Dr. Evans, page 3880 of the record, is not sound:

> "We could not hold our typhoid death rate as low as it is without diversion, nor do I believe we could maintain our general death rate as low as it is without diversion."

8209 There are other ways of protecting water supply equally or more effective than diversion. I am basing my opinion on the Cleveland experience. In Cleveland the sewage is returned to the Lake, "only a small portion treated, and the lake is used for a source of water supply.

We do not, nor could we, practice diversion of the sewage. Our general death rate, nevertheless, has remained consistently lower than the death rate of Chicago in recent years, and the typhoid rate has remained practically identical with Chicago. On this account I conclude that Chicago could duplicate the Cleveland performance.

Assuming that Chicago installs complete sewage treatment, including disinfection of the sewage effluent, and no diversion down the Drainage Canal, that method of handling the sewage problem at Chicago would not re-
8210 sult in any increase of typhoid fever among bathers at the public bathing beaches.

It is our practice in Cleveland to make a careful investigation of typhoid cases as shown by Exhibit 193, and we have observed that bathing at public beaches has not contributed to our typhoid. All of the sewage in Cleveland is discharged into the lake only partially treated and in close proximity to the public beaches. I conclude from this that at Chicago with complete sewage treatment there would also be no increased typhoid from the use of the public beaches.

8211 The greatest danger from typhoid at beaches arises from the bathers themselves. That is shown by the experience in connection with indoor swimming pools where the number of intestinal bacteria in the pools increases in direct ratio with the number of bathers.

Complainants' Exhibit 194 is a chart entitled "Cleveland Typhoid Mortality Rate per 100,000 Population by Years 1911 to 1926," designed to show the change in the typhoid rate if out-of-town cases are eliminated.

8511 For my comparison of the general death rates of the two cities of Chicago and Cleveland I am using for the
8512 Chicago rate those shown in the Chicago Department of Health Reports for the years 1923-1925, a table on page 784, giving deaths from all causes exclusive of still births,

and for the Cleveland rates I am using Exhibit 189. I find that since 1900 there are but 2 years, namely, 1918 and 1919, when the Chicago general mortality was lower than the Cleveland mortality.

8513 For infant mortality I am using the Public Health reports for the City of Chicago, page 234, Table 109 which shows the infant mortality 1914 to 1925.

For Cleveland I am using a publication of the Division of Health known as Statistical records, years 1916 to 1924, on page 35 of which in Table 16 the infant mortality rates are given from 1916 to 1924.

I find that for 1916 the Chicago rate was 122.4 per thousand births; the Cleveland rate 105.4. For 1917 Chicago rate 117.7, and Cleveland 106.8. For 1918 Chicago rate was 117 and Cleveland was 95.4. For 1919 Chicago was 100.9 and Cleveland was 92.8. For 1920 Chicago was 99.5 and Cleveland was 86. For 1921 Chicago was 89.3 and Cleveland was 73.1. For 1922 Chicago was 85.5 and Cleveland was 75.9. For 1924 Chicago was 76.9 and Cleveland was 66.2.

I am also using for the Cleveland rate the annual re-
8514 port of the Cleveland Division of Health for 1925. Page 25, which shows the infant mortality rate as 65.8, the Chicago rate for the same year being 74.7.

This indicates that from 1916 to 1926 in each year consecutively the infant mortality rate in Cleveland was well below that of Chicago.

In diarrhoea and enteritis the deaths under two years of age are considered separately from deaths over two years of age, and almost invariably, except in epidemic seasons, the deaths from this disease, among children under two, equal 90 per cent of all deaths from these causes as shown by death certificates.

In the Chicago report previously referred to, using the deaths from these causes reported in that publication,

and using as a population divisor for each year the population as submitted in the same report, on page 783, I have computed that for the previous three years, 1925, 1924, and 1923, the rates for Chicago as compared with Cleveland per 100,000 population deaths caused from
8515 diarrhoea and enteritis under two years of age were as follows: Chicago rate, 1923, 38—Cleveland rate, 29; 1924, Chicago, 30—Cleveland, 20; 1925, Chicago, 30—Cleveland, 25. The data for the Cleveland figures are shown on page 119 of the annual report of the Division of Health of the City of Cleveland, Table No. 30.

The Hazen Theorem, as it has been called, is in reality a derivation from a similar formula known as the Mills-Reincke phenomenon, which was named from the fact that a Mr. Mills of Lawrence, Massachusetts, at the time when Lawrence was having considerable difficulty, not only with typhoid but with the question of water purification, made public an observation that at approximately the same time a Dr. Reincke of Hamburg, Germany, made a similar public observation, to the effect that whenever water supplies were purified and a drop in typhoid fever incidence resulted therefrom, at the same time the general mortality rates of the population groups affected were similarly reduced, and the Hazen Theorem attempts to set up a ratio as to the amount of reduction and has been interpreted variously by various authors, which substantially is to the effect that a reduction or prevention of 1 typhoid death at the same time prevents from 2 to 4 deaths from other general causes in the same population group.

The theorem, however, is discredited by most public health authorities and can be shown very definitely to be unworkable under existing conditions, whereby typhoid rates have been reduced to a small fraction of their
8517 former level and play on this account a very slight part in death rates.

For example, in Chicago, according to the annual reports, in 1916 the typhoid death rate is given as 5.1 per 100,000 and for 1917 as 1.6, a reduction of nearly 80 per cent.

Reference to the table on page 784, which illustrates deaths from all cases, indicates that the death rate in 1916 in Chicago from all causes was 14.42, the total deaths being 36,304 and the following year the death rate was 14.79 and the total number of deaths 38,027. Instead of being a reduction, there was an actual increase in the number of deaths. This same illustration could be repeated, of course, for Cleveland and most communities of the same type.

Cross-Examination by Mr. Adcock.

As to what authorities besides myself have discredited the Hazen Theorem, you will find a rather extensive
8518 discussion in "Rosenau's Preventive Medicine." That was a standard text, and there are several editions. I should say that the edition of 1910 or 1911 would certainly carry that statement.

There had been a marked decrease in the typhoid death
8519 rate generally in 1910. The average death rate at Cleveland from 1890 to 1899 was about 41; from 1900 to 1909 the average, including the epidemic years, was about 34.2.
8520 That was a decrease of about 7 per 100,000.

I am not familiar with Mr. Ellms' work on Water Purification, published in 1917.

Mr. Ellms' book, page 40, in substance as follows:

8521 "Sedgwick and MacNutt have called this expression 'Hazen's Theorem,' and have concluded from the studies which they have made that the statement appears sound and conservative, but not necessarily precise. The ratios they worked out varied widely. For example, at Hamburg, Germany, for every death less from typhoid fever after filtration, there were

15.8 deaths less from other causes; at Lawrence, Massachusetts, the ratio was 1 to 4.4; at Lowell, Massachusetts, 1 to 6; at Albany, New York, 1 to 4.1; and at Binghampton, New York, 1 to 1.5."

I disagree with that statement only to this extent: As I understood what you read there, it says the death rate has fallen and refers to a period back of 1904. In the light of later observations it is now generally concluded that much of the changed death rate was not due to water purification, but takes into consideration such things as the reduction of infant mortality from purified milk supply, and the reduction in tuberculosis from causes en-
8522 tirely separate from those that have to do with the reduction in typhoid fever, and that the Hazen Theorem received the benefit of those reductions which were going on at that time.

The following is a foot note from Mr. Ellms' book:

"W. T. Sedgwick and J. Scott MacNutt: On Mills-Reincke Phenomenon of Hazen's Theorem, concerning the decrease in mortality from diseases other than typhoid fever and following the purification of a public water supply. Journal Infectious Diseases, Volume 7, page 10."

It would appear that the observation of Sedgwick and MacNutt referred to in Mr. Ellms' book was published in 1910.

I think it is very reliable to take one year like 1916, and compare it with another year, 1917, without knowing whether there were some extraordinary conditions existing in 1917 that might have caused deaths in Chicago other than from typhoid fever infection as the very statement of the theorem takes into consideration those con-
8523 ditions. It does not exclude epidemic conditions for other causes.

I do not think it is necessarily true that a city must have a typhoid epidemic every few years, if the proper pre-

cautions are observed. In Cleveland in 1907 we had a rate of 16.44. The rate has never exceeded 20 since 1905.

8524 I account for the difference between the Chicago typhoid rate of 67 from 1890 to 1899 and the Cleveland
8525 rate of 41 by the epidemic or peak at Chicago of 173 in 1891. There was an epidemic in 1881, when the rate reached 105, and there was another in 1872. There is no question but that the amount of sewage had something to do with the death rate in that period.

The population of Chicago in the decade of 1890 to 1900 is given as from 1,099,000 to 1,698,575. The population of Cleveland in 1900 was 381,768. I do not know the figure in 1890, but I think it was about 175,000.

8526 Unquestionably, the increased population of towns from which sewage is put into the lakes has something to do with the problem of water supply.

Q. So in 1890, Chicago had the problem that Cleveland now has, practically, did it not, as far as water supply was concerned, and the pollution of its water supply?

A. As far as the ratio in Chicago is concerned, the increased population would bring an increased amount of sewage and hence more provision for caring for such sewage.

8527 I judge it is true that until 1910 there was a good deal of sewage going into the Lake at Chicago by means of sewers. The statement in Exhibit 187 indicates that subsequent to 1900 there were several interceptors which were finished and put into operation.

8528 The death rate for typhoid in Chicago from 1900 to 1909 is probably close to 22. The year 1902 was 44. I would call that a pretty stiff year. We had one of 108 at Cleveland, and that was an epidemic. We never had a year as high as Chicago. The average for Cleveland from 1900-1909 was 34.

8529 Graduated medicine in 1909, Western Reserve; have

been engaged in medical work since; interested in tuberculosis and medical director of a 300 bed institution at Cleveland, known as the Municipal Tuberculosis Sanitarium; have been connected with the Sanitarium since 1913, and my connection in 1913 is the same as now; resided at the institution for two or three years and have been Health Commissioner of Cleveland since 1918.

8531 It is undoubtedly true in Chicago as well as Cleveland that a great many people who die of typhoid were infected in other places, probably in the same ratio. Of 8532 course, it is true that they have many hospitals. It is quite likely that people have been infected with typhoid in Chicago and died elsewhere. The same is true of Cleveland. There is also a Marine Hospital at Chicago. There is also a Hines Memorial Hospital for Disabled Soldiers of the World War. Those two hospitals would have an effect upon the typhoid rate of Chicago.

8533 I cannot state with accuracy the cities or villages outside of Cleveland which get their water supply from the Cleveland Waterworks. The Cleveland Health Department has no supervision over health conditions in those cities or villages, although they have a good deal of concern regarding them. It makes no investigations of health in them.

I did not say that the typhoid infection had ever been 8534 traced to bathing beaches. We have traced one instance 8535 to a bathing beach, but not a public beach. It was a private beach along the lake shore east of the city, but I am unable to recall the name of it.

I am familiar with the Treasury Department Reprint No. 659 entitled "Typhoid Fever in Cleveland, 1918-1920, by Roger G. Perkins, M. D., Professor of Hygiene and Preventive Medicine, Western Reserve University, Chief, Bureau of Laboratories, Cleveland Division of Health."

8536 Page 10 of said report in substance is as follows:

"The main bathing areas at Cleveland are in Edgewater Park on the West Side, and from Gordon Park eastward on the east side. All these beaches are subject to heavy contamination from untreated sewage, those on the west side from the West 58th Street sewer less than a mile away, and draining the greater part of the west side; and those on the east side from the intercepting sewer outlet at East One Hundred and Fortieth, a maximum of two miles from any of the beaches and within a mile of many. Laboratory tests show a high degree of pollution, and there is little question that infection can occur while swimming. It is interesting, however, to note that of the many thousands who have used the beaches in the last three years, only 12 give a history of bathing at these points being followed by a typhoid infection within a reasonable period.

8537 It is obvious that the interval between exposure and the onset of the disease is within the average of the incubation period of typhoid, and while the fact that other persons in the same vicinity, with no history of bathing, developed the disease, makes it impossible to make an absolute statement, yet, in the absence of other factors, it seems probable that these cases must be attributed to sewage infection of Lake Erie."

The cases cited in all but five instances out of the twelve were public beaches, anyway. The others were

8538 all private beaches, and I have not contended anything about those, and according to Dr. Perkins' own statement it is questionable whether these infections occurred at these beaches.

It is true that there would be at times of storms raw sewage going into the lake, but we find that it is not during times of storm that people as a rule enter the lake for bathing. Our bathing season is only ten weeks long at the most, and the period which corresponds with the bathing season is usually the season of dry weather, when there is very little overflow compared with the rest of the year. Sometimes we do have heavy rains at that

time. However, in my experience, these are the exact facts: That this bathing at public beaches, regardless of the exposure to infected water, which we freely admit, has not resulted in a marked or appreciable change in our typhoid incidence. The water has been polluted all the time.

8539 We have never had an unpolluted water supply for bathing, in the sense that probably at no time would the water be found to be free from B. coli, but we must remember that we are not discussing pathogenic matters when we talk of B. coli. We do not to my knowledge find feces around these beaches once in a while after storms. I have never heard such a report referring to the bathing beaches.

