FINAL REPORT

OF THE

International Joint Commission

On the

Pollution of Boundary Waters Reference

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INTERNATIONAL JOINT COMMISSION.

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LETTER OF TRANSMITTAL.

SEPTEMBER 10, 1918.

SIR: We have the honor to inclose herewith the Final Report of the International Joint Commission in the matter of the reference of August 1, 1912, submitted by the Governments of the United States and of the Dominion of Canada, under the provisions of Article IX of the treaty of January 11, 1909, between the United States and Great Britain.

We have the honor to be, sir, your obedient servants,

LAWRENCE J. BURPEE,
WHITEHEAD KLUTTZ,
Secretaries.

The honorable the SECRETARY OF STATE FOR EXTERNAL AFFAIRS,
Ottawa, Canada.

FINAL REPORT OF THE INTERNATIONAL JOINT COMMISSION IN THE MATTER OF THE REFERENCE BY THE UNITED STATES AND THE DOMINION OF CANADA RELATIVE TO THE POLLUTION OF BOUNDARY WATERS.

I.—INTRODUCTION.

Under the terms of Article IX of the treaty of January 11, 1909, between the United States and Great Britain, the following questions were submitted by the Governments of the United States and of the Dominion of Canada to the International Joint Commission under date of August 1, 1912, for examination and report upon the facts and circumstances connected with the pollution of boundary waters, and for such conclusions and recommendations as might be appropriate:

Original reference.

1. To what extent and by what causes and in what localities have the boundary waters between the United States and Canada been polluted so as to be injurious to the public health and unfit for domestic or other uses?

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 insure the adequate protection and development of all interests involved on both sides of the boundary and to fulfil 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?

Definition of boundary waters.

The expression "boundary waters" is used in the treaty with a special meaning, being therein defined as follows:

For the purposes of this treaty, boundary waters are defined as the waters from main shore to main shore of the lakes and rivers and connecting waterways, or the portions thereof, along which the international boundary between the United States and the Dominion of Canada passes, including all bays, arms, and inlets thereof, but not including tributary waters which in their natural channels would flow into such lakes, rivers, and waterways, or waters flowing from such lakes, rivers, and waterways, or the waters of rivers flowing across the boundary.

In this report the term "boundary waters" shall have the meaning attached to it by the treaty.

Amendment of reference.

The reference as thus submitted is broad enough to require an investigation of all boundary waters as the same are defined in the treaty without regard to the present or future transboundary effect of their pollution on either side; but when it first came before the commission at its Ottawa meeting in October, 1912, a doubt arose as to whether or not the two Governments intended that pollution in all boundary waters was to be included in the investigation, and a letter was addressed to both Governments requesting an expression of their views in such manner as they might deem proper—

> As to whether or not the broad scope of the inquiry is to be circumscribed by construction so as to confine the same to cases of pollution of the boundary waters upon one side of the boundary which may extend to and affect the boundary waters upon the other side.

By letter under date of November 19, 1912, the commission was informed by Mr. Knox, Secretary of State, that the Governments of the United States and Great Britain had—

> reached an accord that the inquiry is to be confined to cases of pollution of boundary waters on one side of the boundary which extend to and affect the boundary waters upon the other side.

The original submission as modified by this limitation constitutes the reference under which the commission is acting.

Omission of pollution in rivers crossing the boundary.

The treaty, in addition to prohibiting such pollution of boundary waters as would have the effect of injuring health or property on the side of the boundary line opposite to that in which it originates, prohibits the pollution of rivers flowing across the boundary line which has an injurious transboundary effect. The first question omits entirely any reference to pollution in these rivers, although it is involved in the second question submitted. The facts connected with pollution in rivers crossing the boundary line, however, call for no special investigation; and the commission regards it as clear that the treatment prescribed in the case of rivers which are boundary waters should be made applicable to them.

Interests and territory affected.

The reference has imposed upon the commission grave responsibilities. From the language of the submission and this prohibitory clause of the treaty, it is evident that the object which the two Governments had in view in making the reference was to see that their reciprocal obligations with respect to the pollution of those waters should be fulfilled. By the traditions of each country a treaty obligation is of supreme sanctity and is the highest law of the State. 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.

The people of both countries possess, in the splendid immensity of the series of waterways through which so much of their common boundary passes, a heritage of inestimable value. Millions of people dwell in their watersheds. Along the banks of the rivers and Great Lakes communities which a few years ago were mere villages are now in population, in social and industrial development, among the most important on the continent. Industries which have suddenly sprung up have an annual output of manufactured products aggregating in value $10,000,000,000. Agriculture and mining have kept pace with manufacturing in the line of expansion. According to official information the rural population of the watersheds cultivate to-day over 100,000,000 acres of land, and the yearly yield of the mines is valued at $300,000,000. The boundary waters are the natural channels of interstate and international commerce. The world possesses no other water thoroughfare comparable with the highway leading from the Gulf of St. Lawrence to the head of Lake Superior. While nature left comparatively little for man to do in adapting these waters to commercial needs, canals had to be constructed at certain points, and rivers, channels, and harbors deepened or created. These works involved an expenditure on the part of Canada of $250,000,000 and on the part of the United States of $135,000,000. Vessels drawing 19 or 20 feet can now navigate the Great Lakes from Duluth or Chicago to Buffalo. Some idea of the magnitude of commerce on these waters may be gleaned from the fact that the vessel passages up and down the Detroit River in 1916 amounted to 37,852, the registered tonnage of the vessels reaching 76,677,264, their passengers, including ferry passengers, numbering 15,000,000 and their freight exceeding 100,000,000 tons, valued at something over $1,000,000,000.

The Thousand Islands and hundreds of other attractive spots along the St. Lawrence River, the Great Lakes, and their connecting waterways, as well as in that splendid chain of boundary waters still farther west which lie within the Lake of the Woods watershed, afford unexcelled opportunities for rest, recreation, and pleasure, which are taken advantage of by a very large floating population during the summer months.

The directness of the water route from the Atlantic Ocean to the head of Lake Superior, the adaptation to water carriage of the freight borne by the lake boats, and the cheapness with which this freight can be transported by them, the completion of the barge canal from Buffalo to New York, the proposed enlargement of the Welland and other canals along the boundary rivers permitting the

passage of vessels of 28 or 29 feet draft from the ocean to the heart of the continent, the future settlement of the great wheat belt of Canada, the fringe only of which has been touched, and the possible utilization of the 3,375,000 dependable horsepower of the boundary rivers, render the conclusion inevitable that the commerce and shipping on these waters and the wealth, the industries, and the population along their banks must in the near future reach dimensions far exceeding their present attainment, and may ultimately far surpass any area of similar extent in the world. 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.

Scope of the inquiry.

The first branch of the reference expressly calls for an inquiry into three subjects: (1) The location and extent of the pollution of boundary waters, (2) the sources from which this pollution is derived, and (3) the localities, if any, in which the pollution has a transboundary effect injurious to health or property. Involved in this last subject is the determination of what is an injury to health or property within the meaning of the reference and of the treaty. The second branch of the reference calls for the recommendation of measures and methods for remedying or preventing existing or future evils.

II.—PLAN OF PROCEDURE IN THE INVESTIGATION.

Examination of existing pollution.

While the answer to the question in the first branch of the reference covers chiefly matters of fact, the proper procedure to be followed in the investigations required the most careful consideration of everything involved, of the geographical and experimental limitations that might with advantage be imposed on the scope of the work, of the most suitable form of organization for carrying out the necessarily extensive examinations thoroughly, expeditiously, and economically, and of the minor details of technique and general procedure. Many of the matters involved called for expert assistance, and the commission enlisted the sympathetic aid and cooperation of sanitary experts, health officials, and others interested in both the United States and Canada in the preparation and carrying out of a plan of procedure. A conference was held at Buffalo on December 17, 1912, at which, on the invitation of the commission, the following officials and experts were present and participated: Mr. John Thompson, K. C., representing the Dominion Government; Dr. Frederick Montizambert, director general of public health for the Dominion of Canada; Dr. Charles A. Hodgetts, medical advisor, commission of conservation, Ottawa; Dr. John A. Amyot, director of laboratories, provincial board of health, Toronto; Dr. J. W. S. McCullough, chief health officer for Ontario; Mr. F. A. Dallyn, C. E., provincial sanitary engineer for the Province of Ontario; Mr. Theodore J. Lafrenière, sanitary engineer, provincial board of health of Quebec; Dr. Allan J. McLaughlin, United States Public Health Service, Washington; Hon. George Clinton, Buffalo; Mr. A. H. Seymour, secretary State department of health, Albany; Mr. Theodore Horton, chief engineer, State department of health, Albany; Dr. Edward Clark, medical health officer, State board of health, Buffalo; Mr. George H. Norton, deputy engineer commissioner, department of public works, Buffalo; Dr. Francis E. Fronczak, health commissioner, Buffalo; Mr. H. A. Whittaker, assistant director, laboratory division, Minnesota State Board of Health; Mr. John W. Hill, State board of health, Cincinnati, Ohio; Dr. Edward Bartow, director State water survey, Urbana, Ill.; Mr. W. M. Mills, president Niagara Frontier Pure Water Conference, North Tonawanda, N. Y.; Dr. W. G. Palmer, member of the Niagara Pure Water Conference, North Tonawanda; and Mr. Irving L. Pruyn,

Oneonta, N. Y. Representatives from the health departments of Michigan, Wisconsin, and Pennsylvania, although requested to do so, were unable to attend.

The conference was organized, Mr. A. H. Seymour, secretary of the New York Department of Health, being appointed chairman, and Dr. Allen J. McLaughlin, of the United States Public Health Service, secretary.

The commission requested the advice of the conference as to the points in boundary waters where investigations should be made, the general nature of the investigations at these points, and other matters of detail.

The conclusion was reached that the points of investigation should include Rainy River, St. Marys River, Lake St. Clair, Detroit River, Niagara River, the St. Lawrence River from Lake Ontario to a point as far below the international boundary line as should be thought necessary, the lake waters in the vicinity of Port Arthur, Fort William, and Duluth, the lower end of Lake Huron in the vicinity of Sarnia and Port Huron, the western end of Lake Erie in the vicinity of Cleveland and Port Stanley, the eastern and western ends of Lake Ontario, and sections of the latter lake at Rochester and Toronto. It was contemplated that other points on the boundary outside of the Great Lakes system should be examined if subsequently deemed desirable.

The conference further advised the commission that the investigation should include a bacteriological examination of samples taken, including the bacterial count, the qualitative and quantitative estimation of *B. coli* according to standard methods, and such chemical examination as might subsequently be deemed necessary.

Bacteriological investigation.

In February, 1913, a detailed plan for conducting the investigation in its entirety was adopted, and Dr. Allan J. McLaughlin was employed as chief sanitary expert and director of field work. With him the commission associated Dr. J. W. S. McCullough, Dr. John A. Amyot, and Mr. F. A. Dallyn, C. E. For the sake of convenience these four gentlemen will hereinafter be referred to as "the sanitary experts."