I have been in Chicago very little. I was there the year of the Spanish American War, which I think was 8540 the first time. I was in Chicago in February of this year with Mr. Ellms. I cannot state exactly at what prior time I visited Chicago. I have never been there for any length of time, only passing through to St. Louis and other points. I visited in Chicago in connection with this case to get the lay of the land, so to speak. I did not exceed over two days there.

8541 At Cleveland we exclude typhoid carriers from the food supply. We do not isolate them in the sense that you would a contagious case, but they are excluded from handling food supplies or any other occupation by which they might contaminate the food supply. We do everything we possibly can to prevent infection, although "carriers" must be considered as a relative term. All people who have typhoid are carriers, some for a very short period and some for a long period. It is our custom to examine the feces and urine in every case of typhoid which occurs, and not to allow that case to leave quarantine until these examinations are shown negatived by

typhoid, by two examinations made 24 hours apart. Typhoid infection may cause one to become a typhoid carrier. I think that is the only known way.

8542 As to my understanding of the term "complete purification" of sewage, as applied to Chicago, I think it was defined in the testimony, but my recollection is that it includes the establishment of Imhoff tanks, trickling filters and activated sludge. I have studied various sewage purification processes only so far as they relate to our Cleveland experience. We have no activated sludge plant at Cleveland. I do not think I ever saw one. I have seen experimental activated sludge plants, but not a practical one in operation.

8543 I do not agree that an increase in typhoid fever with no other factors indicates that the water is open to suspicion. You must take into consideration the existing conditions. There might be a very serious epidemic in the neighborhood of Cleveland. These cases in large numbers might be brought into Cleveland hospitals. The increases in Cleveland, therefore, would have no justification for involving the Cleveland water supply.

Even supposing there were cases arising inside Cleveland, you must take into consideration that an epidemic

8544 may occur at any time in the year. When the oyster epidemic occurred in Chicago, and the other one relating to the water supply, in the fall of the year, the increase began in November and the end of the epidemic was not until February. The result is, as far as death rates are concerned, you had practically no increase, because two years bore the epidemic, instead of one.

8545 A typhoid germ has to get into the body by way of the mouth, either through food or water.

The B. coli index is a percentage ratio which allows us to get relative judgment that relates to the infection of the water by B. coli, B. coli being used as an index for

the reason that pathogenic organisms are impossible to draw or find. As a matter of fact, it is almost impossible to cultivate typhoid baccili from sewage. They die out
8546 very quickly. They are not resistant. The water will purify itself when in motion very rapidly from such organisms. They do not propagate very readily in the water.

It is true that if at any time there are living typhoid organisms in sewage, there would be certain potential danger of infection. As to what extent B. coli would be decreased by sewage treatment is the question which would be more related to sanitary engineering, and one
8547 which I can only answer from having had a chance to see the data relating to our Cleveland plant, and some other plants.

We do not have complete treatment in Cleveland. I think the question asked me stated specifically a reduction of 95 per cent of the bacteria. It was solely on that assumption that I answered the question. As to the facts with reference to the effect of the operation of complete treatment plants, I can only take the statements of others
8548 that the complete treatment is effectual. I did not do that for this particular case. It is a matter of record in books on preventive medicine. The books I have used and consulted are Rosenau's of Harvard, Park's of New York, and MacNutt. Rosenau has written on sewage treatment in a recent edition. I cannot say what the year of it is or when I read it.

8549 In saying on page 8175 of the record that I assumed a type of water purification works which would comply with American Public Health and Treasury Department standards, I did not refer to any specific plants. I referred to a plant which would produce that result. Water purification plants can produce such results. I do not know what you mean when you ask about the condition of loading.

8550 Q. If the water that is to be taken care of is heavily loaded with B. coli, what is the limit to which that purification would serve the purpose of producing a water that would pass the United States Treasury Standard? A. Not having any purification plant particularly in mind, I say that I was dealing only with results; so I cannot state what the loading would be.

F. H. Waring, Sanitary and Water Purification Engineer Expert, for Complainants, March, 1927:

8225 *Direct Examination by Mr. Jackson.*

Am Chief Engineer of the Ohio State Department of Health, Columbus, Ohio. Received high school education at Lowell, and Worcester, Massachusetts. Attended the Technical School at Worcester Polytechnic Institute, from which I graduated in 1912 with the degree of Bachelor of Science in Sanitary Engineering.

Following graduation, for two years I was in the employ of Metcalf & Eddy, consulting sanitary engineers at Boston and engaged upon field studies at Cincinnati, Ohio, on sewage disposal investigations and the effect of
8226 sewage disposal upon the Ohio River and the water supply therefrom.

During 1914 I entered the employ of Pollard & Ellms, consulting engineers, Cincinnati, Ohio, and was engaged in the study of nuisance investigations and the design of waterworks.

From August until December, 1914, I was valuation engineer for the Big Four Railroad. From December, 1914, until January, 1916, I was in the employ of the United States Government as filtration chemist in the Panama Canal zone, as chemist in charge of water purification plants, first at Mt. Hope and second at Miraflores.

From January, 1916 to March, 1927; that is, up to date, I have been in the continuous employ of the Ohio State Department of Health; first, as Assistant Engineer up to 1920, then as Principal Assistant Engineer up until 1926, and from April, 1926 to date, as Chief Engineer.

During that interval the important duties have been the supervision of water filtration plants for the State of Ohio, the review of plans and recommendations for or against approval of waterworks and sewerage projects, stream pollution studies leading to orders for cor-
8227 rection of nuisance conditions by municipalities and industrial establishments; and active co-operation with the division of communicable diseases in epidemiological studies of typhoid and other water-borne diseases.

In the performance of my official duties, I have direct supervision of the operation of all water purification plants for the State of Ohio. I have exercised control in my official capacity over water purification plants in Ohio for some 11 years; that is, control and supervision of the water treatment plants was begun in 1916 when I entered the employment of the State Department of Health, and this control and supervision was placed upon a state-wide basis covering all plants shortly after the close of the war, or about 1919.

8228 There are about 70 municipal water purification plants under my supervision, serving approximately 50 per cent of the entire population of Ohio. That represents some 70 per cent of the urban population, and the total amounts to about 3,500,000 people.

The surface water sources of supply for these filtration plants are, without exception, contaminated, some of them very badly. For example, the plants along the Ohio River serving the cities along the Ohio River take their supply from a badly polluted stream. The City of East Liverpool, for example, is located 44 miles by

river below the metropolitan district of Pittsburgh, where some several hundred thousands of people reside, and contribute sewage untreated into this river. This plants are required to make official monthly reports to the State Department of Health under my direction.

8229 I absolutely do not agree with Dr. Evans, as stated on pages 3879 and 3880 of the record, as follows:

> "But there are few places, if there are any, that depend upon a filtered water supply that have not experienced breaks in their method of protection, for one reason or another. Literature is full of illustrations of typhoid outbreaks and diarrhoeal outbreaks as the result of breaks in operation, physical or otherwise, of filtration plants."

Properly designed modern water purification plants operated with due regard to the provision of proper personnel may be fully depended upon to produce a water of satisfactory quality. Modern water purification is not experimental or speculative; it is an exact science. Many public water supplies are dependent upon such works;

8230 for instance, we have in our State works installed at Cincinnati and at Columbus, provided in 1907 and 1908, respectively, which have been in continuous service and have produced at all times water of satisfactory quality, meeting at all times the prescribed standards of purity.

During the past 7 years, when the State Department of Health, under my direction, has exercised careful supervision and control of the many water purification plants in that State, there have been no instances of breaks in the operation of such plants, and, there have been no outbreaks of typhoid or water-borne diseases attributable to the public water supplies furnished by these works.

I have had in my official capacity experience in the epidemiological study of typhoid fever cases.

Based upon the studies which have been brought to

my personal attention, therefore, I state that it is not sufficient merely to note the incidence of typhoid fever in any given community, nor to draw conclusions about the quality of the public water supply.

A critical study of all cases in any given community reported with an epidemic is needed before a proper interpretation of the causes of the epidemic may be made.

I have read the testimony of the witness Fuller.

8238 Complete sewage treatment, as the term has been used in this case—and I will confine my remarks to the same definition—is a plant consisting of Imhoff tanks, trickling filters, secondary settling tanks or activated sludge process of sewage treatment, or possibly a combination of the two types of treatment, such that the effluent from these works would have a biochemical oxygen demand of 85 per cent removal or better.

Assuming the complete treatment of all sewage of the Sanitary District of Chicago by the activated sludge process or by Imhoff tanks, trickling filters or final sedimentation, no diversion of water through the Chicago Drainage Canal, and the present location of the water intakes, water purification works could be so constructed that the public health conditions in Chicago, with special reference to the public water supply, would be as well safeguarded, as under present conditions.

8241 Assuming complete treatment of all of the sewage of the Sanitary District of Chicago, according to my definition of complete treatment, no diversion of water through the Chicago Drainage Canal, replacement of the present water intake by a super-tunnel located 4½ miles off shore in the vicinity of Wilmette and 20 miles from the mouth of the Chicago River, with chlorination of the water sup-

8242 ply only, the public health conditions in Chicago, with special reference to the public water supply, would be as well safeguarded as under the conditions now obtaining.

I reason by analogy from the experience which we have had at Cleveland in the treatment of Lake Erie water by chlorination only.

As already stated by the witness, Doctor Rockwood, complete filtration or complete water purification, including filtration, was not practiced at Cleveland until 1925. From 1911 to 1925, therefore, we have had all or a portion of the water supply treated only by chlorine.

8243 From 1918 to 1925 approximately 60 per cent of the Cleveland city water was filtered and chlorinated, but the other 40 per cent was chlorinated only. We have observed the ability of chlorination to treat this water and render it safe for drinking. It is to be borne in mind that the Cleveland intakes are only 4½ miles from the shore and opposite the center of the city, and that the sewage of some 1¼ million people, including suburbs, is discharged into Lake Erie about at the center of the city.

The sewage at Cleveland is only partially treated. We estimate at the present time that there may be less than 10 per cent of the sewage receiving treatment.

8244 Therefore, with the relocation of the Chicago intakes as proposed, chlorination only will be able to meet the situation and produce a safe drinking water.

If in connection with the treatment of the sewage and the relocation of the water intake in the way described in the last question, there is installed water filtration or purification works at this intake off Wilmette, that would improve still further the water supply of Chicago.

Assuming complete treatment of all of the sewage of the Sanitary District according to my definition of com-

8245 plete treatment, no normal or dry weather diversion of water, but with a diversion of all sewage and storm water by reason of proper controlling works, the present location of the water intakes with suitable water purification works for the water supply, the public health condition in

Chicago, with special reference to water supply, would be safeguarded as under the conditions now obtaining.

With the controlling works installed and in operation, not only would storm water be prevented from entering the Lake but any untreated sewage, by reason of the overflow from the sewer system would also be prevented from reaching the lake, and hence the most important pollution factor would be eliminated. The water treatment would, therefore, be more easily controlled.

8246 Assuming complete treatment of all sewage, with no normal or dry weather diversion, but with diversion of all storm water by means of proper controlilng works, relocation of the intake off Wilmette, and the chlorination only of the water supply, the public health conditions in Chicago, with special reference to water supply, would be better safeguarded than by the conditions presently obtaining and for the same reasons.

8247 Assuming the substitution of a large water purification plant instead of chlorination, only, assuming the same conditions otherwise, that would still further improve the water supply and produce an entirely satisfactory and safe water supply.

The water supply of Chicago should be filtered, regardless of the method of sewage disposal, and regardless of the location of the intake. It is most certainly advisable to remove the turbidity which is in evidence in lake waters. People object to the silt from a common decency standpoint. They desire a clean water, and I believe they are entitled to it. It is also to be borne in mind that filtration works constitute an added factor of safety

8247 in the treatment of water. That is, each step in the process is a purification step, and of course if chlorination alone can meet the requirements, coagulation, filtration and chlorination must easily meet the requirements with factors of safety at each step. Chlorination of the

effluent of the sewage treatment plant, if carried to the point as I would see it of disinfection, commonly reported as a residual chlorine in the effluent, the chlorine remaining some time after its application to the effluent, results in a disinfection of the bacteria, but more particularly of the pathogenic variety, which is disease producing. If such organisms are eliminated from the body of the water from which the water supply is taken, most certainly it renders the problem of water treatment easier.

8622 *Cross-Examination by Mr. Adcock.*

8636 When I had entered the employ of the Ohio Department of Health in January, 1916, I reported immediately
8637 to W. H. Dittoe, Chief Engineer. He was my superior until April, 1926, when I took his place.

I have never constructed nor designed any sewage disposal works. One of the duties of the Department of Health is to observe sewage treatment plants under construction, but it is not our function to assist in construc-
8638 tion. I operated a sewage disposal plant in a suburb of Cincinnati previously referred to, while in the employ of Metcalf and Eddy. I supervised the process and the steps to be taken in the conduct of the treatment. I had one laborer under me at the plant, and I directed him in what he was to do. I gave instructions as to the conduct of the several steps in the treatment, such for example, as when to clean the settling tanks, and where to put the sludge from the tanks, and how to conduct the operation.
8639 How to conduct the operation of the trickling filters, as to alternation of the beds, and also secondary tanks, when to clean those tanks, and what to do with the sludge. That was a special study lasting about 3 months.
8643 There are about as many sewage disposal plants in Ohio as water purification plants, say, some seventy.

Not all of these sewage treatment plants are operated

during the entire year. The Marion and Canton works are. At Canton, Imhoff tanks are now in service, and it is expected to place the trickling filters in service very
8647 soon. The works at Canton are not all constructed nor in full operation. Marion is the only large city in Ohio which has complete treatment, and which is operated all
8648 the year.

8655 It is my understanding that all of the dry weather flow of sewage is to be treated at a location such as Chicago, plus a proportion of storm water runoff during early portions of such storms or all of the flow if the storms are small. Referring to what I had in mind in giving my answers, the amount of storm water to be conveyed to the treatment works, would be possibly two to two and a half
8656 times the dry weather flow.

I could not say offhand what Ohio plants treat 200 to 250 per cent of the dry weather flow or whether there were any. I cannot say offhand whether any plant in Ohio at storm time treats more than 150 per cent of the dry weather flow. I do not know of any plant in the country which does. I cannot say whether there is any place in the United States where there is a population of over 50,000 where the sewage effluent is chlorinated for the full 12 months or for 6 months. I think it has
8657 been stated that the Cleveland plants chlorinate for the summer months. The Cleveland plants do not chlorinate
8658 throughout the year. I cannot say the exact number of days.

Joseph W. Ellms, Sanitary and Water Purification Engineer Expert, for Complainants:

8257 *Direct Examination by Mr. Jackson.*

8262 I am familiar with modern methods of sewage treatment and the results obtained therefrom. I am familiar

with the present methods of sewage disposal and water supply protection at Chicago, having made inspections and studied conditions there. There are in my opinion other methods of protecting Chicago's water supply than the present method of diversion, which will be equally
8263 or more effective in providing a safe supply.

The two modern and accepted methods of sewage treatment at the present time consist of Imhoff tanks, and trickling filters, with secondary sedimentation in connection with those filters, and the so-called activated sludge method. Such methods may be practiced at Chicago, and the plants which would care for the large volume of sewage which this city produces could be installed to take care of the sewage even though that sewage should be diverted after treatment directly into the lake. The methods of further protecting the water supply since it is drawn from the lake, would be filtration, disinfection with chlorine, either one or both depending upon the location of the intakes. These methods are
8264 well known and standardized, and fairly present some problems which require more or less research. Nevertheless, they offer practicable methods for protecting public water supplies and disposal of sewage.

Referring to the estimate of defendants' witness Fuller, that the cost of a water purification and filtration plant for Chicago, with a capacity of 1,000 million gallons daily, would be $53,500,000, I have made an estimate of cost for such plant. Depending upon the elaborateness with which such a plant might be constructed, more particularly with reference to the design and cost of building, I would say that the reasonable cost would be anywhere from $35,000,000 to $40,000,000. I would say
8265 that a unit price per m.g.d. capacity is a reliable basis of estimate, for the reason that it is based on actual cost of construction, and, therefore, it is not subject to any assumptions with respect to price of material.

I have studied the testimony of Witness Evans and Witness Fuller with respect to the dependability of water purification devices. I believe that water purification works are a reliable protection for public water supplies.

Since 1907 I have been in constant touch with or had actual supervision over two large filter plants, and have been consulted with respect to the operation of other plants. I know that in connection with the plant at Cincinnati we had a water which was polluted, and which required the proper operation of the plant, and that with that operation we did succeed in producing a potable water, a safe water from every standpoint. The same is true of the two Cleveland plants with which I am at present connected, and these two plants are also able to produce a safe, potable water, even though the supply contains more or less pollution from sewage.

8267 In my general experience I have not know that plants have broken down where properly operated by sufficient men and technical talent that understood the process involved. I was in charge of the Cleveland water purification plant in October, 1925, the time at which the witness Fuller stated that it experienced a break down. On account of foundation difficulties, with which this Division Avenue plant has had to contend ever since it was constructed, certain remedial measures have had to be taken, among them being a line of steel sheet piling, surrounding the north and part of the ends of the east and west sides of this plant. In order to make that piling complete, that is, to make it water tight, to have no break in it, it was necessary on the 13th of

8268 October to shut the plant down, because the piling crossed two effluent pipes, 60 inches each in diameter, and these pipes had to be cut. In consequence, the plant could not be operated, and we were obliged to take the raw water from the adjoining pumping station and dis-

infect it with chlorine. The bacterial content of that water is the figure which has been cited by the witness, Mr. Fuller, as evidence of the breakdown. It was not a breakdown, because the plant was not in operation. The water which Mr. Fuller cited as evidence of improper operation of the filtration, had not passed through the plant at all. The shut down was not occasioned because of any imperfection in the plant or its operation.

Assuming the complete treatment of all of the sewage of the Sanitary District of Chicago, by the activated sludge process, or by Imhoff tanks, trickling filters and
8269 final sedimentation, no diversion of water through the Chicago Drainage Canal, and the present location of the water intakes, water purification works could be so constructed that the public health conditions in Chicago, with special reference to the public water supply, would be as well safeguarded, as under present conditions.

Assuming a complete treatment of all of the sewage of the Sanitary District of Chicago as heretofore defined, no diversion of water through the Chicago Drainage Canal, the replacement of the present water intakes by a super-tunnel located 4½ miles off shore in the vicinity of Wilmette and 20 miles from the mouth of the Chicago
8271 River, with chlorination only of the water supply, the public health conditions in the City of Chicago, with special reference to the public water supply, would be as well safeguarded as under present conditions.

My opinion is based upon the fact that the intakes would be removed a considerable distance away from the point of discharge at the mouth of the Chicago River for the treated sewage of the city; that it would be located a distance of some 4½ miles off the shore of Wilmette, and that the chlorination of the purer water would be an added safeguard to its quality when distributed to the citizens of Chicago.

Assuming the same conditions and that there was substituted the construction of a modern water purification plant at the proposed Wilmette intake in lieu of chlorination of the water supply, that would further improve the water supply of Chicago.

8272 Assuming complete treatment of all of the sewage of the Sanitary District of Chicago, with no normal diversion of water from Lake Michigan, but with the diversion of all sewage and storm waters by means of proper control works, the present location of the water intakes, with suitable water purification works for the water supply, the public health conditions in the City of Chicago, with special reference to the public water supply, would be safeguarded as well as under present conditions.

They would be better safeguarded. The water which escapes at times of storm into the Lake would be prevented and the water of the Lake would in consequence remain in a purer condition than it would if such overflows escaped into the Lake, and the purification of the supply would be very much easier because the load would be considerably less than it would be even supposing that such overflows should reach an intake located 20 miles away from the mouth of the River. If the water

8273 supply were given only treatment by chlorination, the supply would be as good as at present. With purification works, the supply would be improved over the present.

8274 In my opinion the water supply of Chicago should be filtered without regard to the method of sewage disposal. The water at times is not clear and contains more or less suspended matter. Without filtration larger quantities of chlorine are necessary for disinfection purposes, but, with filtration less quantities would be required, and hence complaints of excess treatment would be largely eliminated. For aesthetic reasons alone, the water would be greatly improved.

In connection with the foregoing opinion, chlorination or sterilization of the effluents of the sewage treatment plants would be a further protection to the water supply, because they would very largely eliminate the pathogenic organisms which are always probably present in sewage.

At the time of the shut down of the Cleveland filtration plant, there was a plant that was started, known as the Baldwin filtration plant, on the 15th of September, or a month previous to the shut down; but until the 20th
8275 of October, the water which was supplied in that section of the city was a mixture of filtered water and disinfected raw water, but after the Division Avenue plant was again placed in operation on the 24th of October the entire city was supplied with filtered water.

The two periods happened to overlap, but this was done for the express purpose of providing as much filtered water as it was possible to provide during this period when we were obliged to shut down the Division Avenue plant. Up to the time of the reopening of the Division Avenue plant, the proportion of filtered water was about the same because of the opening of the Baldwin Plant just at the time of the closing of the Division Avenue Plant.

8396 *Cross-Examination by Mr. Adcock.*

8397 I have official title in Cleveland of Engineer of Water Purification and Sewage disposal.

8423 The shut-down of the Division Avenue Plant in October, 1925, was due to a structural difficulty. It was shut
8424 down 10 days. The Baldwin Avenue Plant was in operation during that period and had been since the 15th of the preceding month. It only filtered part of the water supply. While the Division Avenue Plant was shut down the only barrier against infection was chlorination.

8425 During the month of October the average number of

B. coli delivered in the disinfected water to the mains was 15 per 100 c.c. The Treasury Standard is 1 per 100 c.c. During the 10 days the average B. coli was 37 per 100. That would not be a satisfactory water supply, according to those standards. The Treasury Standard is accepted for water purification. It is established for the purpose of endeavoring to produce water which will at all times be sanitarily safe.

As to how I reach the conclusion that this was not a breakdown of the Division Avenue Plant, if you stop a plant it does not necessarily mean that it was broken down.

8427 It was broken down in the respect that you could not operate it and it had to be repaired; but that was on account of structural difficulty, not on account of the process.

There might be in most any plant some structural difficulty that would require it to be shut down. Of course, that is possible in any mechanical device, no matter what it is.

It is true that it would be better to have something that would operate automatically, if it is possible to find it.

8429 Cleveland has no opportunity to divert its sewage. All of its sewage goes into its water supply. The water supply has been very seriously polluted at times. We have been extending our cribs out all the time, the purpose being to get away from the pollution that was directly discharged into the Lake. If we had 3,300,000 people at Cleveland we might have to extend the cribs still farther or to remove them to some point not opposite the thickly populated center. Those waters are always liable to pol-
8430 lution in the vicinity of densely populated areas.

I understand the Hazen Theorem to be the probability that for every death from typhoid fever prevented prob-

ably 2 or 3 other deaths may also be prevented on
8432 account of general improvement of the quality of the water supply. I do not remember whether it is 3 or 4 instead of 2 or 3. For every death from typhoid fever I would expect there had been 10 cases. There are carriers of typhoid produced after infection. I
8433 always presumed they were carriers because they had had the disease. The typhoid rate in Chicago was less than 2 or something like. I do not remember whether it was less than 1.

A suitable standard of B. coli index for bathing beaches would be the standard which is set up for swimming pools, which is practically equivalent to the drinking water supply of the city in which they may be located.

8441 I made a survey of the bathing beaches in Cleveland in 1920 and found the B. coli index 6 miles from shore in 40 feet of water was 1,000 per 100 c.c. on certain lines. That was beyond our intakes about a mile and a half. We have not been able to meet the Treasury Standard at Cleveland without chlorination because we have not used a sufficient quantity of coagulant on account of cost, and we depended very largely on chlorine which we added afterwards to bring the bacteria down. By filtering and chlorinating we have come very close to the Treasury Standard. In 1925 it was 1.3 on an average, including
8442 the month when we were only chlorinating the water, but since 1926 I think the figure was below 1; that is, during the year in which all the water was filtered.

In the examination of the bathing beaches in 1924 the B. coli index was found to vary all the way from 12,300 to 81,100 per 100 c.c.

8443 I do not regard the water at the bathing beaches east and west of the Cuyahoga River as satisfactory for bathing. There was evidence of fecal deposits there after storms due to the limited amount of treatment which the sewage of Cleveland receives at the present time.

8445 I would say we could practically filter water containing 386,000 B. coli per 100 c.c. I think it has been done. It would be a pretty good performance. It seems to be done at times in the Ohio River. I have not the data here.

The United States Public Health Standard 6,500 B. coli per 100 c. c. representing the most that should be found in water in order to treat it by filters is a tentative figure for certain processes, chiefly single stage coagulation and sedimentation and filtration, which has been successfully
8446 handled and produces a water of less than 1 B. coli per 100 c.c. Those studies were not completed and the figures are regarded only in a sense as tentative.

Referring to the report entitled "Fifth Annual Report of Ohio Conference on Water Purification, Akron, October 15, 1925," pages 79 and 80, those are the figures that I had in mind for the average yearly result of operation at Ironton. The average yearly B. coli per 100 c.c. in raw water at Ironton in 1924 was 16,700. This does not represent maximums, and I believe since this period even larger quantities of B. coli have been successfully
8447 handled. Ironton may be a place of 10,000 people possibly.

Whether the tentative figure of 6,500 B. coli per 100 c.c. could be increased 50 or 60 times and still have satisfactory results in a filter plant, I only know that it seems to be done with certain combinations of processes. It has been done, so there is no guess-work about it.

However, I do not know that it has gone as high as that figure, but it seems to me it has gone as high as 100,000, and I am not so sure but that it may have gone as high as 325,000. That would probably be the maximum load.
8448 In connection with purification plants, we are apprehensive of sudden loads, just like on any machine. It is pos-
8449 sible for the load to run away up suddenly. In such case

if the factors of safety are sufficient the water that is turned out still continues to be satisfactory. In speaking of factors of safety, I refer to sufficient coagulating chemicals, sufficient previous disinfection, and sufficient excess lime in order to prevent bacterial growth, and chlorination.