The carrying out of the adopted plan involved what is probably the most extensive bacteriological examination of waters the world has ever known. It embraced Rainy River, parts of Rainy Lake, parts of Lake of the Woods, Thunder Bay in Lake Superior, St. Marys River, Mud Lake, Detour Passage, lower Lake Huron, St. Clair River, Lake St. Clair, Detroit River, the western end of Lake Erie, the central portion of Lake Erie, the eastern end of Lake Erie, Niagara River, the western and eastern portions of Lake Ontario, the St. Lawrence River from Lake Ontario to Cornwall, and the St. John River so far as it forms the international boundary. The num-

ber of sampling points exceeded 1,500, and the number of samples collected at them was over 18,000. The following table shows the location of the laboratories, the waters examined, the dates of the examination, the number of sampling points, and the total number of samples:

Date.	Waterway.	Location of laboratories.	Number of sample points.	Total number samples.
1913.				
July 8–22	Rainy River	Fort Frances, Ont	192	955
July 28–August 15	Lake Superior (Thunder Bay).	Port Arthur, Ont	66	922
June 28–July 16	Lake Superior, St. Marys River.	Sault Ste. Marie, Mich	104	1,065
July 25–August 25	Lake Huron, St. Clair River.	Sarnia, Ont	142	1,606
September–October 10	Lake St. Clair, Detroit River	Windsor, Ont	174	1,755
September–October 3	Detroit River, Lake Erie	Amherstburg, Ont	114	1,306
October	Lake Erie, Port Stanley	Windsor, Ont	51	214
May 26–June 17	Lake Erie, Niagara River	Fort Erie, Ont	133	1,375
May 27–June 12	Niagara River	Niagara-on-the-Lake, Ont.	59	840
April 10–May 23	Lake Ontario, St. Lawrence River.	Kingston, Ont	113	928
May 23–August 27	St. Clair River, Lake St. Clair, Detroit River, Lake Erie.	Detroit, Mich	70	1,812
June 12–July 23	Lake Erie	U. S. revenue cutter "Morrill."	20	480
May 12–July 29	Lake Erie, Niagara River	Buffalo, N. Y	60	1,624
August	Lake Ontario, St. Lawrence River,	Clayton, N. Y	32	482
October	St. John River	Van Buren, Me	32	672
July 3–August 13	Lake Huron, St. Clair River.	Port Huron, Mich	45	720
August 1–August 21	Niagara River, Lake Ontario.	Youngstown, N. Y	42	338
August	St. Lawrence River	Montreal, Quebec	8	480

Points for the collection of samples were carefully located, but positions which might show exceptional pollution at sewer outlets were avoided, except in certain cases where information touching them was desired for special reasons. Owing to the extraordinary amount of navigation on these waters, fixed buoys were not feasible for the purposes of locating sample collection points and the work was carried on by a time and course method, the samples being collected at prescribed time intervals and along definite courses laid down on the charts of the waters. In swift-running water, as in the Niagara, Detroit, and St. Clair Rivers, diagonal courses were necessary in order to give some length to the cross sections and allow sufficient time intervals between the taking of the samples. The various field parties were all furnished with United States War Department maps showing a great deal of the topography of the areas under investigation, and also with copies of the sewer maps for the adjacent municipalities.

In addition to the examination at these points, samples were collected to show the relation between local situations and municipal water supplies and to ascertain the character and extent of the pollution which might be due to vessels navigating boundary waters. Both surface and deep samples were simultaneously taken at certain

points in the St. Clair, Detroit, and Niagara Rivers in order to determine the effect of stratification. While some situations show definite stratification, it may be accepted in interpreting the results that for the waters under investigation surface samples measure directly the extent of bacterial pollution.

The investigations were essentially bacteriological and the work was continued at each sample-collection point during a period of time sufficient to observe the quality of water, irrespective of minor variations.

Other data collected.

Besides this bacterial examination, some float and temperature observations were made and inquiries were carried on and data collected and compiled as to area, population, location of water-supply intakes, quantity of sewage discharged, for each of the several municipalities in the areas under investigation.

Meteorological data relative to the several points of investigation for the periods of examination were furnished by the meteorological departments of the United States and Canada, and the State and provincial health bodies assiduously supplied the commission with such vital statistics as were available. From these statistics the death rate from typhoid fever per 100,000 has been computed for each of the municipalities either abstracting water from or draining into the boundary waters.

The immense amount of information thus gathered and presented to the commission appears in the report of the sanitary experts. Maps were prepared to show the location of sample collection points, and charts and tables to show the bacterial counts, *B. coli* averages per 100 cubic centimeters for each of the sample collection points, together with the dates of collection and the maximum amounts encountered during the period of examination. This material was published with the progress report of the commission under date of January 16, 1914.[1]

Investigations at sittings of commission.

With the object of obtaining information in addition to what had been gathered by the sanitary experts in their exhaustive investigation, the commission held sittings at many places along the border and took the evidence of a large number of people who were acquainted with the insanitary conditions of several of the districts affected by pollution. Members of the commission also personally examined most of the points where pollution was strongly complained of.

Messrs. Streeter and Powell, as a committee of the commission, took evidence at Buffalo in the month of June, 1913, touching the

[1] Progress report of the International Joint Commission on the reference by the United States and Canada in re the Pollution of Boundary Waters. Including report of the sanitary experts. 1914.

extent of pollution in the Niagara River and the effect of this pollution upon the riparian towns on the United States side of the river.[1] Subsequently, during the months of September, October, and November, 1914, and the months of June and August, 1916, meetings of the commission, at which the pollution of boundary waters was inquired into, were held at a number of places along the Niagara, Detroit, and St. Clair Rivers.[2, 3]

Conference with sanitary engineers at New York.

In order that the commission should, in a matter of such vital importance as was being investigated, know the attitude of leading exponents of sanitary science, it prepared and submitted a series of questions to a number of sanitary engineers of large experience and wide reputation in the United States and Canada, namely: Mr. George W. Fuller, of New York City; Prof. Earle B. Phelps, of the United States Public Health Service; Mr. George C. Whipple, of Harvard University; Mr. W. S. Lea, of Montreal; Mr. T. J. Lafrenière, of the Provisional Board of Health of Quebec; and Mr. F. A. Dallyn, of the Provincial Board of Health of Ontario. These six engineers afterwards, on the invitation of the commission, attended a conference with it in the city of New York.[4] They are hereafter referred to as the "advisory engineers." Some days were spent in their examination, but the lengthy testimony they gave was condensed by them into a résumé of 14 points, as follows:[5]

Résumé of testimony.

1. Speaking generally, water supplies taken from streams and lakes which receive the drainage of agricultural and grazing lands, rural communities, and unsewered towns are unsafe for use without purification, but are safe for use if purified.

2. Water supplies taken from streams and lakes into which the sewage of cities and towns is directly discharged are safe for use after purification, provided that the load upon the purifying mechanism is not too great and that a sufficient factor of safety is maintained, and, further, provided that the plant is properly operated.

3. As, in general, the boundary waters in their natural state are relatively clear and contain but little organic matter, the best index of pollution now available for the purpose of ascertaining whether a water-purification plant is overloaded is the number of *B. coli* per 100 cubic centimeters of water expressed as an annual average and determined from a considerable number of confirmatory tests regularly made throughout the year.

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[1] Preliminary report of committee having general supervision of the investigation relating to the pollution of boundary waters; with documents * * * relating to the petitions of the Erie and Ontario Sanitary Canal Co. for permission to divert 6,000 second-feet from Lake Erie. 1913.

[2] Hearings of the International Joint Commission in re remedies for the pollution of boundary waters between the United States and Canada. 1914.

[3] Hearings of the International Joint Commission in re remedies for the pollution of boundary waters between the United States and Canada. 1916.

[4] Conference with sanitary engineers at New York City, May 26 and 27, 1914.

[5] Résumé of testimony of consulting sanitary engineers in the matter of the pollution of boundary waters, New York, 1914.

4. While present information does not permit a definite limit of safe loading of a water-purification plant to be established, it is our judgment that this limit is exceeded if the annual average number of *B. coli* in the water delivered to the plant is higher than about 500 per 100 cubic centimeters, or if in 0.1 cubic centimeter samples of the water *B. coli* is found 50 per cent of the time. With such a limit the number of *B. coli* would be less than the figure given during a part of the year and would be exceeded during some periods.

5. In waterways where some pollution is inevitable and where the ratio of the volume of water to the volume of sewage is so large that no local nuisance can result, it is our judgment that the method of sewage disposal by dilution represents a natural resource and that the utilization of this resource is justifiable for economic reasons, provided that an unreasonable burden or responsibility is not placed upon any water-purification plant and that no menace to the public health is occasioned thereby.

6. While realizing that in certain cases the discharge of crude sewage into the boundary waters may be without danger, it is our judgment that effective sanitary administration requires the adoption of the general policy that no untreated sewage from cities or towns shall be discharged into the boundary waters.

7. The nature of the sewage treatment required should vary according to the local conditions, each community being permitted to take advantage of its situation with respect to local conditions and its remoteness from other communities, with the intent that the cost of sewage treatment may be kept reasonably low.

8. In general, the simplest allowable method of sewage treatment, such as would be suitable for small communities remote from other communities, should be the removal of the larger suspended solids by screening through a one-fourth inch mesh or by sedimentation.

9. In general, no more elaborate method of sewage treatment should be required than the removal of the suspended solids by fine screening or by sedimentation, or both, followed by chemical disinfection or sterilization of the clarified sewage. Except in the case of some of the smaller streams on the boundary, it is our judgment that such oxidizing processes as intermittent sand filtration and treatment by sprinkling filters, contact beds, and the like, are unnecessary, inasmuch as ample dilution in the lakes and large streams will provide sufficient oxygen for the ultimate destruction of the organic matter.

10. Disinfection or sterilization of the sewage of a community should be required wherever there is danger of the boundary waters being so polluted that the load on any water-purification plant becomes greater than the limit above mentioned.

11. It is our opinion that, in general, protection of public water supplies is more economically secured by water purification at the intake than by sewage purification at the sewer outlet, but that under some conditions both water purification and sewage treatment may be necessary.

12. The bateriological tests which have been made in large numbers under the direction of the International Joint Commission indicate that in most places the pollution of the boundary waters is such as to be a general menace to the public health should the water be used without purification as sources of public water supply or should they be used for drinking purposes by persons traveling in boats.

13. It is our judgment that the drinking water used on vessels traversing boundary waters should not be taken indiscriminately from the water traversed, unless subjected to adequate purification, but should be obtained preferably from safe sources of supply at the terminals.

14. While recognizing that the direct discharge of fecal matter from boats into the boundary waters may often be without danger, yet in the interest of effective sanitary administration it is our judgment that the indiscriminate discharge of unsterilized fecal matter from vessels into the boundary waters should not be permitted.

These views of the advisory engineers were given after most mature consideration on their part, and not only have they been of great assistance to the commission in arriving at the conclusions and recommendations expressed in this report, but their thoroughness and exhaustiveness have been recognized by scientists on this continent and in Europe, frequent applications having been made to the commission for copies of both the testimony and the résumé.

Engineering investigations.

It was necessary that the commission should form some reliable estimate of the cost of installing the requisite remedial works, and it determined to carry on its investigations in such detail that the engineering possibilities and difficulties would be fully considered and the cost of the ultimate projects determined within reasonably close limits. Prof. Earle B. Phelps, of the United States Public Health Service, was engaged as the commission's consulting engineer and was put in charge of the investigation. Engineering offices were established at Detroit and Buffalo, each office comprising a small but well-organized force, under Prof. Phelps' supervision, but in immediate charge of a district engineer. The Detroit office had charge of the investigation in the cities and towns bordering upon the St. Clair and Detroit Rivers, and the Buffalo office had charge of the investigation along the Niagara River. The investigations covered the following cities and towns:

In the United States: Port Huron, St. Clair, Marine City, Algonac, Detroit, River Rouge, Ecorse, Ford City, Wyandotte, Trenton, Lackawanna, Buffalo, Tonawanda, North Tonawanda, Lasalle, Kenmore, Niagara Falls, Lewiston, and Youngstown.