In the usual method of chlorinating water the chlorine gas is withdrawn through special apparatus and dissolved and passed in to the water to be treated in solu-
8450 tion form. The efficiency of the chlorination depends upon the machine and upon the vigilance with which the operator looks after it. Whether I would require a greater factor of safety in connection with the filtration of lake waters than in connection with a river like the Ohio, would depend entirely upon the bacterial load which it was necessary to remove, the extent of the pollution of the water being treated, and also the evenness of the load.

Whether I would expect the load to be as even in lake
8451 water as I would in river water, I think variations can occur in both places, as far as that is concerned, and be very sudden and indeterminate. In the case of lake water such sudden changes are caused by storms and wind, and by sufficient current induced by wind movement over the surface of the water, meteorological conditions, barometric changes, etc.

You might have 5,000 or 6,000 B. coli per c.c. in the effluent of a trickling filter or activated sludge plant.
8452 The B. coli in sewage run about 120,000 per c.c. with a total bacterial count of 2,000,000 or over, so that if 95 per cent of the bacteria were removed we would expect to have about 6,000 left in the effluent. I have never made a test to determine the count in the effluent of the trickling filter or activated sludge plants. I am just
8453 assuming that there might be 95 per cent purification.

I do not think anybody knows how many different kinds of bacteria are found in sewage. Identification of organisms of that kind is not generally undertaken.

Taking this situation at Chicago, putting this effluent into the lake, supposing all the sewage were purified by trickling filters or activated sludge, and then depending upon chlorination of the water supply alone,—I do not know that I would recommend it. I think it can be done, though.

8454 All this effluent could be put into the water supply and then chlorination might be made a sufficient barrier.

8455 I believe that 100 per cent elimination of pathogenic organisms from sewage effluent could be accomplished if you used a sufficient amount of chlorine. That has never been done. I cannot say what we have accomplished at Cleveland in the removal of bacteria. We cannot determine the pathogenic organisms or elimination of B. coli. We reduced them from 186,000 per c.c. to about 6,000 per c.c.

8456 Of course, this is a plant which has nothing but screens —no trickling filters or activated sludge process. It has no settling tanks. At the plant where we have the Im-
8457 hoff tanks we reduced the B. coli from 128,000 to 34,000. That was with greater treatment than at the other plant. The percentage of reduction was about 69 per cent. During that year we used 72.1 pounds of chlorine for each million gallons. I do not remember how much chlorine we used in 1924, but it has always been around 75 or 80 pounds, as I remember.

8458 I never have made any experiments to determine whether all the pathogenic organisms could be eliminated by chlorination, nor do I know of any place where it has been done. I think I have seen the reports of March, 1926, of the Municipal Research Bureau of Cleveland on

the correlation of water purification and sewage disposal in Cleveland. I furnished some data in connection with it and I know Mr. Layton E. Carter.

I do not agree with their interpretation of the data.

I agree with the statement in that report that Cleveland is heading toward a crisis with respect to the pollution of the Lake and must take immediate steps to complete sewage treatment.

That is my own statement. I do not know when it
8460 was made, some time within the last 2 years, probably.

Page 27 of the same report is generally true, to the effect that only a part of the general pollution of Lake Erie can be controlled; that if sewage is given the most refined treatment pollution would still be extensive; that surface wash contributes a considerable part of the pollution for which there is no known treatment; that treatment of storm overflow would be very expensive; that this source is an appreciable part of the general pollution, but is objectionable primarily because of nuisance and that it may be desirable to ultimately remove the solids, even though the cost is seemingly prohibitive.

8461 Page 28 of the same report presents a good picture of the conditions regarding the Cuyahoga River to the effect that it is at all times heavily charged with sewage and the spread of its discolored waters has been plainly observed well beyond the water intakes, that it has been observed that the occurrence of phenolic tastes due to wastes brought down by the river is simultaneous with heavy bacterial contamination; that the sources of pollution are not important because of the numbers of bacteria which are discharged, but on account of their
8452 relation with contamination of the intakes which is dependent on current and distances (dilution); that lake currents are changeable from day to day; that there is no settled general current eastward; that movements

of the water are almost entirely dependent on the topography of the lake bottom, the river current and the winds, the last of which are the most essential; that the location of intakes and beaches with reference to sewer outfalls is less significant than might at first be supposed; that there is no evidence of the relative importance of sources of pollution with respect to their effect on intakes, except that it is certain that the river does pollute at times; and that the reported reduction
8463 of 85 per cent of the bacteria in the lake outfall discharges by chlorination during the bathing season did not have an apparent effect on the water intakes.

I agree with page 30 of the same report that neither of the lake front plants materially reduces the number of bacteria in the sewage, but, inasmuch as the westerly plant is at capacity and the easterly has nearly approached capacity, it is apparent that general pollution will not be appreciably increased by outfall discharge if the southerly plant is constructed to provide for expansion of the easterly and westerly districts; that if a new water intake is installed opposite East 185th Street, as now planned, the influence of the easterly plant will be much more serious than at present, and treatment of the discharge will become necessary, and that the lake front outfalls by reason of their position and amounts and condition of sewage are obvious sources of nuisance.

8465 I agree with page 31 of the same report, that it is questionable if the greatest care in sewage treatment and control of surface drainage would ever restore the water along the bathing beaches to the bacterial purity usually exacted in closed pools.

I agree with the statements in a paper entitled, "Foul Tastes in Cleveland Water Again Caused by Phenol. Wind and Ice Carry by-Product Coke-Oven Wastes to

Intake and Chloro-Phenolic Compounds Cause Bad Taste in Water," appearing on page 453 of the Engineering News Record of March 13, 1924, written by me, that coincident with the appearance of the foul taste in the water supply bacterial samples showed a tremendous increase in the number of bacteria present in intake waters; that samples from both intakes for a week or 10 days had shown less than 100 bacteria per c.c.; with usually less than 50 and practically no evidence of B. coli in 10 c.c.; that on March 3, however, the number of bacteria increased to 10,000 or 20,000 per c.c. with B. coli present in .1 c.c.; and that these figures plainly indicate the direct nature of the pollution and also show its dangerous character.

I agree with page 31 of the Municipal Research Bureau Report that a canvass of those with experience of lake front conditions discloses that deposits of feces and other objectionable animal and vegetable waste are common on the beach, especially after storms; that similar matter may usually be observed floating and decomposing in the water, together with finer suspended material, causing unpleasant odors; that oil and grease in sufficient quantities to befoul the beaches are also reported; that observations indicated that the discharge of storm water from the interceptor system is most responsible for the coarse material deposited, and that it is probably true that treatment of sewage would not eliminate the oil nuisance, but it would put the city in a much better position to discover and control the sources of such wastes.

The phenol taste arises from the wastes discharged from by-product coke-ovens on the Cuyahoga River which are discharged into Lake Erie, and coming in contact with the chlorine we use for disinfecting produces a compound of objectionable taste. Taste arises in connection

with the use of chlorine when there is a sufficient quantity of the wastes in the water. Gas works are one source of such waste.

I wrote a paper which appeared in the Canadian Engineer on April 30, 1926, entitled "Pollution of Boundary Waters, Problems of Cities on Great Lakes Discussed in Paper Read at Meeting of Central States Section, A. W. W. A." and I now subscribe to the statement that it was found that at the mouth of the Detroit and Niagara Rivers serious pollution extended normally more than 10 miles into the lakes, and sometimes was found 16 to 18 miles from the shore, and at Cleveland contaminated water may be found at times as far out as 8 miles; that the high natural purity of the Great Lakes is, therefore,
8468 to a great extent of merely academic interest, so far
8469 as a source of water supply is concerned, particularly in the neighborhood of large cities; that the high cost of intakes and long tunnels and the engineering difficulties involved in constructing such works in water over 70 feet in depth forced the conclusion that effluent purification is usually necessary for the maintenance of a safe water supply, and that further means for diminishing the load on water purification processes must in many cases also be taken; that far too little has been done towards diminishing pollution of the waters of the Lake by more complete purification of sewage; that there is no question that the natural sources of dilution should be availed of, but that it should also be realized that there must be a limit to the ability of purification processes to make safe from a sanitary standpoint waters which have once been contaminated; that cities on the Great Lakes are in a peculiar position regarding water supply and sewage disposal; that they are all fouling their own nests, and that whether they realize it or not the problems of a safe water supply and the proper and adequate treatment

of their sewage are so intimately related that one cannot be solved without solving the other.

In other words, all these lake cities are sending their own sewage into their water supply except Chicago. I presume you might say, as counsel suggests, that they are stewing in their own gravy.

8471 I wrote a work entitled "Water Purification" and page 32 of said work states that the pollution of the Great Lakes is to a large extent local, but since these communities draw their water supply from the same source the problem of preventing the contamination is a troublesome one; that the common remedy of extending intakes has been resorted to with fair success and with marked decreases in the typhoid rate; that the City of Chicago has diverted a large part of its sewage, thus keeping a constantly increasing volume of sewage from polluting the lake water farther and farther from the shore; that other large cities are contemplating partial purification of sewage, and that the effect of wind on these large bodies of water is causing currents; that the influence which the shore lines may have on these currents and the movement of ice polluted with sewage from the shores out into the lakes in the spring months are all factors which may at times be the cause of waterborne epidemics.

I did not know that I had stated it as well as I had.

The pollution affects the use of water for recreational purposes and for bathing and it affects fish life and recreational boating, to some extent. It depends, of course,

8473 upon the degree of pollution of the shore waters, but it certainly would become more or less objectionable, I imagine; that is, if very large volumes of untreated sewage are turned directly into the Lake. The floating solids are the things most objectionable from the point of view of boating and bathing. It is true that a person in a launch or sail-boat or row-boat is liable to become infected.

8474 The paper which appeared in the Canadian Engineer contains the following statement, with which I agree, to the effect that in 1911 the U. S. Public Health Service completed a survey of the Great Lakes on the United States side, finding that in certain localities there was dangerous sewage pollution, but the bulk of the water remains in its pristine purity; that the colon bacillus is practically never present in the unpolluted waters, and that the normal bacterial content is less than 10 per c. c.;
8475 that the dangerous contamination of the lake waters arises from the discharge of sewage from towns and cities located on the shore, and from vessels and from surface wash, and that the distance which polluted water may travel depends upon volume, natural currents induced by flow and the currents induced by wind action;
8476 that the zones of pollution opposite Cleveland have increased in area between 1904 and 1924 and contaminated water has forced its way farther out into the Lake; that the natural advantages of these waters as a source of pure supply and for recreational purposes have not been properly appreciated; that the natural clarity of the waters leads to a belief that they must be necessarily pure and fit for consumption, and that this idea has been gradually changed during the past fifteen years as a result of the overwhelming evidence obtained in cities located on the shores whose inhabitants have suffered from typhoid epidemics and other intenstinal diseases; that
8477 lake water is the only source of supply for cities on the Great Lakes and the only place for the ultimate disposal of the liquid portion of the sewage, giving rise to the question how far we can safely go in disposing of sewage without treatment before the water is so badly contaminated that purification processes become overloaded, and the further question whether it is a proper policy to encroach too closely upon the barriers set up by filtration

and disinfection; that the economics of water purification versus sewage treatment needs serious consideration in each case; that we should not question costs where life and death are at stake; that so long as we huddle together in large cities we must pay the penalty of concentration; that it is necessary to look forward and provide in our engineering structures for concentration of population;
8478 and that the public will continue to demand more effective measures for the disposal of sewage and trade wastes, not only for reasons of health but of ordinary decency.

The size of the city has something to do with the question of providing a water supply.

8486 I made a report with reference to the Milwaukee filter and recommended filtration in 1920. My reason for recommending filtration was to safeguard the water supply
8487 against sewage pollution. They were then building an activated sludge sewage disposal plant considered to be one of the modern plants of the country. In 1920 it had just begun, that is, the construction. They had been carrying on experiments for quite a long time, and they had been preparing plans in connection with it. They began operations some time in 1926. All the sewage of
8488 Milwaukee and the area which it serves is passing through the plant. I do not know to what extent the sewage is receiving complete treatment, though I believe it is about one-third, including the processing of the sludge. I presume the remainder passes into the Lake. It was designed for the treatment of all the sewage. The plant was designed by T. Chalkley Hatton who has gained considerable reputation as an engineer in that
8489 line. He has elaborated the activated sludge method considerably further than some other engineers, though there are other plants in the United States. I understand the reason that they do not operate the plant so as to

take care of all the sewage is because they cannot process the sludge. So that so far as present operation is concerned, the plant is really effective to only one-third of what it was intended to be.

Milwaukee water at the intakes contains, as a rule, very little suspended material. I do not know whether or not it is less turbid than in Chicago, but I imagine
8490 it may be. It averages less turbidity than Cleveland by
8491 10 or 12 parts per million. I recommended filtration at Milwaukee because of the sewage that might pass into the lake at any time. I believe there are portions of the sewage plant designed and constructed to handle considerably more than the average flow for partial treatment. Just to what extent I am unable to say. My recommendation was because of the liability of the water supply becoming polluted, even after the treatment plants were put
8492 in. The filtration plant has not been built. The city depends solely on chlorination. The intake is about a mile and a half from shore. It may be 6 miles from the mouth of the Milwaukee River. I do not remember exactly. I do not know that I would be surprised to hear that within the last two weeks notices have been issued by Milwaukee authorities that people should boil water before using it. This is not surprising if they are only taking care of a portion of their sewage through the plant.

8493 In making my report I expected the plant to be completed and to operate to the full extent for which it was designed. I do not have the figures as to the quality of tap water in Chicago.

8498 I cannot say what the pumpage capacity in Cleveland was in 1915. Cleveland has been metering practically 98 or 99 per cent ever since 1908.

8499 My recollection is that the lowest pumpage per capita since metering has fallen below 100 gallons per capita

per day. The present consumption per capita is, I think, in the neighborhood of 150 gallons. It might be more accurate to say 162 gallons per day for 1925.

Redirect Examination by Mr. Jackson

8503 As to the problem of phenol wastes at Cleveland the waste from the coke-oven plant has been impounded; that is to say, it is accumulated constantly and used for cooling the water in order that it may not pass into the Cuyahoga River, and within the last year that has been successfully accomplished and the difficulty from phenol waste in the water supply has been virtually eliminated. There has been no offensive taste recently.

8504 The excess of the B. coli content over the Treasury Standard in 1925 was because of the fact that disinfected raw water was supplied during the 10 days mentioned in the testimony, and when that was included in the yearly average the B. coli content of the water ran slightly above the standard. Considering only the part of the supply treated by the purification plant, it was way below the Treasury Standard in 1925, in the sense that it had a smaller B. coli content than required by the standard.

Since October, 1925, there has been 100 per cent filtration at Cleveland. The average B. coli content for 1926

8505 at the Division Avenue Plant was .3 and for the Baldwin Plant .23, which is that fraction of one better than the Treasury Standard. This included chlorination. That is the water supply that was delivered to the city system.

Referring to the papers that I have written, it is my opinion that all sewage should be completely treated before it is turned into lakes and streams.

L. R. Howson, Sanitary Engineering Expert, for Complainants. March, 1927:

Direct Examination by Mr. Jackson.

8932 With no diversion, works could be installed for the complete disposal or treatment of the sewage—the effluent from those plants might be further chlorinated, the water supply might be filtered through plants in connection with the present intakes; the water supply might be changed by building a large tunnel extending out into the lake north of the city some 20 miles from the river's mouth. The other works that might be installed would be controlling works either in the channel out at the river's mouth or above. The water supply should be metered in order to reduce the quantities and make the prob-
8933 lem of taking care of the water supply and sewage disposal less costly. These, either individually or in combination might be adopted. All of them would not be required.

By complete treatment for the disposal of the sewage I mean settling tanks, sprinkling filters, and secondary sedimentation as one type, and activated sludge as another type.

The efficiency in the removal of bacteria practical to secure through chlorination of the effluent in sewage-disposal plants of modern types, approaches 100 per cent.
8945 Assuming the completion of the sewage treatment program outlined and the diversion of 1,000 c. f. s. through the Chicago Drainage Canal, the conditions on the Illinois and the Des Plaines Rivers would be very much better than those which have obtained in the past. So far as the prevention of nuisance in the Illinois River is concerned, the effluent from these plants could be discharged into the river without dilution and without subsequent nuisance.

Assuming complete treatment of the sewage in the Sanitary District of Chicago, either by the activated sludge process or Imhoff tanks, trickling filters and sedimentation, with occasional dilution due to storm water overflows, the aquatic growths would not be promoted to such extent in the Des Plaines and Illinois River as to create a nuisance.

The addition of dilution water would have no appreciable effect in improving conditions in this respect.

The reasonable cost of a water supply purification plant for Chicago, based upon an assumption of complete
8947 metering would be $30,000,000.

Assuming a super-tunnel as outlined by the witness Fuller were built in the vicinity of Wilmette, 4½ miles off shore, approximately 20 miles from the mouth of the Chicago River, for the purpose of replacing of the present water intakes of Chicago, such a tunnel to be
8948 approximately equivalent to the present water intakes of the City of Chicago, should start at the crib with a diameter of 27 feet, and it would maintain that diameter from the crib to the point of the first connection with the pumping station; that is, the Lake View and the Mayfair stations. It would decrease in size there and progressively decrease with each additional station served until at its terminus it would be 15 feet in diameter.

The reasonable cost of the construction of such a tunnel would be $40,000,000, and assuming funds to be available, a reasonable time for the construction would be
8949 from 5 to 8 years.

The water level between the proposed regulating or control works at the northern terminus of the Drainage Canal and Lockport, would be maintained at about 7 feet or more below the water level lakeward of the proposed controlling works.

8954 It would be possible to construct a separate sewer

system in Chicago, and I have estimated the cost of that to be approximately $130,000,000 to $150,000,000. Assum-
8955 ing funds to be available, the time required for such construction would be somewhere between 10 years and 20 years.

Counsel read from Exhibit 1061, page 2566, the recommendation of Mr. Rudolph Hering, as follows:

> "It is practicable, however, to exclude the storm water from the sewers over a large portion of the future city by adopting a separate system of sewers. The area north of the town of Jefferson, and of the middle of Lake View may be treated to advantage in this way, and also a large portion of Hyde Park, Lake Calumet, and other adjoining towns."

8956 There is a present necessity for a reconstruction of the sewer system in downtown Chicago. The sewer system there is very badly overloaded, and is operating to-day practically with only the capacity required for sanitary sewage. During storms the water pools on the
8957 streets, and backs up into the basements that are not protected by backflow devices.

Assuming complete treatment of all of the sewage of the Sanitary District of Chicago by the installation of sewage disposal works as heretofore described by me, no diversion of water through the Drainage Canal, the present location of the water intakes and the installation of water purification plants, the public health conditions in Chicago, with special reference to the public water supply, would be as good as those which presently obtain.

Assuming complete treatment of all of the sewage of the Sanitary District of Chicago, no diversion of water through the Chicago Drainage Canal, the replacement of the present water intakes, by a super-tunnel located 4½ miles off shore, in the vicinity of Wilmette, and 20 miles from the mouth of the Chicago River, with chlorination

of water supply only, the public health conditions in Chicago, with special reference to public water supply, would be as good as those now obtained.

8958 The installation of a complete water purification plant, in addition to the relocation of the intake off Wilmette, would make the water supply very much better than at present.

Assuming complete treatment of all of the sewage of the Sanitary District of Chicago with no normal diversion of water from Lake Michigan, and by that I mean no diversion except at times of storm, but with diversion of all the sewage and storm water overflows, by means of controlling works located near Western Avenue, the present location of the water intakes with filtration and chlorination of the water supply the public health conditions in the City of Chicago, with special reference to water supply, would be safeguarded as well as under present conditions.

Assuming complete treatment of all of the sewage of the Sanitary District, no normal or dry weather diver-

8959 sion, but diversion of storm water overflow through the controlling works proposed near Western Avenue, replacement of the present water intakes by a super-tunnel located 4½ miles off-shore, in the vicinity of Wilmette, and 20 miles from the mouth of the Chicago River, with chlorination only of the water supply, the public health conditions of Chicago, with special reference to the public water supply, would be better than those presently obtaining.

The installation of filtration or purification works would improve the quality of the water supply. In the three preceding questions the addition of controlling works at the mouth of the Chicago River for use in time of storm would be a further safeguard. In all these questions involving no diversion or diversion of storm

water only, if the effluent from the sewage disposal plants were chlorinated, this would still further safeguard the
8960 water supply.

8965 On page 8, of Exhibit 202 the table shows that under the present metering plan there will be an excess of expenditure over income of $67,000,000. If, however, universal metering is adopted, there would be a surplus of revenue of $131,000,000, making the difference accomplished by metering between 1925 and 1960, $198,000,000. That outlay was only for operation; that is, cost of pumping, labor, fuel, etc., repairs and renewals, additions and
8966 extensions, over a period of 35 years.

I made a very detailed study of the saving in consumption of water to be derived from universal metering some 10 years ago, and at that time came to the conclusion that the water consumption could be reduced from 275 gallons per capita to 125. The biggest part of this saving is in the dwellings and flat buildings. Prior to the universal metering, about 9½ per cent of Chicago's service was metered. That included all manufacturers and large consumers, but did not include the small consumers, except those who specifically requested it, or who had lived in a suburb which had meters before it was
8967 taken over by Chicago.

The saving is all with respect to what is wasted; it does not mean any curtailment in convenience.

Complainants' Exhibit 204 is a true copy of a report
8975 on universal metering for Chicago by Maury & Gordon.

Beginning on page 3 of Exhibit 204, certain conclusions are stated in substance as follows:

Chicago pumps more water than any other city in the world.

The average daily pumpage in 1924 was 840,000,000 gallons, equivalent to 280 gallons per day for every man, woman and child in the city. The amount pumped per

8976 capita is constantly increasing. Unless meters are installed it will exceed 300 gallons per day within 10 years, and will continue to increase thereafter.

Two-thirds of this enormous pumpage is waste, caused either by the reckless use of the water by consumers or by unchecked leakage in their plumbing fixtures. At least one-half of the total pumpage can be saved by the installation of meters, and in no other way.

8977 Meters stop waste, but they never restrict the use of water to the detriment of health. After the city has been metered, and filters have been installed, consumers will have plenty of water of first class quality on the third and fourth floors of buildings, and the fire protection of the city will be greatly improved.

8982 Assuming intakes replaced by a super-tunnel, the total expenditure for water purification plants, intake relocation, up to 1945 or 1955, would be $70,000,000, which includes $30,000,000 for the plant, and $40,000,000 for the tunnel. The total expenditures for both Chicago and the Sanitary District according to my estimates, would be $152,000,000.

8994 *Cross-Examination by Mr. Adcock.*

I got my degree of civil engineer in 1912, as the result of writing a thesis. I did not attend the institution after 8995 1908.

Interceptors for cities of 100,000 inhabitants are about the largest size that I have laid out. The population of Lincoln in 1920 was 65,989. Gary, Indiana, is now approximately 100,000. We made a preliminary layout for Gary. I cannot say what was the size of the interceptors there. What we did was to pick up the intercepting sewers. We built one 8-foot sewer in 1908 and 1912, and we picked that up and pumped up by cast iron force

main, which, I think, was 36 inches, and picked up a couple of additional sewers and pumped them the same way.

9038 The report was made about 3 years ago. According to my recollection we designed the interceptor on the first installation to be about 36 inches.

9117 I had a great many conversations with Major Putnam, District Engineer at Chicago, before we were employed and some subsequently, with reference to our employment and making report to the War Department (Special Master's Exhibit B), but I had no conversations with Major Putnam with direct reference to the Chicago permit of March 3, 1925.

9118 On some items we probably gave Major Putnam some information prior to March 3, 1925, such as the effect of metering upon waste water. I think that had been discussed. We were at that time about in the middle of our report. So we had reached no conclusions. We did not discuss with Major Putnam the question of standard of water or what conditions we wished to be produced by the operation of the disposal plant in the Des Plaines and Illinois Rivers. The definition of the pollution standard and what it was to accomplish was given to us as part of our employment. We had no part in stating that stipulation.

9402 I believe it is a well-known fact that where meters are introduced into a city and the waste is cut, there is subsequently a gradual rising tendency in the consumption.

I am referred to page 63 of a report entitled "The Commonwealth of Massachusetts—Report of Joint Board Relative to Water Supply Needs and Resources," dated January, 1922, by Mr. Goodnough, in substance as follows:

The general use of meters has caused at first a great reduction in the consumption of water per capita, but in Cleveland and Milwaukee, since the bulk of the services

were metered, the consumption has again rapidly increased, notwithstanding the fact that the percentage of
9403 metered services has increased until practically all of the services are metered. In Detroit and Cincinnati the experience has been too short to enable safe conclusions, one having shown an increase since complete metering, and the other a decrease in a period of one or two years. In the case of Newark, where the records are limited, the full effect of meters appears to have been obtained when the percentage of metered services amounted to from 55 to 60 per cent. Since that time the increase of metered services to over 90 per cent has been accompanied by an increase in the per capita use of water.

9404 I disagree with it in respect to Newark. I disagree with it with respect to Detroit and Cincinnati. It is correct in respect to Cleveland and Milwaukee. That is according to my information, which is some three years more recent than the article. I have the tabulation of data on universal metering in all cities of over 100,000 population, from a compilation made by the Chicago city
9405 engineer. I did not furnish the data to the city engineer. I have checked it on a few cities.

9448 At the end of 1925 there were in Chicago 2,871 miles of sewer in the combined system, of which 72 per cent were pipe sewers and 28 per cent were brick sewers.

I investigated the costs of those sewers per mile and in total expenditure for the past 15 years, and I found the portion of sewers which had been built in each of the past 15 years.

First, this estimated cost of a sanitary sewer system, will, of course, involve smaller sizes than a storm water sewer system or a combined sewer system; but I assumed that for all sewers built since 1918, which is about one-seventh of the total mileage, sanitary sewers could be built today for the same price that combined sewers of

three or four times the capacity were built at that time. That mileage of sewers under that condition costs $12,000,000.

For sewers built between the period 1909 to 1919, during which period they spent approximately $10,000,000, I doubled the cost of the combined sewers for the separate sewers and added 50 per cent for additional interference—another $25,000,000.

I then took all sewers except those in the Loop which were built prior to 1910, some 63 or 64 per cent of the total. I doubled for the sanitary sewers the cost of the combined sewers and multiplied this by a factor of 2 for price levels, and it comes to $118,000,000.