In Canada: Sarnia, Ford, Walkerville, Windsor, Sandwich, Amherstburg, Fort Erie, Bridgeburg, Chippewa, Niagara Falls, Queenston, and Niagara-on-the-Lake.

All of these cities and towns were asked to assist in the investigations in which they were respectively concerned. The examinations at Detroit and Buffalo were of much greater magnitude than the others, and this fact, coupled with the wish of the commission that these cities should be associated with the investigation in which they were interested, led to an invitation being extended to their officials to collaborate with the consulting sanitary engineer in the prosecution of his work; and the commission expresses its apprecia tion of their sympathetic and efficient cooperation.

Cooperation of public authorities.

On December 5, 1914, Detroit appointed Mr. Clarence W. Hubbell, a consulting sanitary engineer, to review the data and the conclusions of the commission's sanitary experts, and to report what means, if any, should be adopted by the city for the purification of its sewage, and to what extent it would be justified in incurring expense for that purpose. Mr. Hubbell's office cooperated most closely with the commission's Detroit office during the whole period of the investigation so far as the work related to Detroit; and the commission is pleased to report that his recommendations to the city and the recommendations of the consulting engineer of the commission are in substantial accord. Buffalo furnished office space and equipment for the commission's staff at that city and furthered the progress of the investigation by supplying all information in its possession and by rendering valuable assistance to the commission's engineers, in addition to making readily available all city maps and documents required.

The commission also expresses its satisfaction with the readiness and promptness with which the smaller cities and towns furnished the maps, data, and information in their possession. The Provincial and State health authorities also afforded the commission's engineers valuable assistance by providing them with maps and data in their possession relating to the sewerage systems of those cities and towns. This was particularly the case in the Province of Ontario. The reports of the Chief of Engineers of the United States Army supplied hydraulic data of great importance, especially the data dealing with Great Lakes levels, river discharges, and elevations.

Treatment projects.

The investigations began in March, 1915, and were completed in March, 1916. In carrying them out it was necessary to prepare plans for treatment works adapted to local requirements and sufficient for the general needs of the situation. For economic reasons the consulting engineer adopted the existing sewerage systems as points of departure. When available, sites for treatment works were tentatively determined upon and the necessary collecting systems were planned to bring the sewage to these points. This procedure was necessarily largely experimental, as there were usually several possible and available sites for treatment works and frequently more than one possible system of main drainage. It was also necessary to plan these works with due regard to the future growth of the cities, and consequently in some instances sewer interceptors were planned for sections thereof almost wholly undeveloped. This procedure generally led to the tentative adoption of several major projects, all of them feasible and practicable, but differing in the type of treatment works, in the number and location of the concentration points for treatment, the arrangement of trunk-

line interceptors, and the substitution in some cases of pumping-station plants for deeper interceptor construction. In each case these various projects were worked out in detail, the necessary structures were designed to a point sufficient for comparative cost estimates, and they were then compared upon the basis of cost and general desirability. No attempt was made to exhaust all the possibilities; and it is not assumed that the remedial works planned are the most economic or desirable. Neither time nor funds were available for field surveys, except in some minor instances, such surveys not being considered essential to the work. The engineering investigations were naturally and necessarily much less detailed than would be those in connection with a city about to construct new works. They were, however, in sufficient detail to develop in the case of all cities and towns feasible and workable plans for the collection and treatment of their sewage. The estimated cost is ample for the application of satisfactory remedial measures. Details of the proposed plans for collecting and treating the sewage of the various cities and towns are set forth in the report of the consulting engineer.[1]

Meetings.

As soon as this report was submitted to the commission it was printed, and copies were supplied to the different municipalities along the Niagara, Detroit, and St. Clair Rivers, with an invitation to attend the meetings of the commission held, as before mentioned, at Buffalo and Detroit in June, 1916.[2] At these meetings the remedies suggested by the consulting engineer were discussed with the representatives of the various municipalities interested. A meeting of the commission was also held at Ogdensburg in August, 1916, at which a large number of the municipalities on the upper St. Lawrence were represented by their mayors, city engineers, and health officers.

The commission also devoted considerable attention to the investigation of existing methods of sewage disposal.

[1] Report of the consulting sanitary engineer upon remedial measures, Mar. 8, 1916.

[2] Hearings of the International Joint Commission in re remedies for the pollution of boundary waters between the United States and Canada. 1916.

III.—EXISTING POLLUTION.

The first question in the reference is—

To what extent and by what causes and in what localities have the boundary waters between the United States and Canada been polluted so as to be injurious to the public health and unfit for domestic or other uses?

Sources and extent of pollution.

To enable the commission to answer this question the detailed bacteriological examination hereinbefore described was made by the sanitary experts. A brief epitome only of their report can be given here. An extensive examination was made of the waters in Thunder Bay and White Fish Bay of Lake Superior, the lower end of Lake Huron, and the eastern ends of Lake Erie and Lake Ontario. They were found to be practically free from *B. coli* in 100 c. c. quantities, and to have a bacterial count of less than 10 on agar at 37° C. This, then, is the condition of the water as it enters the St. Marys, St. Clair, Niagara, and St. Lawrence Rivers. The lower portions of Lake St. Clair and Rainy Lake, the sources of the Detroit and Rainy Rivers, respectively, while appreciably polluted by agricultural and other drainage, show a remarkable freedom from extensive bacterial pollution.

The waters of Rainy River, St. Marys River, St. Clair River, and of the Detroit and Niagara Rivers, in consequence of the unrestricted discharge of sewage from vessels and towns, are no longer fit for domestic use unless subjected to extensive treatment in water-purification plants. Below the cities of Detroit and Buffalo the waters of the Detroit and Niagara Rivers, respectively, are so intensely polluted that it is highly questionable whether by the aid of any ordinary purification plant they can be made at all suitable for drinking purposes.

Rainy Lake, Rainy River, Lake of the Woods.

The waters of Rainy Lake, Rainy River, and Lake of the Woods were examined during the period from July 8 to July 22, 1913. In this examination 995 specimens were collected and reported upon. The waters of Rainy Lake, subjected to agricultural drainage, showed a pollution amounting to 19 *B. coli* per 100 c. c., presumably the effect of this drainage, and of the construction of a big fill for railway purposes. The drinking water of the towns of Fort Frances and International Falls is taken from the head of Rainy River, and

was found to be seriously contaminated owing to the discharge of polluting matter in the vicinity of the respective waterworks intakes. Below the falls a very considerable pollution, averaging about 300 *B. coli* per 100 c. c., exists throughout the length of the river. This is mainly attributable to the discharge of raw sewage by these towns. The polluted condition of the river is augmented by drainage from farms and small villages located at intervals along its banks, and markedly by sewage from the towns of Rainy River and Baudette.

An examination was made of the water in the Lake of the Woods in the vicinity of the mouth of Rainy River and showed an average of only 34 *B. coli* per 100 c. c. It appears that the self-purification and dilution had here operated to lessen pollution in the river.

Rainy River throughout its entire course has been rendered unfit for domestic uses owing to the unrestricted discharge of sewage and other wastes. The population along the banks is sparse, with the exception of that of the villages and towns. If subjected to extensive water purification, the river may be used as a source of drinking-water supply.

Thunder Bay.

The waters of Thunder Bay were examined during the period from July 28 to August 15, 1913. In all, 922 samples of water were collected and reported upon. 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.

St. Marys River.

The waters of the St. Marys River were examined during the period from June 28 to July 16, 1913, 1,065 samples being collected and reported upon. The results of the investigation show that Lake Superior at the head of the St. Marys River is practically pure. In White Fish Bay the pollution measures 6.5 *B. coli* per 100 c. c. 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 (Mich.) and Sault Ste. Marie (Ontario). The average pollution at the waterworks intake of the former city during investigation was about 25 *B. coli* per 100 c. c., and at the waterworks intake of the latter over 200 *B. coli* per 100 c. c. Below the towns the pollution was shown to increase to 291 *B. coli* per 100 c. c. A serious condition of the river continues, although in a less pronounced degree, down to Neebish Island.

The pollution present in this river, due to the discharge of raw sewage by vessels and by the two towns of Sault Ste. Marie, affects very seriously the only available water supplies for summer residents and for pleasure boats frequenting its waters. Water examined in the Straits of Mackinac proved to be quite pure.

Lake Huron, St. Clair River, Lake St. Clair.

The laboratories stationed at Port Huron, Detroit, and Sarnia were in operation during May, June, July, and August, 1913, for the examination of the waters of the lower end of Lake Huron, River St. Clair, and Lake St. Clair. In all, 2,336 samples were examined and reported upon. The examination showed that 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. Samples taken about 10 miles up the lake showed absence of *B. coli* even in 100 c. c., while the water at the lower end, where vessel pollution is concentrated, showed an average of 9 *B. coli* per 100 c. c. 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 *B. Coli* content found in the river water exceeding 200 per 100 c. c. The pollution below these towns is due to the combined effects of the discharge of untreated sewage from vessels and the towns along the shores. Any tendency toward self-purification of the river by natural agencies is counterbalanced by the sewage and drainage from the small villages and residences along its course.

Lake St. Clair, which receives the discharge of the river, showed less evidence of pollution. Natural agencies promote in the lake a purification not found in the river.

Detroit River and western end of Lake Erie.

The laboratories for the study of the Detroit River and the western end of Lake Erie stationed at Detroit, Windsor, Amherstburg, and on the United States revenue cutter *Morrill*, were operated during the months of May, June, July, August, September, and October, 1913. Some 5,353 samples were collected and examined, including those taken in the western end of Lake Erie and at the mouth of the Detroit River. The situation with reference to the Detroit River is described by the sanitary experts in their report to the commission in 1914,[1] as follows:

> 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 sewage above these intakes and to a potential danger of climatological variation diverting the intense shore pollution to points from whence it would affect the water intakes. In spite of the efforts made by these towns to protect their supplies by means of chlorination,

[1] Progress report of the International Joint Commission on the Reference by the United States and Canada in re the Pollution of Boundary Waters. Including report of the sanitary experts. 1914.

the typhoid rates remain too high. 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 and totally unfit as a source of water supply. It is our opinion that such raw water would impose an unreasonable responsibility on any known method of purification, even with the most careful supervision. Unfortunately, Wyandotte, Trenton, and Amherstburg are taking their water supplies from this part of the river.

The extensive pollution of the Detroit River is perhaps better indicated by saying that at its head the *B. coli* count is approximately 5 per 100 c. c., and in the lower portions just below Amherstburg it reaches the enormous figure of 10,592 *B. coli* per 100 c. c.

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.

The investigations at the laboratories at Detroit, Windsor, and Amherstburg show that while the waters of the western end of Lake Erie are extensively polluted by the flow of the Detroit River, this pollution does not extend past the islands which separate this end from the remainder of the lake.

Lake Erie.

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. The purity of the main body of the lake was amply established by examination of its water at several widely separated stations.

Niagara River.

The laboratories for the study of the Niagara River established at Buffalo, Port Erie, Niagara-on-the-Lake, and Youngstown were operated during the months of May, June, and July, 1913, 4,137 samples of water being collected and examined. This investigation showed that 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, N. Y.

The effect of the pollution of the lower Niagara is to render the river water totally unfit for domestic uses unless purified. All of the lower municipalities have been forced to install and operate water-purification plants, and the results of their operation show

only too clearly that the use of the water is accompanied by no proper margin of safety.

Lake Ontario.

The investigation revealed the fact that 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, of limited areas at the mouths of other rivers, and of the littoral waters of the lake and of the lanes of vessel travel.