9449 Then the Loop sewers which include about 67,000 feet of sewer, were estimated at $3,000,000, a total of $158,000,000.

I then took a second basis in which I made a very tentative layout of a sewer system of separate sewers, estimated the mileage of the various sizes, studied the contracts let by the City of Chicago for sewers of those sizes in the last couple of years, found the cost per foot of those sewers and added in some 72,000 manholes and came to the conclusion that a sanitary sewer system would cost to date, exclusive of interference with paving and other construction, $52,000,000, an average of $17,300 per mile.

Chicago now has 2,474 miles of paving, practically as much paving as its sewer system, although a lot of this paving is in alleys. I added for the paving, assuming we would have to cut through 634 miles of macadam, 333 miles of asphalt, 507 miles of brick blocks, and estimated that paving at prices which amounted to an additional $12,810,000.

9450 Then I made a separate allowance for the item of obstructions. One-third of this mileage, or approximately

1,000 miles, is built in more or less outlying territory. I added 50 per cent to these costs as representing an average of the additional difficulty since those sewers were built. That made $8,500,000, another third. I added 100 per cent for difficulties, making $17,000,000 additional; and the last third I added 200 per cent, making the cost three times the cost of the equivalent sewers without obstructions, adding $59,500,000 to the previous total. I then added 500,000 house connections, making a total of $4,700,000 for those connections.

Adding all these allowances together, I reached the result of $129,010,000, which gives me a range of from $130,000,000 to $150,000,000. The house connections in-
9451 cluded connection from the building line to the sanitary sewer. I put in an allowance of 75 feet which is sufficient to go to the house from the center of the street.

I have made a mistake in that item. My total here should be $171,000,000 instead of $129,000,000. My range therefore, should be between $158,000,000 and $171,000,-000, rather than $130,000,000 to $150,000,000. My mistake was due to a misplaced decimal point.

All of my calculations of the degree of treatment required and the amounts of water required for disposing of the effluents of Chicago sewage down the Illinois River are based entirely upon supplying enough dissolved oxygen to satisfy what I have taken as the 5 day demand of these effluents.

I bear in mind the only source of dissolved oxygen considered in that question is the dissolved oxygen supplied
9479 from diversion water. Under that pollution standard I did not use the dissolved oxygen in the sewage effluents or in the oxygen available from nitrate or nitrite. The testimony which I gave regarding the saving from metering was based upon the assumption that water consumption would increase to 440 gallons per day per capita

without metering, based upon Exhibit 202, the report made by the City Engineer, Mr. Ericson.

9481 As to whether any city in the United States over 100,000 population ever got as high a consumption as 440 gallons, Buffalo got to 373 before they started to meter. I know of no other city which has ever let it get that bad before putting in meters. The Buffalo rate just mentioned was in 1905 and in 1915 it was 345. Last year it was down to 208, and they are still only a small percentage metered. Those are figures for 1925. I have not the figures for 1926.

9482 I know where the yacht harbors are located in Chicago only in a general way. I think probably there are a number of yacht harbors there. I am not informed as to that. The lake about Chicago is used for rowboating and sailboating and launches.

Every bit of our report of April 16, 1925, was used in making up the estimates we have offered in this case. I have made no investigation since three years ago when the report was turned in. The estimates of cost that I put in in this testimony are an exact copy of the estimates in our report.

9533 *Redirect Examination by Mr. Jackson.*

The standard sought by the Government for the purpose of my report requiring such as would permit a thriving fish life in the Des Plaines and Illinois Rivers, is a very rigorous standard, particularly in a stream—that is, the restoration of thriving fish life—in a stream in which there has been none for a period of 20 years or more. Such a pollution standard is not necessary to prevent nuisance. There are factors of oxygen supply which are available for preventing a nuisance, and which are not available for permitting a thriving fish life. There are two principal sources of oxygen which 9535 are in the effluents themselves. These sources are the

dissolved oxygen of the effluents and the oxygen which is contained in the effluents as nitrates and nitrites.

With the standard set up by the District Engineer the nitrate and the nitrite oxygen is not available, because that only becomes available for satisfying the oxygen demand of the sewage effluents after the dissolved oxygen has been exhausted; and as fish life is stifled when the dissolved oxygen is drawn to below about 3 parts per million, the big source of oxygen from the nitrate and nitrite is not available in the pollution standard which requires a thriving fish life. Therefore, the factor of safety against nuisance is about twice as great as the factor of safety against killing fish life. There is a further reason as to a greater factor of safety, in that fish life once established, if through a temporary reduction in plant efficiency the oxygen supply is reduced, the fish life is killed and it takes years to replace it; whereas, if only a nuisance were established a temporary
9536 break in the operating efficiency would result only in a nuisance for 2 or 3 days which could be corrected with no injurious effects other than the temporary nuisance.
9545 Referring to page 211 of the report where appears a statement that sterilization of sewage removes 90 to 95 per cent of the bacteria, this refers to sterilization of raw sewage, and not to sterilization of effluent.

Even though there is an increase subsequent to metering, the ultimate rate is much lower than that prevailing without metering.

George B. Gascoigne, Sanitary Engineering Expert, for Complainants, March, 1927:

Direct Examination by Mr. Jackson.

I have considered the effect of storm overflows, and
8921 in my opinion it would be practicable to treat sewage

and storm water flows in Imhoff tank trickling filter plants substantially greater than 1½ times the average dry weather flow. It will be possible to treat approximately 4 times the average dry weather flow. If this were done, the amount of pollution from storm overflows will be practically eliminated. This procedure would involve very minor, if any, changes in the proposed treatment plants of the Imhoff type.

Assuming the complete treatment of all of the sewage in the Sanitary District of Chicago by the installation of sewage disposal works as heretofore described, no diversion of water through the Drainage Canal, the present location of the water intakes and the installation of water purification plants, the public health conditions in Chicago with special reference to the public water sup-
8922 ply, would be as good as those which presently obtain.

Assuming complete treatment of all of the sewage of the Sanitary District of Chicago, no diversion of water through the Chicago Drainage Canal, the replacement of the present water intakes by a super-tunnel located 4½ miles off-shore in the vicinity of Wilmette and 20 miles from the mouth of the Chicago River, with chlorination only of the water supply, the public health conditions in Chicago, with special reference to the public water supply, would be as good as those now obtaining.

If there should be substituted water purification or water filtration for chlorination only of the water supply, the supply would be improved.

Assuming the complete treatment of all of the sewage of the Chicago Sanitary District with no diversion of water from Lake Michigan except in time of storm overflows, but with diversion of storm water overflows by the operation of controlling works located in the vicinity of Western Avenue, the present location of the water intakes, with filtration and chlorination of the water sup-

ply, the public health conditions in the City of Chicago, with special reference to the water supply, would be safeguarded as well as under present conditions.

8923 Assuming complete treatment of all of the sewage of the Sanitary District, with no diversion of water through the Chicago Drainage Canal except in time of storm, but with diversion of all storm water overflows through the Drainage Canal by the operation of the controlling works, located in the vicinity of Western Avenue, the replacement of the present water intakes by a super-tunnel located 4½ miles off-shore in the vicinity of Wilmette, and 20 miles from the mouth of the Chicago River, with chlorination only of the water supply, the public health conditions in Chicago, with special reference to the public water supply, would be better than those presently obtaining.

8924 If there should be substituted filtration of the water supply for chlorination only, the water supply would be
9659 improved.

9661 *Cross-Examination by Mr. Adcock.*

To my personal knowledge I do not know of Imhoff tanks serving 100,000 population or over where 4 times the average dry flow is treated.

I think I delivered a paper before the Cleveland Engineering Society about June 10, 1925, the subject being "Plans for Meeting Sewage Treatment Problem of Cleveland." I said in that paper that in the matter of disposing of sewage—

9698 "We are not as favorably located as Chicago in having available a back yard into which we can discharge our filthy sewage or used water supply. If we were so situated, there is no question in my mind about the wisdom of taking advantage of such an asset."

EXTRACTS FROM COMPLAINANTS' EXHIBIT 1, ENTITLED

"DIVERSION OF WATER FROM LAKE MICHIGAN"

BY MAJOR PUTNAM, DISTRICT ENGINEER, NOV. 1, 1923.

"Deliberate efforts on the part of the Sanitary District of Chicago to establish and maintain a uniform flow of 10,000 cubic feet per second through the Chicago River have been unsuccessful. While these attempts were experimental, they indicate that the stream is still too crooked and narrow to permit that volume of discharge under ordinary conditions of head." (Page 34)

"It has been estimated that rates of storm run-off from the drainage area of the Chicago River have the following frequency:

3,000 cubic feet per second 10 to 12 times per year.
4,167 cubic feet per second 7 to 8 times per year.
5,000 cubic feet per second 5 to 6 times per year.
7,500 cubic feet per second 3 to 4 times per year.
9,500 cubic feet per second 2 times in 3 years."

"Without going into details it might be stated that the present average consumption of water in the city of Chicago is 800,000,000 gallons per day, or about 1,200 cubic feet per second. The per capita consumption is about 275 gallons per day. Chicago pumps more water than is supplied to Greater New York, Milwaukee, Cleveland and Newark combined, although the total population served in these four cities is nearly 7,500,000. Water is now furnished to about 325,000 premises, of which only 10 per cent are metered." (Page 66)

"The ultimate solution will be to filter the water supply of the city. The economies resulting from universal metering will pay for filtering, and when that is done there is no reason why the discharge through the drainage canal could not be safely decreased to a very low limit, as far as protection of water supply is concerned, for the damages attending the reversal of flow of the river would be entirely eliminated." (Page 68)

EXTRACTS FROM DEFENDANTS' EXHIBIT 1157 ENTITLED

REPORT OF THE ENGINEERING BOARD OF REVIEW OF THE SANITARY DISTRICT OF CHICAGO ON THE LAKE LOWERING CONTROVERSY AND A PROGRAM OF REMEDIAL MEASURES.

"18. WATER CONSUMPTION—In 1924 the City of Chicago pumped 826,000,000 gallons daily into the system for its own use, equivalent to a per capita consumption of 280 gallons. Approximately one-half of the water pumped is wasted." (Page 28)

"Records of the Health Department of Chicago show that of 253 days in 1924, in which observations were made, the Calumet Rivers were discharging into Lake Michigan on 115 days, occasionally the flow being continuous for several consecutive days." (Page 32)

"While the filtration of water supplies and the complete treatment of sewage appear to be capable of affording a large degree of protection from infection through contaminated water, and both of these agents are practicable in the case of Chicago, it is nevertheless desirable to prevent, in so far as practicable, the contamination of any water which may reach public waterworks intakes. Chicago is remarkably well situated through the use of the Main Drainage Canal already built and in operation to avoid such contamination. To abandon this plan and to discharge the sewage into the lake, however well the sewage may first be treated, would be a backward step, highly repugnant from the sentimental viewpoint and equally objectionable from the point of view of the public health.

"If a Lakes-to-Gulf waterway is to be maintained, water for its successful operation will probably be obtained from Lake Michigan. Regardless of the amount necessary, the volume represented by the effluent from sewage treatment plants performs the same service as would water taken directly from the Lake. If this effluent is such that objectionable conditions are not created thereby in the canal or Des Plaines-Illinois Rivers, then it is logical to have the effluent flow through this course instead of into the Lake." (Page 44)

Terms of Decree Submitted by Defendants to Special Master on Re-reference.

The Court finds:

A.

The defendant, the Sanitary District of Chicago, has presented a program for the construction, completion and placing in operation of sewage treatment works to treat and dispose of, from a practicable standpoint, the sewage and industrial wastes arising within the territorial limits of the Sanitary District of Chicago. This program for sewage treatment and disposal embraces various and sundry plants, works and appurtenances, including intercepting sewers and pumping stations completed, in process of construction and to be constructed by the Sanitary District of Chicago. The works completed consist of six treatment works, plants and equipment, intercepting sewers and appurtenances, as follows:

1. *Morton Grove Sewage Treatment Works.*

2 Imhoff tanks, 1 covered trickling filter with settling basins, sludge drying beds and pumping station, designed for population of approximately 1,200 people, located at Morton Grove and known as the Morton Grove Sewage Treatment Works.

2. *Glen View Sewage Treatment Works.*

1 Imhoff tank, trickling filter, settling tank, sludge drying beds and pumping station for population of approximately 1,200 people, located at Glen View, Illinois, known as the Glen View Sewage Treatment Works.

3. *Northbrook Sewage Treatment Works.*

1 small Imhoff tank, trickling filter, secondary settling tank, sludge drying beds and pumping station for popu-

lation of approximately 1,500 people at Northbrook, Illinois, known as the Northbrook Sewage Treatment Works.

4. *Des Plaines River Sewage Treatment Works.*

Main pumping station and blower house, grit chambers, fine screens, 4 aeration tanks, 12 settling tanks and activated sludge processing equipment for population of approximately 45,000 people, located at or near the Des Plaines River, near Maywood, Illinois, known as the Des Plaines River Sewage Treatment Works.

5. *Calumet Sewage Treatment Works.*

30 Imhoff tank units, 2 aeration tanks, constituting an activated sludge process in 2 remaining Imhoff tank units, with 2 settling tanks and connections, small trickling filter, secondary settling tank in two units, for population of approximately 225,000 people, located in the southern part of the City of Chicago, known as the Calumet Sewage Treatment Works.