St. Lawrence River.

The laboratories operated at Kingston and Clayton, as well as at Montreal, during the months of April, May, and August, 1913, for the purpose of examining the waters of the St. Lawrence River, collected and examined 1,890 samples.

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. Before the tourists appear in June, with the consequent increase of boat traffic, the waters are in a remarkable state of purity. Below the Thousand Islands population is denser and considerable pollution exists throughout the river, the source of which is the discharge of sewage from vessels and from the riparian communities.

St. John River.

The laboratories stationed at Van Buren in October, 1913, for the study of the St. John River collected and examined 672 samples. The pollution in this river amounted to about 125 *B. coli* per 100 c. c. in the late fall. This is excessive in comparison with the figures in the Detroit and Niagara Rivers, population and stream flow considered. This abnormal condition is attributable in large measure to the potato starch factories located along this river, the waste from which contains large numbers of bacteria capable of fermenting lactose.

Vessel pollution.

Reference has already been made to the numerous vessels navigating boundary waters and their enormous floating population and the pollution resulting therefrom. This pollution not only clearly exists in boundary rivers, in harbors, and in the vicinity of water intakes, but was found to a harmful extent in the Great Lakes, where its presence is due to the fact that vessels navigating lake waters ply in comparatively narrow lanes in order to avoid collision in the nighttime or during fog. Upbound vessels follow one track and down-bound vessels follow another, and the pollution is confined to the vicinity of these lanes.

Pollution from vessels is of two kinds: (1) Raw sewage in the shape of human excreta, garbage, etc., and (2) water ballast discharged by vessels on approaching ports of designation. This pollution is a serious menace to public health, not alone through the possible contamination of the public water supplies near their intakes, but also by reason of its effect upon the water supplies of other vessels following or crossing the same routes.

Sawmill and industrial wastes.

Complaints were made to the commission regarding a form of pollution which is not of a bacteriological character, existing in the St. John and Rainy Rivers. It results from the deposit of sawdust and other sawmill wastes in the streams, frequently causing nuisances by making the shores and bed of the stream unsightly, unclean, and malodorous. This pollution is also injurious to fish life. At International Falls and at Fort Frances objection was also made to the discharge of wastes from the pulp mills on the Rainy River. Like complaints were made with respect to the St. Croix River, which in part forms the boundary line between New Brunswick and the State of Maine. The pollution complained of in the case of the pulp mills was chiefly due to chemical waste resulting from the manufacture of pulp. This form of pollution is also injurious to fish life and the fishing industry. The pollution from sawmill and pulp-mill wastes has in every instance transboundary effects detrimental to property and health.

With the exception of sawmill and pulp-mill wastes no reference has been made to industrial and chemical wastes as a source of pollution. Contamination from these sources is at present so limited and local in its extent that the commission did not regard it as of sufficient moment from an international standpoint to call for any extensive scientific investigation. Unquestionably in the future, unless preventive measures are taken, pollution from all these wastes will have a very injurious effect, and the commission has not been unmindful of this fact in preparing the recommendations hereinafter made.

Typhoid fever statistics.

The grossly polluted condition of boundary waters is doubtless the cause of the abnormal prevalence of typhoid fever throughout the territory bordering thereon.

The table following gives the statistics of death from typhoid fever in the cities and towns therein mentioned for a period of 14 years, beginning with the year 1903:

Typhoid death rates per 100,000 of population.

	1903	1904	1905	1906	1907	1908	1909	1910	1911	1912	1913	1914	1915	1916
Rainy River:														
International Falls, Minn														
Fort Frances, Ontario	665	665	775	96	86	133	66	393	342	0	72	0	0	0
Baudette, Minn														
Rainy River, Ontario	0	0	200	200	0	0	0	0	63	0	0	0	0	63
St. Mary's River:														
Sault Ste. Marie, Mich	115	52	68	59	17	73	56	24	54	23	22	29	7	7
Sault Ste. Marie, Ontario	152	26	150	191	91	68	90	15a	280	85	127	84	24	31
St. Clair River:														
Port Huron, Mich	25	35	15	56	46	21	58	74	48	197	10	0	5	30
Sarnia, Ontario	116	34	33	55	87	110	82	101	148	139	45	26	34	60
etroit River:														
Detroit, Mich	20	17	20	21	25	19	20	23	16	17	29	13	13	15
Walkerville, Ontario	0	47	0	40	0	35	0	0	30	57	25	0	0	0
Windsor, Ontario	30	59	42	41	78	63	56	49	34	38	10	27	35	0
Sandwich, Ontario	122	182	57	54	52	96	47	47	0	173	35	34	35	0
Wyandotte, Mich	(1)	(1)	(1)	72	107	123	87	75	12	54	92	33	47	63
Trenton, Mich		166	0	164	163	80	80	0	163	0	243	0	80	0
Amherstberg, Ontario	0	0	0	83	0	0	40	0	78	118	37	0	42	85
Niagara River:														
Buffalo, N. Y	34	24	24	23	28	20	24	20	25	12				
Fort Erie, Ontario	0	108	0	0	99	0	0	0	87	0	0	0	0	0
Bridgeburg, Ontario	0	0	0	0	0	68	0	0	0	0	56	0	0	0
North Tonawanda, N.Y.				28	46	53	51	42	97	16	15	60	29	36
Niagara Falls, N. Y	127	140	181	150	131	103	87	98	194	67	23	10	0	10
Niagara Falls, Ontario	0	14	0	40	38	84	26	60	90	44	85	34	9	27
Lewiston, N. Y											0	0	0	0
Youngstown, N. Y											0	0	0	0
Niagara-on-the-Lake, Ontario	0	78	78	0	0	0	0	0	0	0	0	0	0	60
St. Lawrence River:														
Cape Vincent, N. Y											0	0	0	0
Kingston, Ontario	100	22	38	38	27	32	32	80	26	32	25	43	28	5
Clayton, N. Y											0	0	0	53
Gananoque, Ontario	55	0	0	0	27	0	0	0	0	0	0	0	0	0
Alexandria, N. Y											0	48	48	0
Brockville, Ontario	66	66	22	109	21	43	32	10	42	64	10	72	162	0
Ogdensburg, N. Y	54	61	40	86	39	32	25	50	31	37				
Prescott, Ontario	0	0	34	34	103	34	0	70	36	0	0	0	0	36
Cornwall, Ontario	30	45	30	90	75	111	64	64	48	61	15	30	77	73

[1] Average for years 1889–1905, 85 deaths.

It may be incidently mentioned that there is a marked improvement in the statistical showing in the period since the commission's investigation in 1913. This is largely attributable to the fact that in consequence of this investigation greater efforts have been made to protect water supplies by the use of bleaching powder and liquid chlorine. The condition, however, is still far from satisfactory. 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.

IV.—TRANSBOUNDARY EFFECTS OF POLLUTION.

This report so far has dealt with pollution generally in boundary waters. The reference as amended calls for a further inquiry into pollution of the waters on one side of the boundary line which may extend to and effect those upon the other side. Some persons who appeared before the commission argued for a literal interpretation of the language of the amended reference and suggested that the only pollution with which the commission is concerned is that which actually crosses the boundary line and has a transboundary effect. While the commission does not accept this narrow interpretation, it must consider the extent to which, and the places at which, pollution has such an effect.

Detroit River.

The most intense and the most clearly demonstrable cases of pollution crossing the boundary exist in the Detroit and Niagara Rivers. 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 enormous 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. Beyond question the pollution from Detroit and the towns lower down the river crosses the boundary line and affects detrimentally health and property on the other side. A notable example of this is to be found in the condition of the shore waters of Bois Blanc Island, a summer resort on the Canadian side of the river which is extremely popular, especially with the inhabitants of Detroit. The island shore waters are very greatly polluted by the sewage from that city. The transboundary effect of this pollution may be estimated from the data given in Tables XII, XIII, and XIV, and the maps opposite pages 38, 39, 40, 41, and 42 of the Progress Report. Transboundary effects are detectable along the lower stretches of the river generally. Owing to the comparative smallness of the towns on the Canadian side, it is not at present possible to trace pollution from them across the boundary, but these towns are growing rapidly, and if they ever attain anything like the size of Detroit or Buffalo, unless successful preventive or remedial measures are adopted, the river will be absolutely unfit for domestic purposes.

Niagara River.

In the Niagara River, owing to the discharge into it by the city of Buffalo of the sewage of an estimated population of 500,000, the waters below the city on the United States side are grossly polluted. This pollution is increased by the sewage from towns on both its banks but particularly from towns on the United States side. Until the Falls are reached the great bulk of the pollution, as has already been stated, is confined to the marginal waters into which it is discharged. At the Falls and in the rapids below the Falls, however, the waters are thoroughly intermixed; and the entire river from the whirlpool to Lake Ontario shows an intense pollution from shore to shore and from the surface to the bed of the stream. The flow of such an enormous quantity of grossly polluted water into the lake contaminates its waters for a radius of about 18 miles from the river's mouth. The intensity of this pollution may be judged from the data given in Table XIX on page 48 and on the map facing that page of the progress report. This map shows that the maximum average of *B. coli* per 100 c. c. at several points in this polluted area of the lake during the period of examination by the sanitary experts was 10,000. The Canadian area of this portion was found to be much more densely polluted than the United States area, the map showing at some points in the former, distant about 10 miles from the mouth of the river and about 6 miles from the international boundary line, a maximum average count of 1,000 *B. coli* per 100 c. c.

Rainy, St. Marys and St. John Rivers.

There is a well-marked crossing of pollution from one side to the other in the case of the Rainy River, the St. Marys River, and the St. John River, although much less pronounced than in the cases of the Detroit and Niagara.

Other boundary rivers.

In the remaining boundary rivers pollution does not exist to as great an extent as in the Niagara and Detroit; and its transboundary effect, where such effect exists, is not easy of detection. The communities along their banks which have sewerage systems all discharge raw sewage into the streams. It was contended that the polluting material discharged into them "hugs their shores," and while the effect may be very harmful to the health and property of lower communities on the same side of a river, its effect upon the waters on the other side of the boundary may be, and in the case of the larger rivers is, practically nil. In judging of the transboundary results of pollution people are ordinarily influenced by the lack of palpable effect at or near the point where the sewage is discharged. In all of the boundary waters, notwithstanding the disposition on the part of the urban sewage they receive "to hug the shore" (assuming

there is such a disposition), winds, cross currents, eddies, rapids, shoals, reefs, ice jams, differences in specific gravity between the sewage and the water of the streams, the form and varying courses of the channel, and the churning of the waters by the propellers of steamboats may, and in some cases do, cause such a commingling and diffusion of their waters that the pollution originating on one side is carried to some extent to the other side of the stream, although the contaminating element may be so colorless as not to be detectable by the eye. Even in cases where transboundary evil results can not be proved the probability of the pollution on one side passing over or affecting the waters on the other side of the boundary line is so great that the inhabitants on the latter side should not be forced to run the consequent risk to life, health, and property. The idea is deeply rooted in the minds of many that running water always purifies itself. This belief was put forward by some as a reason why no action should be taken in respect to these rivers. Undoubtedly water does purify itself if it receives no accretions of contamination and runs in its course a sufficient length of time. The banks of these remaining boundary rivers are generally densely peopled, and the communities along their course discharge their sewage untreated into them, thus more than counteracting this cleansing or purifying influence.

The Great Lakes.

The waters of the Great Lakes constitute a class by themselves, and except at the points where the Niagara and Detroit Rivers enter Lake Erie and Lake Ontario, respectively, there is no pollution in them which crosses from one side of the boundary line to the other, except it may be vessel pollution. This is clear when the condition of the central portions of the lakes is considered. Outside of a margin along their shores and the polluted areas at the mouths of the rivers tributary to them, these waters are, with the exception of places where pollution from vessels exists, in their pristine purity. Take Lake Ontario and Lake Erie for examples. Notwithstanding the facts that these lakes are fed entirely by streams more or less polluted, including the Niagara and Detroit Rivers, with their immense flow of extremely contaminated water, and that there is poured into them the raw sewage of several very large cities and towns, so efficacious is the self-purifying power of water that, with the exception of this littoral margin and of those limited areas at the mouths of the tributary rivers, their waters, when unaffected by vessel pollution, are absolutely pure. This condition is an interesting one. The purifying power of nature, assisted by time, accomplishes here what human agencies and human resources find it impossible to duplicate.

Transboundary effects of vessel sewage.

Vessel sewage, which was found on examination by the sanitary experts to be a much greater factor in polluting boundary waters than is generally supposed, is a matter of great international moment, and must be referred to in this connection. The commission does not commit itself to any view of the fiction or theory of vessel territoriality, which has been much discussed by writers of international law, but a vessel may, and for the purpose of this investigation the commission thinks should, be looked upon as a portion of the territory of the State from which she hails or in which she is registered. If sewage is discharged by a vessel on her own side of the boundary and then passes over the line, and there affects harmfully health and property, the treaty is violated both in letter and in spirit. Is violation of the treaty, however, limited to cases of this kind? The words of the treaty are broader than the language of the reference. The latter, taken literally, deals with pollution in boundary waters on one side of the boundary, which extends to and affects the waters on the other, or which, in other words, has both a transboundary extension and a transboundary effect. To bring pollution within the treaty it need only have one of these features—a transboundary effect.

It might not be straining too much the language of the treaty, "health and property on the other" (meaning the other side of the boundary line), to regard it as indicative of national ownership or sovereignty rather than location. This construction, for instance, would prohibit the pollution of Canadian boundary waters that might injure citizens of the United States who for the time being were exercising their treaty right to free and open navigation of these waters, and would also prohibit pollution of the United States boundary waters by Canadian vessels discharging their sewage therein. If the language is susceptible of this interpretation, such a construction would certainly be consonant with the spirit of the treaty.

Independently of the point whether this construction is or is not warranted, the relations of the United States and Canada, especially with regard to boundary waters, demand that the question of their pollution should be treated on the broadest possible lines.

International situation along boundary waters.

The international situation along the boundary line is a phenomenal one. Not only is it one of the most vital practical importance to each country, but it is one on which each nation may felicitate itself as affording a great object lesson to the world, showing how two liberty-loving, morally directed, and law-abiding peoples can live side by side in the spirit at once of friendly rivalry and perfect peace. Along the thousand miles of their territorial contact from the At-

lantic to the Pacific there is nothing which suggests the existence of enmity or the possibility of military strife. The provision of the treaty of Ghent that "there shall be a firm and universal peace between His Britannic Majesty and the United States, and between their respective countries, territories, cities, towns, and people of every degree, without exception of places or persons," has happily fair promise of perpetual observance. Practically the two peoples commingle with all the freedom consistent with the physical and political barriers which separate them. This condition has led to an interweaving of interests which makes the bond between them one of more than international comity. The treaty right of navigation is exercised at present to an enormous extent, and in the future will be exercised to a still greater extent. Along the boundary waters the citizens of both countries fraternize socially, select and patronize their summer resorts, invest their capital and engage in industries and enterprises, almost without regard to territorial sovereignty. Such freedom of intercourse, however laudable, has the attendant danger of being conducive to the spread of disease and infection if either country fails to observe sanitary principles. 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.

V.—INJURY TO HEALTH AND PROPERTY WITHIN THE MEANING OF THE REFERENCE.

Language of reference and treaty.

The commission having ascertained the necessary facts, both as to the extent and effects, including the transboundary effects, of existing pollution, was confronted with the very difficult problem of deciding whether or not the effect of this pollution was an "injury" to health and property within the meaning of the reference. From the language of the second question in the reference it is evident that the object which the two Governments had in view in making the submission was, as has been previously stated, to see that the treaty was observed in its integrity. This object is expressed as follows:

> In order * * * to fulfill the obligations undertaken in Article IV of the treaty.

Article IV, so far as it is necessary to quote it, reads as follows:

> It is further agreed that the waters herein 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.

The controlling words of this prohibition are "to the injury of health or property on the other." It is necessary to consider the meaning which is to be attached to the word "injury." Does it mean simply harm or damage, actual or potential, to health or property, without regard to any extrinsic considerations, such as justification or excuse on the part of those who cause the damage or ease of avoidance on the part of those who suffer from this harm or damage? It appears to the commission that a broader and more liberal view should be taken than would suggest an affirmative answer to this question. It is necessary to consider the language of the reference and of the treaty, and also the law and practice of both countries with respect to the pollution of waters.

Pollution of water courses at common law.

The common law respecting rights in streams is admirably set forth in the leading textbooks of both countries on "waters," and is especially well summarized by Lord Macnaghten in the case of *Young* v. *Sankier Distillery Co. et al.*, decided by the British House of Lords in 1893.[1]

> A riparian proprietor is entitled to have the water of the stream, on the banks of which his property lies, flow down as it has been accustomed to flow down to his property, subject to the ordinary use of the flowing water by upper pro-

[1] Appeal cases, House of Lords and Judicial Committee of the Privy Council, 1893, p. 698.

prietors, and to such further use, if any, on their part in connection with their property as may be reasonable under the circumstances. Every riparian proprietor is thus entitled to the water of his stream, in its natural flow, without sensible diminution or increase and without sensible alteration in its character or quality. Any invasion of this right causing actual damage or calculated to found a claim which may ripen into an adverse right entitles the party injured to the intervention of the court.

These principles are applicable to public bodies as well as private persons. While private rights, however, may be overridden by the acquisition of a prescriptive right, public rights can not. Without exception the riparian communities which pollute the waters of the boundary rivers do so in violation of the principles of the common law.

Inadequacy of common law.

It must be observed, however, that the circumstances under which these principles were evolved have greatly changed, and the physical features of the boundary rivers differ very much from those of the streams of England, where the common law originated. When settlements had been made along our boundary waters to an extent that urban communities commenced to grow, and sewerage systems in consequence of this growth began to be installed, such was the immensity of these rivers that settlers living farther down stream probably neither noticed nor protested against the discharge into them of what was relatively an infinitesimal amount of pollution. When these communities, therefore, installed sewerage works they took advantage of the diluting powers of the rivers, and resorted to the simple and inexpensive expedient of discharging into them their sewage in its raw condition. The custom of doing so has now become universal. The selfishness of vested interests, familiarity with evil conditions, which has begotten an indifference to both the doing and the suffering of wrong, an ill-directed spirit of economy averse to the assumption of financial burdens to remedy what was only regarded as an existing or potential evil to other communities, and the disinclination to change ingrainted in humanity, have resulted in a situation along the frontier which is generally chaotic, everywhere perilous, and in some cases disgraceful. The common law having proved inadequate to the task of controlling affairs, it has been supplemented or superseded by legislative enactments, which in their practical working have about as signally failed.

Changed nature of problem of "injury."

The great difficulty is that in the United States and in Canada, as in all countries, in fact, modern development, social and economic, has introduced a number of new elements into the question of sewage purification which call for the reconsideration of views and methods which have fallen into disuse.

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, which contains the following provisions:

> The following order of procedure shall be observed among the various uses enumerated hereafter for these waters (meanng boundary waters), and no use shall be permitted which tends materially to conflict with or restrain any other use which is given preference over it in this order of procedure:
>
> 1. Uses for domestic and sanitary purposes.
>
> 2. Uses for navigation, including the service of canals for the purposes of navigation.
>
> 3. Uses for power and for irrigation purposes.

"Injury" a complex question.

Although this order of procedure is in respect to certain uses enumerated in this particular article, it may be taken as indicative of the view of the high contracting parties regarding the importance of sanitation. Notwithstanding this, the discharge of sewage into streams can not be looked upon exclusively from the standpoint of its harmful effects upon health and property. The reference itself does not so look upon pollution. One of the questions in its second branch is, "By what means or arrangement can * * * a system or method of rendering these waters sanitary and suitable for domestic and other uses be best secured and maintained in order to insure the adequate protection and development of all interests involved on both sides of the boundary?" The growth and development of riparian communities would be seriously arrested if pollution were looked upon from this standpoint exclusively. While public health is the paramount consideration, it must be looked upon, however, as only one of a large number of elements in the many-sided and complex question of the public weal.

The pollution of rivers in England has been the subject of investigation by royal commissions which have been studying the question very thoroughly and almost continuously for about 50 years. Their investigations have covered nearly all the rivers of England and practically all the various phases of the problem of river contamination, and the voluminous reports submitted by them from time to time are very valuable and deserving of careful study. The conclusions and recommendations made in these reports, while recognizing sanitary considerations as first in order of precedence, are based upon the implied assumption that the solution of the problem lies in the proper balancing of the various conflicting elements existing in the individual cases.

"Injury" as between lower and upper communities.

The parties who appeared before the commission discussed the question of "injury" almost entirely as viewed from two standpoints: First, from the standpoint of the relation between the riparian communities which pollute the waters of the streams and those communities which suffer in consequence of the pollution of their water supply; and, second, from the standpoint of the agriculturists, the floating population of summer resorts, casual visitors, picnickers, campers, yachtsmen, and crews and passengers of vessels frequenting boundary waters.

The difficulties arising from viewing the situation from the first standpoint will appear by considering the supposititious case of town "A" and town "B," the first town being situate above the other on the same bank of a boundary stream, the former discharging raw sewage from its sewerage system into the river, the latter being obliged to drink the water thus contaminated or to purify it at its own expense. To compel "A" to purify its sewage absolutely or completely would, under present conditions and in the present state of sanitary engineering practice, involve a financial burden too great for that town to bear, a burden which might retard its progress both industrially and in respect to population. On the other hand, to permit "A" to relieve itself of any reasonable financial burden by throwing its raw sewage on the waterworks intake of "B" and thus compelling that town either to drink contaminated water, or to assume an unreasonable financial burden in purifying it, would be an act of injustice which no fair-minded community, with a proper appreciation of the evil inflicted, would perpetrate or continue, and one to which no community should be asked to submit. If the harm which would be done "B" could be remedied, however, by the assumption of a financial burden which would be reasonable under all the circumstances of the case, there would not be an "injury" within the meaning of the reference or the treaty.

"Injury" from the standpoint of summer residents, etc.

From the second standpoint, that of the agriculturist, the floating population of summer resorts, etc., the question of "injury" under the reference is a much more difficult one. The shores and islands of the boundary rivers and lakes must particularly be considered. Their scenic attractions, their pure air and salubrious climate, their opportunities for bathing, fishing, and yachting, and their ease of access, affording facilities for rest, enjoyment, and health restoration to unlimited numbers, are invaluable assets, factors in progress and civilization which should not, unless under the pressure of absolute necessity, be destroyed. The harm done by existing pollution to bathing resorts can not 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. Such systems have been installed by sanitary engineers and generally afford a reasonably pure drinking water. These classes, however, have no such protection and it is difficult to devise adequate means of protection which they could utilize. The fact that they consist in a large measure of children, especially at the summer resorts, must also be taken into account. What would, therefore, be an "injury" to them might not be an "injury" to riparian communities with water-purification systems.

Definition of "injury" as used in the reference.