6. *North Side Sewage Treatment Works.*

North Side Sewage Treatment Works, known as an activated sludge plant, with buildings, tanks and appurtenances, located on approximately 100 acres of ground at or near Howard Street and McCormick Road in the eastern part of the Village of Niles Center, designed for a population of 830,000 people. (In order to bring this plant to full completion, it will be necessary to complete the North Branch Pumping Station, hereafter to be mentioned)

B.

The said program for the construction and installation of treatment works to dispose of all the sewage, as far as practicable, arising within the Sanitary District,

also involves and embraces the following plants to be entirely constructed or completed, including their pumping stations, intercepting sewers and appurtenances:

1. *North Side Sewage Treatment Works.*

There is required to complete this plant for the practicable treatment of the sewage of a population of 830,000 as of the year 1930, the completion of the North Branch Pumping Station which is appurtenant to said plant and will furnish part of the means by which all the sewage of said population will be delivered to the said plant.

2. *West Side Sewage Treatment Works.*

This plant is under construction and is located at or near 52nd Avenue and the Main Channel or Canal of the Sanitary District in the Village of Stickney, just outside the limits of the City of Chicago.

This plant is designed to treat the sewage of a population of 1,850,000 people as of 1940 by sedimentation in Imhoff tanks, in addition to providing for the digestion of sludge from the North Side Sewage Treatment Works.

Part of the intercepting sewers for these works have been constructed, bringing in sewage from the west as well as the east. A large amount of intercepting sewer work is still to be done. The treatment plant proper now under construction comprises pumping station, skimming tanks, grit chambers, Imhoff tanks, sludge drying beds, and a standard gauge railroad to carry the dried sludge to points along the Drainage Canal some miles south and west of the said plant. Certain portions of said West Side Sewage Treatment Plant have been substantially completed, such as the pumping plant, two batteries of Imhoff tanks, sewers and conduits within the plant area.

Upon the completion of the Imhoff tank plant and appurtenances, it is proposed to add an activated sludge plant to give so-called complete treatment.

Intercepting sewers are under construction to convey the sewage now and hereafter tributary to the Des Plaines River Sewage Treatment Works, to the West Side Sewage Treatment Works, and when such intercepting sewers are constructed after the completion of the West Side Works, the Des Plaines River plant will be abandoned except in so far as it may be retained for experimental purposes.

3. *Southwest Side Sewage Treatment Works.*

This plant has not been designed or constructed, nor has the site therefore been obtained. The program of the Sanitary District contemplates the design of a plant known as the Southwest Side Sewage Treatment Works, to be located to the south of the West Side Sewage Treatment Works and south of the Main Channel of the Sanitary District, including the South Side intercepting sewer project and Racine Avenue pumping station, as well as all other intercepting sewers and appurtenances thereof. It is proposed that this plant will take care of the sewage of approximately 1,200,000 people plus the trade or industrial wastes of the stockyards and packing town area, which has a volume of waste equivalent to the sewage of aproximately 1,000,000 people.

It is proposed that the plant shall be, when constructed, of the activated sludge type of sewage treatment works having the necessary pumping stations, blower house, grit chambers, skimming tanks, Imhoff tanks, aeration tanks, sludge drying beds, sludge processing equipment, mechanical and electrical equipment, intercepting sewers and appurtenances.

4. *Calumet Sewage Treatment Plant.*

This plant is to be extended to handle the increase of population on the present tributary area, as well as the population of an additional area, and will consist of Imhoff tanks, trickling filters, grit chambers, secondary settling tanks, sludge drying beds and appurtenances, and treat a total population of 455,000 as of the year 1945. The additional site required has yet to be obtained.

5. *Miscellaneous Works.*

Miscellaneous intercepting sewers, pumping stations, disposal stations and other work incidental and appurtenant to the construction program herein outlined to collect and treat all the sewage originating within the boundaries of the Sanitary District of Chicago.

6. *Controlling Works.*

To prevent flow so far as practicable of the Chicago River into Lake Michigan at all times, controlling works may be constructed and installed in the Chicago River at or near its mouth and near Lake Michigan, or at or near the northern and eastern terminus of the Main Drainage Canal. These works may consist of dams, locks and other devices designed, when operated, to prevent the discharge of sewage or sewage effluent, rain-water runoff or storm waters from the Chicago River into Lake Michigan. The controlling works at the northern or eastern terminus at or near Blue Island of the Calumet Sag Channel of the Sanitary District may be operated so as to cause the ordinary flow of the Calumet River to pass to said Calumet Sag Channel and the storm flow of said Calumet River to the maximum amount of 3,000 cubic feet per second to be discharged into said Calumet Sag Channel.

C.

The said works above described completed and in operation, and those to be completed or to be entirely constructed, are commonly known in the art of sewage treatment as works embodying Imhoff tanks with trickling filters and secondary sedimentation or embodying preliminary sedimentation followed by the activated sludge process.

When all of the said works under construction or to be constructed are placed in operation and all of said works, including those already constructed, are continued in operation in a practicable and efficient manner, such practicably efficient operation of said sewage treatment works and appurtenances should accomplish the utmost practicable treatment of the dry weather flow of sewage and wastes of the Sanitary District, in the elimination of solids and organic matter; that at storm times only approximately 150 per cent, more or less, of the ordinary dry weather flow of sewage and wastes in the sewers may be practicably treated or disposed of, and the balance of the storm flow in the sewers exceeding the volume presently to be treated, will pass into the Chicago River and its branches and the canals of the Sanitary District, and any storm flow so passed or by-passed to such channels or canals at storm times will contain sewage and wastes untreated by any treatment works.

D.

The Sanitary District of Chicago should proceed with all practicable speed and diligence with the construction and completion of all of said sewage treatment works and appurtenances, including intercepting sewers and pumping stations, not now completed and in operation. The said sewage treatment works above described should

be completed and placed in operation to treat practicably and efficiently the sewage of the population for which they are respectively designed, as follows:

(1) North Side Sewage Treatment Works and appurtenances, July 1, 1930.

(2) West Side Sewage Treatment Works—
Battery A—Imhoff Tanks—January 1, 1930.
Battery B—Imhoff Tanks—July 1, 1930.
Battery C—Imhoff Tanks—June 1, 1932.

(3) Southwest Side Sewage Treatment Works—as to that portion of the works to settle sewage—January 1, 1936.

(4) Calumet Sewage Treatment Works, complete—January 1, 1936.

(5) West Side Sewage Treatment Works, complete—January 1, 1941.

(6) Southwest Side Sewage Treatment Works, complete—January 1, 1943.

(7) All said works to be fully completed and in practicably efficient operation January 1, 1945.

(8) The dams, locks and controlling works to be constructed in the Chicago River at or near its mouth and near Lake Michigan or at or near the northern or eastern terminus of the Main Drainage Canal by the Sanitary District, shall be completed and in operation within a period of two years subsequent to the date of the approval of plans therefor by the Secretary of War, upon the recommendation of the Chief of Engineers. The Sanitary District shall immediately submit plans for such works to the Chief of Engineers or such other officer as he may direct, in order that the plans may be approved at the earliest practicable time and the work thereunder instituted.

It Is Therefore Ordered, Adjudged and Decreed As Follows.

The Court hereby retains jurisdiction of this controversy and of these causes until all the said treatment works and their appurtenances, including all controlling works that may be installed in the Chicago River or in the Main Drainage Canal, as above enumerated, are completed and placed in operation in a practicably efficient manner, for the purpose of entering any orders that may be appropriate to accomplish the completion and placing in operation of the said works at the time or times above mentioned, or with all reasonable and practicable speed.

REQUESTED FINDINGS OF FACTS, CONCLUSIONS OF LAW AND RECOMMENDATIONS FOR A DECREE SUBMITTED BY COMPLAINANTS TO THE SPECIAL MASTER ON RE-REFERENCE.

The above named complainants deeming the facts and conclusions of law, hereinafter set forth, to be respectively proven and established by the evidence and the law applicable to said facts, and material to the framing of a decree under the terms of the decision and mandate of the Supreme Court of the United States rendered in the above entitled causes on January 14, 1929, request the Special Master to make and find the following findings of fact, conclusions of law and recommendations for a decree in these cases.

FINDINGS OF FACT.

I.

For the purpose of providing for the treatment of all of the sewage of the Sanitary District of Chicago by artificial processes, the area of the Sanitary District of Chicago has been divided by the Sanitary District into four parts, which are respectively known as the North Side project, the West Side project, the Calumet project and the Southwest Side project. All of the domestic sewage and industrial waste arising in each one of said four divisions of the area of the Sanitary District of Chicago will be treated in a single sewage disposal plant located in each of said districts.

II.

A modern activated sludge plant has been completed on the North Side project. This plant is now in operation to the extent of taking care of the sewage of from 200,000 to 250,000 of the population of that District. That all of the sewage of the entire population of the area covered by the North Side project is not presently being treated by the North Side sewage disposal plant is due to the fact that the North Branch pumping station, which is necessary for the conveyance of the sewage of the remainder of the population to the plant, has not been completed and placed in operation. The North Side pumping station could have been completed and placed in operation during 1929. Owing to the fact that the Sanitary District suspended all physical construction work on sewage disposal plants and auxiliary structures during 1929 up to the middle of September of that year, the

North Side pumping station will now be completed, and in full operation April 1, 1930. After the completion and placing in operation of the North Side pumping station all of the industrial wastes and all the sewage of the population of the area covered by the North Side project wil be treated by the North Side sewage works. On and after April 1, 1930, the North Side plant will provide the equivalent of 100 per cent treatment of the sewage of a population of 602,500 people.

III.

At the Calumet project an Imhoff tank or preliminary treament sewage disposal plant has been completed and in operation since 1922, furnishing partial treatment for about one-half of the population of the area covered by the Calumet project which is the equivalent of 100 per cent treatment of the sewage of 64,500 people. The Calumet sewage disposal plant can be enlarged and extended for complete treatment by the trickling filter process so as to provide for complete treatment of all of the sewage and industrial waste of the area covered by the Calumet project by December 31, 1932.

IV.

At the West Side project, the pumping station, outdoor substation, one-half the skimming tanks, the grit chambers, the coarse screens, the meter vault and one of the three batteries of Imhoff tanks were substantially completed in March, 1929, so that they could be placed in operation in a month if the money had been then available to pay the contractors. The second battery of the Imhoff tanks at the West Side plant and the remaining skimming tanks were more than one-half completed and some work had been done on the sludge drying beds in

March, 1929. The second battery of Imhoff tanks at the West Side plant, together with the remainder of the skimming tanks and auxiliary structures for that battery of tanks could have been completed and placed in operation by December 31, 1929. Owing to the fact that the Sanitary District suspended all physical construction work on sewage disposal plants and auxiliary structures during 1929 up to the middle of September of that year, the second battery of Imhoff tanks at the West Side project, together with the remainder of skimming tanks and auxiliary structures will be completed and placed in operation by April 1, 1930, and will provide the equivalent of 100 per cent treatment of the sewage of the population of 240,000 people. The third battery of Imhoff tanks and the additional structures necessary to provide complete treatment on the activated sludge principle of all of the domestic sewage and industrial waste arising in the area covered by the West Side project can be completed and placed in operation by December 31, 1933.

V.

On the Southwest Side project, no contracts had been let when the testimony was closed. The program for sewage disposal at the Southwest Side project provides for the construction of a plant on the activated sludge principle for the treatment of all of the domestic sewage and industrial waste arising in the area covered by that project. The site for the Southwest Side Plant was selected prior to taking testimony on the original hearing in these suits. Studies with reference to the proper method of treating the sewage and industrial waste, and the location and type of sewage disposal plants to be constructed, have been carried on by the Sanitary Experts of the Sanitary District of Chicago since 1909. General plans, detailed

estimates of quantities and a tentative lay-out of the structures involved in the construction of the Southwest Side plant have been prepared by the Sanitary District of Chicago and offered in evidence on this re-reference. This plant can be designed, constructed and placed in operation by December 31, 1935.

VI.

While the completion of said sewage disposal plants, with chlorination only of the domestic water supply as presently practiced, will undoubtedly provide as good a water supply as presently obtains and one which is adequate to safeguard the public health, the construction of water filtration plants for the filtration of the entire domestic water supply of Chicago would be a further factor of safety or protection to the public health and would unquestionably provide a safe public water supply. In the present state of the art a comprehensive and scientifically sound program for the sanitation of Chicago should include the construction of water filtration works for the domestic water supply. Since the construction of water filtration plants is not an indispensable element in the practical disposal of the sewage of the Sanitary District of Chicago by means other than Lake diversion, the construction of such water purification works should be left to the discretion of the defendants.

VII.

The design and construction of water filtration plants is under the jurisdiction of the City of Chicago. The evidence discloses that the construction of such plants has been under consideration by the Engineering Department of the City of Chicago for a number of years. No evidence was offered through the Engineering Department of Chi-

cago with reference to the progress which has been made on plans for water filtration works, other than that it appears that the number and location of such plants have been tentatively determined. Regardless of whether any progress has been made upon these plans by the Engineering Department of the City of Chicago, the water filtration plants, if included in the program, can be designed, constructed and placed in operation by December 31, 1934.