The commission regards the word "injury" when used in the reference or treaty as having a special signification—one somewhat akin to the term 'injuria' in jurisprudence. It does not mean mere harm or damage, but harm or damage which is in excess of the amount of harm or damage which the sufferer, in view of all the circumstances of the case, and of all the coexistent rights (if it be permissible to use the term in this connection), and of the paramount importance of human health and life, should reasonably be called upon to bear.

"Injury" in Detroit and Niagara Rivers.

In the case of the Detroit and Niagara Rivers pollution exists on one side of the boundary line which unquestionably is an "injury" within the meaning of the treaty to health and property on the other.

"Injury" in Rainy and St. John Rivers.

In the case of the Rainy River and the St. John River, pollution also exists on one side of the boundary line which is an "injury" within the meaning of the treaty to health and property on the other.

In the case of these four rivers the pollution is transboundary both in its effect and extension.

In the case of the other boundary rivers the commission is unable to say that at the present time pollution does exist on either side of the boundary line to the injury of property upon the other, although it is of the opinion that at times it does. As populations along their banks grow, pollution having both transboundary extension and transboundary effect will doubtless increase.

In the division of this report which treats of pollution having transboundary effects a broader view of the question of pollution is taken than the literal words of the reference and treaty might be thought to justify. In the broad view there expressed pollution exists throughout the whole range of boundary waters, which is an "injury" to health and property in both countries, and comes within the spirit of the prohibition of Article IV of the treaty. It is now necessary to consider the limits of permissible pollution, or the extent to which pollution which might cause this "injury" should be restricted.

VI.—LIMITS OF PERMISSIBLE POLLUTION AND STANDARDS OF SEWAGE PURIFICATION.

Two distinct lines of policy with regard to the disposition of sewage in boundary waters were suggested to the commission. (1) To look upon them as open sewers for the reception of riparian pollution of all kinds, and (2) to restore the purity of the boundary waters as far and as fast as a comprehensive and adequate appreciation of all interests involved will permit.

The first policy would not only be contrary to the treaty and the principles of international law, but the continued discharge of untreated sewage into boundary waters by either country would, in the case of the Niagara and Detroit Rivers especially, be increasingly injurious to its own riparian communities farther downstream.

The advisory engineers in their résumé, which has already been set forth in full in this report, say:

Opinion of advisory engineers. "A" as to the discharge of raw sewage in boundary waters.

> While realizing that in certain cases the discharge of crude sewage into the boundary waters may be without danger, it is our judgment that effective sanitary administration requires the adoption of the general policy that no untreated sewage from cities or towns shall be discharged into the boundary waters. (Sec. 6.)

"B" as to feasibility of purifying water after pollution.

> Water supplies taken from streams and lakes into which the sewage of cities and towns is directly discharged are safe for use after purification, provided that the load upon the purifying mechanism is not too great and that a sufficient factor of safety is maintained, and further provided that the plant is properly operated. (Sec. 2.)

"C" as to utilizing streams for dilution.

> In waterways where some pollution is inevitable and where the ratio of the volume of water to the volume of sewage is so large that no local nuisance can result, it is our judgment that the method of sewage disposal by dilution represents a natural resource and that the utilization of this resource is justifiable for economic reasons, provided that an unreasonable burden or responsibility is not placed upon any water-purification plant and that no menace to the public health is occasioned thereby. (Sec. 5.)

This "burden or responsibility" is a very important element to be considered in arriving at a standard of purification or the limits of permissible pollution.

"D" as to the load of purification plant.

The advisory engineers were interrogated very fully on this subject at the New York conference and were pressed to define this limit in as exact terms as possible. Their answer is contained in the fourth section of their résumé:

> While present information does not permit a definite limit of safe loading of a water-purification plant to be established, it is our judgment that this

limit is exceeded if the annual average number of *B. coli* in the water delivered to the plant is higher than about 500 per 100 cubic centimeters, or if in 0.1 cubic centimeter samples of the water *B. coli* is found 50 per cent of the time. With such a limit the number of *B. coli* would be less than the figure given during a part of the year and would be exceeded during some periods.

Commission's recommendations.

It is scarcely necessary to remark that the engineers are speaking of bacterial pollution only. In view of the present stage of progress in sanitary science, this limit or standard must be regarded as tentative. Their evidence shows that they regarded the question as profoundly affected by conditions and in no sense capable of absolute generalization. The commission agrees with the statement of principles set forth in these four sections. It therefore recommends that all sewage should, before being discharged into boundary waters, receive some purification treatment, and the degree of such treatment is to be determined in a large measure by the limits of safe loading of a water-purification plant.

To determine the extent of remedial treatment required in each particular case would involve consideration of the varied lines that have been followed by the commission throughout the present inquiry; the existence of pollution and of harm, actual or potential, to domestic or other uses, to public health, or property; the results of the engineering studies of feasible remedies; and the economic facts relating to the conservation of stream resources. It would require the balancing of the value of remedial measures in the terms of public good against the cost of the requisite improvements.

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. These make impossible the recommendation of such lenient remedial measures as would work economic injustice or would indorse officially the continued spoliation of a natural resource to the injury of the citizens upon both sides of these waters.

On the other hand, sewage-treatment requirements must not be made so excessive and unreasonable as to involve the cities and towns along these waters in an expenditure entirely unjustifiable. They should be reasonable and feasible from the standpoint of engineering construction, of adaptability to local conditions, of the availability of necessary lands, of outfalls and incident structures, and of costs.

In view of the fact that pollution in the Detroit and Niagara Rivers, and its transboundary effects therein, are much greater than in the other boundary waters, these two rivers will be treated as one class and the remaining boundary waters as another class.

The problem of necessary bacterial purification of the sewage discharged into the two former is one of extreme perplexity, owing to the difficulty or impossibility of obtaining definite and ample data

and the relative importance to be attached to many of the factors which enter into it.

After a great deal of consideration the commission has, in view of all the circumstances of the case, come to the conclusion that for the present, and as an immediate step in the way of restoration of the purity of these streams, the communities responsible for the discharge of raw 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.

In other words, the standard of purification required of these communities should be such that the streams after receiving their treated sewage would have a mean annual cross-sectional average of *B. coli* not exceeding 500 per 100 c. c.

Compliance with the requirements of this standard would not impose upon the riparian communities along these rivers discharging their sewage therein a burden which would be unreasonable or greater than that ordinarily imposed upon urban communities which purify their sewage.

Both water and sewage standards tenative.

It necessarily follows that this standard of sewage purification, being based upon a tentative standard of safe loading of water-purification plants, must itself be tentative. The growing appreciation of sanitation, the consequent demand for a higher degree of purity in water supplies, and the constant improvement that is taking place in the processes of sewage treatment tend to make a proper standard of sewage purification one of ever-increasing stringency. The discovery of a new and much more economical, or possibly a profitable, method of disposal of sewage, for example, would naturally lead to the adoption of a stricter standard of permissible pollution in heavily polluted streams. Furthermore, any limit of permissible impurity that might be established even temporarily for a given stream must be influenced largely by strictly local considerations.

The data necessary for the formulation of a fixed standard either of sewage purification or of water purification are not sufficiently well established at the present time. By more precise methods of experimental study there will doubtless be obtained in the future a more ample and accurate command of facts, which will admit of the determination of a more definite standard.

Better working rule required than bacterial standard.

In view of the difficulties and uncertainties of bacteriological technique, it is distinctly advantageous to have, if possible, a working rule which is more accurate and readily determinable than the bacterial standard suggested. Prof. Phelps, the consulting engineer, taking the results of the extensive investigations reported upon in the Progress Report as an index of the conditions actually

existing, worked out, as will appear from his calculations on page 9 of his report to the commission, such a rule or standard.

He found that if the sewage of the cities be diluted in a stream flow of 4 cubic feet per second, per capita of the population, the resulting water will contain approximately 500 *B. coli* per 100 c. c. If the dilution is proportionately less than this, a corresponding degree of purification of the sewage will be necessary to maintain this final stream condition. Further investigations will no doubt make possible a more accurate statement of these relations, but, as the entire matter of standards is always subject to revision in the light of accumulated knowledge, it is considered that for all purposes of a present inquiry the practical equivalence of the dilution and the bacteriological standards may be accepted.

The case of boundary rivers standard of sewage purification in other rivers.

These standards are not applicable to rivers other than the Niagara and Detroit, but it is in no sense to be inferred, however, that remedial or protective measures are not required in their case where the effect of pollution based upon the entire cross section of the streams exceeds in every instance 4 feet per second per capita of the population.

As has been stated, the view of the advisory engineers is adopted that no untreated sewage should be discharged into boundary waters, but the commission considers it inadvisable at the present time to prescribe what the amount of treatment should be in the case of these remaining rivers. The sewage from each community along their banks must be considered by itself in respect of the degree of purification that is necessary, basing the standard on the reasonable use of the waters, the practical possibilities of remedial and protective measures, the economic value of stream purification, and also the economic value of stream pollution, proper regard being had to the public health.

After giving much attention to the question of standards of purification in these six boundary rivers the commission has come to the conclusion that the fixing of standards for them, and the subsequent modifications of those standards from time to time, should be left as hereinafter recommended to some authority clothed with the necessary power to deal with the question. This authority should also have power to vary, from time to time as conditions demand, the standards of sewage purification in the Detroit and Niagara Rivers.

VII.—REMEDIAL TREATMENT REQUIRED.

The second branch of the reference is concerned with remedying and preventing pollution in boundary waters.

Second branch of reference.

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 insure 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?

Attitude of municipalities.

The question of securing treatment of the sewage discharged into boundary waters is one in respect of which, fortunately, the communities responsible for the pollution are inclined to take a reasonable view. At several meetings held by the commission the representatives of the various communities interested generally recognized the intolerable condition of boundary waters from a sanitary standpoint, and expressed their assent to any reasonable remedial measures the commission might suggest. Some objections were made to any disturbance of the existing order of things, but the commission was pleased with the sympathetic reception generally met with in dealing with this problem.

In this connection the following extract is given from the report made by Mr. Clarence W. Hubbell, consulting sanitary engineer of the city of Detroit, in November, 1916. It is at one and the same time the expression of the opinion of a well-known sanitary engineer and an evidence of the commendable attitude taken by him and the city of Detroit with respect to sewage purification.

In regard to the second part of the problem, as to what expense would be justified for sewage treatment, it is difficult to formulate an answer in terms of money alone. However, it is believed that, aside from the international features of the problem, the combined benefits which would accrue from a more cleanly water front, purer water at the bathing beaches and summer playgrounds, reduction in typhoid and other water-borne diseases, due to the use of sewage-laden water along the river front; betterment of raw-water supplies for the municipalities below the city, and the protection of Detroit's

water from gross sewage pollution at times when the Detroit River flows backward, amply justify the expenditure required for sewage-treatment works as above outlined. In round figures, the cost would be about $6,000,000, and in my judgment the expenditure of this sum would be justifiable.

The duty devolving upon the commission in answering the first question contained in this branch of the reference is not to lay down any particular scheme of remedial works which the communities interested should adopt, but to ascertain whether or not there is any means by which the pollution of boundary waters can be prevented or remedied which is at once practicable and within their financial ability. Subject to the requirement that the remedial works should be ample to accomplish the desired results, the adoption of the particular type of works to be installed should be left to the communities themselves, which may be able to select more efficient and less expensive methods than those which the commission has found sufficient to work out the desirable standards of sewage purification.

Various types of sewage nuisance and treatment.

The art of sewage treatment has developed along divers lines, and there are available at the present time various types of treatment adaptable to the needs of varying conditions. The most important type of pollution is the bacterial contamination of drinking-water supplies. 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 exercises, and also, although to a less degree, in the case of shore waters on account of possible indirect infection through cattle and insects.

Certain types of sewage treatment processes, such as sand filters, having as their chief function oxidation of sewage, are incidentally more or less efficient as a means of disinfection; but sewage disinfection as a primary requirement is most economically and efficiently carried out by chemical means. Among the various chemical agents that have been proposed from time to time and extensively used for this purpose, calcium hyperchlorite or bleaching powder has proved most satisfactory.

Physical pollution.

A second type of pollution or nuisance arising from the discharge of sewage into boundary waters is physical and relates primarily to the condition of streams, as floating matter, turbidity, deposits upon the bottom or banks, and unsightly appearances. Sewage screening by means of so-called coarse screens will remove a considerable portion of the larger and more undesirable floating matter and improve the

appearance of streams. Efficient sedimentation will remove a substantial part of suspended matter generally and nearly the whole of the suspended matter which is capable of settling and producing bottom deposits of an offensive character. Fine screening is intermediate in effectiveness between coarse screening and sedimentation. The requirements of each particular situation and the relative cost of the installation and operation of these three systems must determine in each case the type of treatment to be adopted. There is a third type of nuisance, chemical in its nature, which arises from changes in the chemical characteristics of streams—reduction in the normal degree of aeration, development of offensive odors, and discoloration and banishment or destruction of fish life. It is due to the oxidizable character of the polluted waters. Partial improvement results from screening or sedimentation by the removal of a portion of the oxidizable matter. Biochemical oxidation of sewage, which is the most effective treatment, is brought about by passing it through natural or specially prepared beds of sand or over the surface of stones or other coarse material or by passing it through tanks, with artificial aeration in contact with sludge properly cultivated (activated sludge), for the development of oxidizing organisms.

With the extension of stream pollution by increasing population these three kinds of nuisance appear in the chronological order in which reference has been made to them. A minor physically undetectable pollution may seriously injure a stream bacterially, and a stream may be physically affected by floating débris and deposits, and yet, from a chemical standpoint, be normal or practically so. The final result of continuously increasing pollution is the chemical breakdown of a stream, resulting in the most objectionable conditions, examples of which are becoming increasingly common in the more densely settled sections of both countries. In purely local situations in the Niagara, Detroit, and St. Clair Rivers, for instance, notably in the vicinity of sewer outlets and the mouths of tributary streams, and in the inner harbor at Buffalo, the waters are polluted to the extent of definite chemical nuisance. At these points the difficulty is due to incomplete dispersion of the sewage permitting the overloading of the immediate waters. The rivers as a whole, however, are far removed from this condition.

It is advisable to consider the Niagara and Detroit Rivers as a class by themselves so far as remedial and preventive systems are concerned. As has been stated, the most serious condition existing is the bacterial pollution of these streams. To remedy this evil, sewage treatment should be applied in connection with dilution so far as is necessary to bring their waters to the standard mentioned—a mean annual cross-sectional average of *B. coli* not exceeding 500 per 100 c. c. This necessary sewage purification can be effected by fine screen-

ing or sedimentation, and when necessary by chemical disinfection, at a cost which will impose no unreasonable burden upon the urban community responsible for the present pollution.

Cost of remedial works at Buffalo and Detroit.

The consulting engineer, Prof. Phelps, investigated the question of installing adequate remedial works at Detroit and Buffalo. The results of his investigation are given in his report to the commission, to which those desirous of looking into this question at length are referred.[1] A summary of his conclusions, however, is given in the following table:

	First cost.				Annual charges.			
	Interceptors.	Other structures.	Land.	Total.	Fixed.	Operating.	Total.	Per capita.
Detroit	$2,560,000	$2,690,000	$680,000	$5,930,000	$295,000	$216,000	$511,000	$0.54
Buffalo	1,560,000	1,770,000	270,000	3,600,000	203,000	187,000	390,000	.65

The estimated first cost of necessary remedial works for Detroit is about $6,000,000, and for Buffalo something less than $4,000,000. In each case about one-half of the total costs is for treatment works proper, the remainder being the amount chargeable to the collection of sewage. The annual charges include interest, maintenance, and operating expenses, and amount on a per capita basis to 54 and 65 cents, respectively.

The United States Census Bureau furnishes data[2] respecting the combined yearly charges per capita for water and sewerage works in American cities. Tabulated, these data are as follows:

Cities over 500,000 population	$3.48
Cities from 300,000 to 500,000	4.01
Cities from 100,000 to 300,000	3.92
Cities from 50,000 to 100,000	3.71
Cities from 20,000 to 30,000	3.65
Average of all cities over 30,000 population	3.94

These estimated yearly costs per capita for required sewage treatment determined by Prof. Phelps do not appear to the commission to be unreasonable, either in view of the combined water and sewerage costs in the United States cities or in view of the financial standing of the communities interested.

Other rivers.

The sewage pollution of the Rainy, St. Marys, St. Clair, St. Lawrence, St. John, and St. Croix Rivers differs from that of the Detroit and Niagara Rivers in degree, but not in kind. The less concentrated populations on these six rivers have not yet brought about the regrettable condi

[1] Report of the Consulting Sanitary Engineer Upon Remedial Measures, Mar. 6, 1916.
[2] U. S. Census Bureau. Financial Statistics of Cities, 1912. Washington, 1913.

tions existent in the other two. A fortunate opportunity, therefore, is afforded them to avoid the dilemma of the more dense populations along the Detroit and Niagara Rivers and to profit by recent advances in sanitary science and provide at an earlier stage in their development facilities and arrangements for sewage purification, the absence of which makes stream protection in the Niagara and Detroit Rivers a matter of such serious expense and difficulty. Despite the fact that the effects of pollution in these six streams are largely local and confined in the main to shore conditions, the commission has no doubt as to the advisability of their adopting remedial measures in the immediate future. The extent of treatment required is controlled by local rather than by general conditions. By this statement it is meant that while conditions exist in many instances which are in substantial contravention of treaty obligations, their immediate local effect is much more serious than their effect upon the stream as a whole. Remedies sufficient to meet the local conditions would be ample to meet the international situation.

In the case of these streams any remedial works installed in compliance with existing legislation, and the regulations of the States and Provinces directly affected, should have in view the safeguarding of international interests, present and future. These interests require as a minimum measure the planning of a sewer system with provisions for the collection of sewerage at one or more points suitable for treatment, the installation of tanks or other devices sufficient for the removal of the larger portion of the suspended solids capable of settling, and ample equipment for the chemical disinfection of all sewage at such times as may be found necessary, the time for taking these remedial measures to be left to the discretion of the authority hereinafter recommended.

The consulting engineer also investigated the question of the cost of adequate remedial works at the following towns in the Province of Ontario: Windsor, Sarnia, Amherstburg, Fort Erie, Niagara Falls, Bridgeburg, Chippewa, and Queenston; at the following towns in the State of Michigan: Port Huron, St. Clair, Marine City, Algonac, River Rouge, Ecorse, Ford City, Wyandotte, and Trenton; and at the following towns in the State of New York: Tonawanda, North Tonawanda, Lasalle, Niagara Falls, Lackawanna, Kenmore, Lewiston, and Youngstown.

In the case of these cities and towns the estimated annual charges in connection with these works, including interest, maintenance, and operating expenses, range from 44 cents to $2.49 per capita, averaging 77 cents per capita of their population. These estimates, as well as the estimates in the case of Detroit and Buffalo, are based on ordinary prices and not on the exceptional prices which, owing to the war, are ruling at the present time. These charges also appear to

the commission to be reasonable, both in view of the financial standing of the towns and cities and in view of similar charges in the case of other towns and cities in the two countries.

Inquiries into methods of sewage disposal.

Although the commission felt itself more concerned with results than methods, it devoted considerable time and attention to the investigation of improved processes of sewage treatment and disposal. The science of sanitation, as has been remarked, is a progressive one, and its advance is marked by important developments from year to year.

Mr. T. Chalkley Hatton, sanitary engineer for the city of Milwaukee, gave evidence before the commission on this subject.[1] One of his statements illustrates the active spirit of research along this line which to-day characterizes the world of sanitary science. He says:

> Before deciding upon the methods of sewage disposal for Milwaukee we built rather an elaborate experimental station, in which we tried to put all those modern methods of sewage disposal now prevalent in this country and abroad, and I think we had 23 different processes going on there at one time—one of the largest experimental stations carried on in this country for sewage-disposal purposes.

A controlling factor in the disposal of sewage is the cost of dealing with the sludge. Great care must be taken in disposing of the settleable solids of sewage in order to prevent local nuisances, and under certain conditions very large expenditures must be made to prevent the substitution of nuisances on land for nuisances in the water of the diluting streams. What sanitary engineers generally are seeking for is some effective process by which the disposal of the sludge can be made a commercial success.

The activated sludge process, which has apparently been finally adopted by Milwaukee, is one of the most promising of modern methods and is meeting with the approval of a large number of sanitary engineers.

A sludge-treatment process operated in England was discussed before the commission by Mr. Edward A. Paterson, chemical engineer of London.[2] The object of this process is to dry prepared sewage sludge so that it can be used as a fertilizer and extract as by-products during destructive distillation, ammonia, oils, gas, fat, phenol, and other materials suitable for drugs and dyes. Mr. Paterson claims that the sludge can be and is being treated by this process in England at a fair profit. Other processes were looked into. Of all of them it may be said that they are still in their experimental stage, and while their results so far have under certain circumstances been very encouraging, they have not been fully tested by time and condi-

[1] Hearings of the International Joint Commission in re remedies for the pollution of boundary waters between the United States and Canada, 1916, p. 99.

[2] Ibid., p. 35.

tions. A full discussion by the commission of these various processes in their present stage of development would not serve any useful end, and its opinions would not be taken, and could not be expected to be taken, as conclusive as to their respective merits.

So far remedial methods have only been dealt with in connection with urban communities. Sewage from vessels, water ballast discharged from vessels, garbage, industrial and manufacturing wastes call for consideration with regard to remedial methods.

Vessel sewage.

The discharge of sewage from vessels has been shown to constitute a series menace to public health in both countries, not only through the possible contamination of water supplies near their intakes, but also by reason of its effect upon the water supplies of other vessels traversing the same areas. Experiments undertaken by the United States Public Health Service have shown that by the use of steam this sewage can be easily disinfected before discharge. A practical test of an automatic apparatus designed for this purpose carried out through two complete seasons upon the *D. C. Kerr*, a lake steamship, met with entire success both as to mechanical operation and bacteriological efficiency. The installation of this apparatus would be quite inexpensive and all steamships on boundary waters should be compelled to sterilize their sewage. Since the navigation of these waters is almost entirely by steamship, the evil now caused by this sewage would be practically remedied. In the case of other vessels some system of purification can doubtless be found which is cheap and practical.

Vessel ballast.

Pollution by water ballast constitutes a more difficult problem. There has not yet come to the notice of the commission any feasible means of purifying the rather large quantities of water which vessels while in the polluted areas of inner harbors frequently take on board for purposes of ballast, and which they afterwards discharge upon approaching their ports of destination, often while passing water intakes. It will probably be sufficient for the present at least to control this practice by suitable regulations, designed to limit or prevent the discharge of water ballast in the neighborhood of intakes. In the event of the failure of such control by regulations, more expensive and time-consuming methods of treatment will have to be developed and prescribed.

Garbage.