VIII.

The completion of the North Side and West Side sewage disposal plants on the activated sludge principle, the completion of the Calumet plant on the trickling filter principle, and the construction of the Southwest Side sewage disposal plant on the activated sludge principle, together with the completion or construction of such additional sewers and pumping stations as may be necessary to convey all of the sewage to said respective sewage disposal plants, will provide a practical method or program for the complete treatment of all of the sewage and industrial waste of the Sanitary District by means other than Lake diversion.

IX.

If Chicago desires to improve the present standard or quality of its water supply, or to provide any additional factors of safety in the case of a breakdown in any of the plants for the disposal of the sewage by artificial processes, it would be practicable to extend the present water intakes farther into the Lake, to substitute a new water intake off the North Shore about 20 miles from the mouth of the Chicago River in the vicinity of Wilmette, to chlorinate the effluents from the sewage disposal plants

and/or install controlling works at the junction of the Drainage Canal and the Chicago River, which would permit almost immediate diversion from the Lake in the case of an emergency. None of the foregoing variations in the program for the practical disposal of the sewage of the Sanitary District of Chicago by means other than Lake diversion is essential. The construction or installation of any such additional works or structures should be left to the discretion of the defendants.

X.

From five to six years is a reasonable, and in fact, liberal, period of time for the design, construction and placing in operation of all of the structures and facilities involved in the completion or construction and placing in operation of the sewage disposal plants which are required in a practical program for the disposal of the sewage of the Sanitary District by means other than Lake diversion. All of said sewage disposal plants can be completed and in operation by December 31, 1935.

XI.

The Corn-Products waste has been eliminated or treated so as to relieve the Chicago River and the Drainage Canal of the equivalent of the sewage of a population of 360,000 people.

XII.

The Imhoff tanks for the Southwest Side plant can be completed so as to provide tank treatment for all of the sewage and industrial waste of the area covered by the Southwest Side project on December 31, 1932.

XIII.

Upon the completion of this program of practical measures for the disposal of the sewage of the Sanitary District of Chicago by means other than Lake diversion, no diversion or flow at Lockport will be necessary to maintain navigation upon the Chicago River as part of the Port of Chicago. Navigable depths will be increased and no nuisance will be created which will obstruct or interfere with navigation.

XIV.

Upon the completion of this program of practical measures for the disposal of sewage of the Sanitary District of Chicago by means other than Lake diversion, it is practicable to flush the navigable channels of the Chicago and Calumet Rivers together with the auxiliary channels by pumping circulating water through the North Branch by means of the existing pumping station near Wilmette, by pumping water into the South fork of the Chicago River or into the Chicago Drainage Canal by means of the existing pumping station at 39th Street and by pumping water through the Calumet-Sag Channel 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. While this procedure is not necessary it is entirely practicable and would afford an adequate factor of safety, if desired, for the prevention of any possibility of interference with navigation in these channels.

XV.

With the completion of this program of practical measures for the disposal of the sewage of the Sanitary District of Chicago by means other than Lake diversion, it is practicable to discharge the effluents of all of the sewage disposal plants involved in this program through outfall sewers or tunnels directly into Lake Michigan so as to wholly remove the said effluents from the Chicago River and its branches and auxiliary channels in the Sanitary District of Chicago. While such procedure is not necessary, it is entirely practicable and affords an adequate factor of safety, if desired, for the prevention of any possibility of interference with navigation in said waters.

XVI.

During the period of construction of the practical measures involved in this program for the disposition of the sewage of the Sanitary District of Chicago by means other than Lake Diversion, the following progressive reductions will be practical:

1. A reduction to 6500 c. f. s. in addition to domestic pumpage on April 1, 1930.
2. A reduction to 5000 c. f. s. in addition to domestic pumpage on December 31, 1932.
3. A reduction to 3000 c. f. s. in addition to domestic pumpage on December 31, 1933.
4. A complete cessation of all diversion or flow (including the domestic pumpage) at Lockport on December 31, 1935.

CONCLUSIONS OF LAW.

I.

That the decree in the above entitled cases should require the Defendants to carry out the practical measures for the disposition of sewage of the Sanitary District of Chicago by other means than Lake Diversion by December 31, 1935.

II.

That the decree in the above entitled cases should require the Defendants to reduce the flow at Lockport to 6500 c. f. s. in addition to the domestic pumpage by April 1, 1930, to 5000 c. f. s. in addition to the domestic pumpage by December 31, 1932, to 3000 c. f. s. in addition to the domestic pumpage by December 31, 1933, and to cease all flow or diversion at Lockport by December 31, 1935.

III.

That the decree in the above entitled cases should require the Defendants to complete and place in full operation the North Side Activated Sludge Plant and Batteries A and B of the Imhoff tanks at the West Side plant (as outlined in the program proposed by the Sanitary District of Chicago) by April 1, 1930, and to continue the operation of the Calumet sedimentation sewage disposal plant which was completed in 1922.

IV.

That the defendants be required to complete and place in full operation the Calumet sewage disposal plant, all of the batteries of the Imhoff tanks at the West Side

plant, and all of the batteries of the Imhoff tanks at the Southwest Side plant (all as outlined in the program proposed by the Sanitary District of Chicago) by December 31, 1932.

V.

That the defendants be required to complete and place in operation all structures (all as outlined in the program proposed by the Sanitary District of Chicago) required to provide complete treatment for all of the sewage and industrial waste tributary to the West Side Plant by December 31, 1933.

VI.

That the defendants be required to complete and place in full operation all structures required to provide complete treatment for all of the sewage and industrial waste tributary to the proposed Southwest Side sewage disposal plant by December 31, 1935.

VII.

That the discharge of liquid sewage or street wash into any of the navigable waters of the United States does not constitute an obstruction to or interference with navigation or impairment of navigable capacity as a matter of Law.

VIII.

That the discharge by the Defendants of the domestic pumpage of the City of Chicago and/or the run-off of the Chicago and Calumet basins, which are naturally tributary to Lake Michigan, constitute an illegal diversion from the Great Lakes-St. Lawrence watershed to the Mississippi watershed.

IX.

That upon the completion of the program of practical measures for the disposition of the sewage of the Sanitary District of Chicago by other means than Lake diversion, no diversion or flow at Lockport from the Great Lakes-St. Lawrence watershed may be lawfully maintained by the defendants, either in interest of the sanitation of Chicago or for the maintenance of navigation on the Chicago River as part of the Port of Chicago.

X.

That the Defendants and each of them should be enjoined from so polluting the Chicago River and the auxiliary navigable channels or the Des Plaines or Illinois Rivers by the discharge of sewage or otherwise as to create an obstruction to or interference with navigation or the navigable capacity of any of said navigable waters of the United States.

XI.

That the defendants have the legal duty of preventing any obstruction to or interference with navigation on or the navigable capacity of the Chicago River and auxiliary navigable channels and that after the completion of the program for the treatment of all of the sewage of the Sanitary District of Chicago, the defendants are legally bound to provide, at their expense, such quantity of circulating water, if any, in and through the various navigable channels in the Chicago Sanitary District as may be necessary to prevent any obstruction to or interference with navigation thereon or the navigable capacity thereof without any diversion or flow at Lockport.

XII.

That defendants should be required by the terms of the decree to provide for the discharge of effluents from the sewage disposal plants involved in the practical program for the disposal of the sewage by other means than Lake diversion, by such methods as will remove all of said effluents from the Chicago River and the navigable channels of the Sanitary District of Chicago and provide for the discharge of such effluents into Lake Michigan or elsewhere in such manner and at such places as will not create any obstruction to or interference with navigation on or the navigable capacity of any of the navigable waters of the United States.

XIII.

That the complainants are entitled to a decree in the above entitled cases enjoining the State of Illinois and the Sanitary District of Chicago, their employees, agents, attorneys and servants from diverting any of the waters of the Great Lakes-St. Lawrence System through the Chicago Drainage Canal and its auxiliary channels, or through or by means of any other method, device or agency in excess of 6500 c. f. s. in addition to the domestic pumpage subsequent to April 1, 1930, in excess of 5000 c. f. s., in addition to the domestic pumpage subsequent to December 31, 1932, in excess of 3000 c. f. s. in addition to domestic pumpage subsequent to December 31, 1933, and from diverting any water or maintaining any flow through the controlling works at Lockport subsequent to December 31, 1935.

RECOMMENDATIONS FOR A DECREE.

1. Complainants request the Special Master to recommend a decree in these cases in substance as follows:

(Caption Omitted)

These causes coming on to be heard, upon the supplemental report of the Master, Hon. Charles E. Hughes, to whom they were referred pursuant to and for the purposes specified in the opinion of this court rendered in said causes on January 14, 1929, and also upon the exceptions taken to said supplemental report on the part of the complainants and defendants, and said causes having been argued by counsel for the respective parties, and due deliberation having been given thereto, it is:

ORDERED, ADJUDGED AND DECREED as follows:

1. That the supplemental report of the Special Master, his findings of fact, conclusions of law and recommendations for a decree be and the same hereby are in all respects confirmed.

2. That the Defendants complete and place in full operation the North Side activated sludge plant and Batteries A and B of the Imhoff tanks at the West Side plant (as outlined in the program as proposed by the Sanitary District of Chicago) by April 1, 1930.

3. That the Defendants continue the operation of the Calumet sedimentation sewage disposal plant which was completed in 1922.

4. That the Defendants complete and place in full operation the Calumet Sewage disposal plant, all batteries of the Imhoff tanks at the West Side plant, and

all of the batteries of the Imhoff tanks at the Southwest Side plant (as outlined in the program as proposed by the Sanitary District of Chicago) by December 31, 1932.

5. That the Defendants complete and place in full operation all structures (as outlined in the program proposed by the Sanitary District of Chicago) required to provide complete treatment for all of the sewage and domestic waste tributary to the West Side Plant by December 31, 1933.

6. That the Defendants complete and place in full operation all structures required to provide complete treatment for all of the sewage and industrial waste tributary to the proposed Southwest Side sewage disposal plant (as outlined in the program proposed by the Sanitary District of Chicago) by December 31, 1935.

7. That the Defendants carry out the foregoing and all other practical measures which may be necessary for the disposition of all of the sewage and trade wastes of the Sanitary District of Chicago by other means than Lake diversion by December 31, 1935.

8. That on and after April 1, 1930, the defendants, the State of Illinois and the Sanitary District of Chicago, their employees, servants, attorneys, agents and any and all persons assuming or purporting to act under their authority or under the authority of either of them be, and they hereby are, ordered to desist and refrain from diverting or abstracting any of the waters of the Great Lakes-St. Lawrence System or watershed through the Chicago Drainage Canal and its auxiliary channels, or

through or by means of any other method, device or agency in excess of 6500 c. f. s. in addition to domestic pumpage.

9. That on and after December 31, 1932, the defendants, the State of Illinois and the Sanitary District of Chicago, their employees, servants, attorneys, agents and any or all persons assuming or purporting to act under their authority or under the authority of either of them be, and they hereby are, ordered to desist and refrain from diverting or abstracting any of the waters of the Great Lakes-St. Lawrence System or Watershed through the Chicago Drainage Canal and its auxiliary channels, or through or by means of any other method, device or agency in excess of 5000 c. f. s. in addition to domestic pumpage.

10. That on and after December 31, 1933, the defendants, State of Illinois and the Sanitary District of Chicago, their employees, servants, attorneys, agents and any or all persons assuming or purporting to act under their authority or under the authority of either of them be, and they hereby are, ordered to desist and refrain from diverting or abstracting any of the waters of the Great Lakes-St. Lawrence System or Watershed through the Chicago Drainage Canal and its auxiliary channels, or through or by means of any other method, device or agency in excess of 3000 c. f. s. in addition to domestic pumpage.

11. That on and after December 31, 1935, the defendants, State of Illinois and the Sanitary District of Chi-

cago, their employees, servants, attorneys, agents and any or all persons assuming or purporting to act under their authority or under the authority of either of them be, and they hereby are, ordered to desist and refrain from diverting or abstracting any of the waters of the Great Lakes-St. Lawrence System or Watershed (including the domestic pumpage of Chicago) through the Chicago Drainage Canal and its auxiliary channels, or through or by means of any other method, device or agency.

12. That on and after December 31, 1935, the defendants, the State of Illinois and the Sanitary District of Chicago, their employees, servants, attorneys, agents and any and all persons assuming or purporting to act under their authority or under the authority of either of them be, and they hereby are, ordered to desist and refrain from so polluting the Chicago River and the auxiliary navigable channels of the Sanitary District of Chicago or any other of the navigable waters of the United States by the discharge of sewage or otherwise so as to create an obstruction to or interference with navigation or the navigable capacity of any of the navigable waters of the United States.

13. That the complainants have and recover from the Sanitary District of Chicago and the State of Illinois their costs and disbursements herein to be taxed and noted at the foot of this decree.

In the oral argument of Attorney General Ward of New York (one of counsel for complainants) before the Special Master on Re-reference, he made the following statement (Transcript Oral Argument, 319):

> "Chicago should be left to say whether it wants to turn its sewage into its water supply. Certainly the complaining States do not want Chicago to turn

its sewage into this water supply. That is our water supply as well as Chicago's."

Respectfully submitted,

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