The floatable character of garbage generally renders it liable to be carried by winds to the shores of the rivers and lakes, where, within a limited radius, it becomes particularly offensive. In the case of one American city of considerable size a substantial part of its garbage was being disposed of by dumping it into the main outfall sewer near its mouth. Such a practice is highly censurable and out of keeping

with the usual practice of American cities. The remedy for pollution from this source is to prohibit the discharge of all garbage into boundary waters.

Industrial wastes.

Pollution from industrial wastes has received a great deal of attention, and expensive works for its purification have been installed both in this continent and in Europe. In some of these works valuable by-products have been recovered, and the cost of treatment thus reduced. The immensity of the boundary waters, and their consequent capacity for dilution, will probably for some time to come prevent pollution from this source other than sawmill and pulp mill wastes becoming an international question. Having regard to the future, however, it is well to provide for its regulation. Specifically the dumping of large quantities of sawdust and other sawmill waste, and the discharge of wastes from pulp mills, have been brought to the attention of the commission. Sawmill waste has in many States and Provinces been prohibited by laws, more honored in their breach than in their observance. It is possible that there will come a time, and not in the very distant future, when all sawmill wastes will become valuable and be utilized in manufacturing; but in the meantime these wastes should be burned, or otherwise prevented from being discharged into boundary waters. At present the St. John Lumber Co.'s sawmill on the St. John River at Van Buren, Me., disposes of all its sawmill waste in connection with the pulp mill in its vicinity, and none of it is permitted to enter the St. John River. Other cases, including wastes from manufacturing and chemical industries, may demand further investigation of a somewhat detailed character before it will be possible to determine the extent of the resulting injury and the feasibility of remedial measures. The nature of the treatment of this waste and the degree of its purification necessary will have to be determined upon the facts and circumstances of individual cases as they arise. The dealing with this class of pollution should be left to the authority hereinafter recommended.

Drainage canals.

The reference specifically calls for consideration by the commission of drainage canals as a possible way or means of remedying or preventing the transboundary effect of pollution. The only suggestion that has been made before the commission of a drainage canal project is of that promoted by the Erie & Ontario Sanitary Canal Company. This company was organized primarily for power purposes, but among the objects in its application for incorporation is remedying the pollution of the Niagara River by the construction of a canal starting at or near the mouth of Smokes Creek in the city of Lackawanna and thence running through a well-settled country to Lake Ontario. It is proposed that the canal should be used free of charge

by the cities of Lackawanna, Buffalo, Tonawanda, North Tonawanda, Niagara Falls (United States), and Lockport, and by all other municipalities and communities on the United States side of the Niagara River to carry off their sewage and storm flows, which are now discharged into Lake Erie and the Niagara River, provided each city or town make its own connection with the canal without expense to the company. The company applied to the Secretary of War for the United States by application dated April 23, 1912, for permission to divert for its purposes 6,000 second-feet of water from Lake Erie and the Niagara River. The necessary authority for the diversion of this water was denied by the Government of the United States, but the company desired to secure from the commission an approval of the canal as a feasible solution of the pollution problem in the Niagara River. Opportunities were afforded the company to appear before the commission on several occasions. The company's president, Mr. Millard F. Bowen, its counsel, Mr. George Clinton, and others on its behalf made at the different sittings able and lengthy arguments, and briefs were submitted to the commission containing statements of fact and arguments from Messrs. Randolph, Clinton, Bowen, and Shiras in support of the scheme. Quite a large amount of evidence was taken, as will appear on reference to the records of the commission.[1] The financial and sanitary features of the project did not, however, appear to have been sufficiently investigated. The plans and data submitted were consequently referred to the consulting engineer for further investigation and report. His report was decidedly adverse to the undertaking for two principal reasons: (1) It proposes to receive sewage in its raw condition into the canal, thus creating a large open sewer. A condition of serious menace would therefore obtain throughout its length; and if the sewage were allowed to pass into Lake Ontario, conditions there would be at least no less objectionable than they are at present. (2) The treatment required to prevent nuisance in such a canal would necessarily be more complete and correspondingly more expensive than treatment required for the protection of the Niagara River—a result due to the comparatively small volume of diluting water available in the canal and the consequent necessity for thorough treatment of the sewage by expensive oxidizing methods. These reasons would apply with much greater force in the future. Buffalo and the towns below are rapidly growing. Should their combined population reach a total of 1,000,000, the diluting power of the diverted water would be so inadequate that

[1] Preliminary report of committee having general supervision of the investigation relating to the pollution of boundary waters, with documents * * * relating to the petitions of the Erie & Ontario Sanitary Canal Co. for permission to divert 6,000 second-feet from Lake Erie, 1913.

during the summer months the waters of the canal would be devoid of oxygen, dark in color, and foul smelling. One nuisance would be abated by the creation of a much greater nuisance, which could only be corrected by the most intense sewage purification. The commission, after full consideration of all the features of the project, is of the opinion that besides being objectionable on other grounds it is inadvisable as a sanitary measure.

On the general question of drainage canals as a method of sewage disposal the commission is unable to express any opinion, as each case must be decided upon its merits. Consideration of any scheme involves a study of the amount of water available for diversion, the water-carrying capacity of the canal, the amount of raw sewage to be discharged into it, the character and cost of treatment of the sewage to be carried, and the consequent interference with the many other interests which may be affected, all of which elements vary according to local circumstances and conditions.

General question of pollution should be considered and controlling authority constituted.

In the discussion of sewage standards and purification and other matters in this report it was recommended that they be dealt with by some authority which should be clothed with the necessary power. In view of what has been said under the heading of "Transboundary effect of pollution," the commission is of the opinion that to the extent that is consistent with a proper degree of autonomy by the urban communities interested, all boundary waters, so far as pollution is concerned, should be subject to the regulations prescribed by this authority. If, during the investigation, one thing impressed itself more than another upon the attention of the commission, it was the view that while pollution which has a transboundary effect must in consequence of the obligation resting on both countries under the treaty be distinguished from pollution which has not such an effect, the distinction is, from a practical standpoint, highly technical and artificial. The question of pollution, if a narrow construction be placed upon the treaty and reference, is but a part of the larger question of pollution in boundary waters generally, in the solution of which both countries are, as has been shown, vitally interested. The present international situation is not the result of any desire on the part of the inhabitants of either country to ignore international obligations either of comity or of law, but is the outcome of the failure on the part of the urban communities in each country, respectively, to recognize from a sanitary standpoint any right in other communities to river waters, especially communities on their own side of the boundary line. Every border community in the United States and Canada has in the matter of sanitation considered its own immediate interests exclusively. The result is that while those communities have been tolerably successful

in the management of sanitary affairs within their own territorial limits and have installed water and sewerage systems fairly ample for their own present needs, they have recognized no responsibility whatever resting upon themselves with regard to their sewage effluents, and by discharging them untreated into river waters they have compelled their neighbors to submit to intolerable conditions. The present practice of discharging sewage in this manner must be restricted until an equilibrium, so to speak, of the rights of all communities in the waters of the boundary rivers is established, in which each may discharge its sewage into these waters, but only to such an extent and of such a degree of purification as shall not interfere with the reasonable enjoyment by other communities of their rights.

The situation on the boundary waters is not unique; many like it exist elsewhere, although not on so large a scale. A close parallel exists in the case of the boundary waters between England and Scotland. By act of the British Parliament passed in 1898 the local government board for England and the secretary for Scotland may, on certain steps being taken, "together constitute a joint committee representing all or any of the countries through or by which such river or any specified portion or tributary thereof passes; and such committee may have all the powers of a sanitary authority with respect to pollution in such waters."

In this connection reference may be made to the views of the British royal commissions already mentioned whose extensive and exhaustive investigations into river pollution, most scientifically conducted for a lengthened period, entitle their opinion to great weight. Their reports, especially the reports of the last commission, repeatedly emphasize the great necessity for sanitary purposes of having a river, as a whole, under one management.

Under existing sanitary laws and their administration the pollution evil has been steadily growing along the boundary. The indifference to injury done others, the financial interests of the different communities, and the practical difficulties in arriving at concerted action are so hard to overcome that the only assurance of betterment lies in the constitution of some authority which shall have jurisdiction over boundary waters and be clothed with ample power to prevent their being unduly polluted. Consistently with the exercise of its powers by such an authority, the installation of remedial works and the expenditures in connection therewith would all be in the hands of the local authorities. The only interference with the latter on the part of the suggested authority would be to prescribe the necessary capacity of the sewage-purification works and the degree of efficiency with which they should be operated. From the international standpoint this capacity and degree of efficiency need

not exceed those which should prevail for the protection among themselves of the communities on either side of the boundary line.

As has been remarked, the question of the pollution of those waters generally is a matter of great international moment. In view of this fact and of the variety and possible conflict of national, State, provincial, and municipal authorities, it is too obvious to require discussion that the recommended authority should be jointly created by the high contracting parties. As the International Joint Commission is under the treaty clothed with jurisdiction over the use, obstruction, and diversion of boundary waters, together with jurisdiction over other international matters, it is recommended that the necessary jurisdiction and authority in respect of the pollution of boundary waters and waters crossing the boundary be conferred upon it; and for the purpose of giving effect to the jurisdiction and authority so conferred that the commission be authorized to make such rules, regulations, directions, and orders as in its judgment may be deemed necessary; and that power be also given to the commission to appoint such engineers and employees as it may consider advisable.

VIII.—CONCLUSIONS AND RECOMMENDATIONS.

The following is a summary of the conclusions the commission has arrived at, and of the recommendations it submits to the two Governments:

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 sewerage 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. It is derived from two sources, sewage waste from vessels and "water ballast" which is taken in by lake vessels at their ports of departure and emptied into these waters at or near their ports of destination. Vessel pollution is distinctly traceable in boundary waters in lanes and channels which vessels traverse in navigating

them, their waters being thereby rendered unfit for drinking purposes.

5. In some cases sawmill and other mill wastes, garbage, offal, carcases, and other refuse matters are discharged into boundary waters. This practice results generally in a contravention of the treaty.

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.

(*a*) In the case of city sewage, this can best be accomplished by the installation of suitable collecting and treatment works, the latter having special reference to the removal of bacteria and matters in suspension.

(*b*) In the case of vessel sewage, a feasible and inexpensive remedy lies in the employment of recognized methods of disinfection before it is discharged. In the case of water ballast suitable rules and regulations should be prescribed with a view of protecting the water intakes.

(*c*) The discharge of garbage and sawmill waste into boundary waters should be prohibited, and industrial and other wastes, which are causing appreciable injury, should be discharged subject to such restrictions as may be prescribed.

7. In order to remedy and prevent the pollution of boundary waters and to render them sanitary and suitable for domestic purposes and other uses, and to secure 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 treaty, it is advisable to confer upon the International Joint Commission ample jurisdiction to regulate and prohibit this pollution of boundary waters and waters crossing the boundary.

Hereto annexed is a schedule showing the reports made to and by the commission, and of the minutes of its sittings, which have already been printed, or which the commission contemplates having printed.

Dated at Atlantic City, N. J., this 12th day of August, A. D. 1918.

OBADIAH GARDNER.
CHARLES A. MAGRATH.
JAMES A. TAWNEY.
HENRY A. POWELL.
R. B. GLENN.
P. B. MIGNAULT.

SCHEDULE.

LIST OF PUBLICATIONS OF THE INTERNATIONAL JOINT COMMISSION RELATIVE TO THE POLLUTION OF BOUNDARY WATERS.

1. Preliminary report of the committee having general supervision of the investigation relating to the pollution of boundary waters, with documents on file in the United States War Department relating to the petitions of the Erie & Ontario Sanitary Canal Co. for permission to divert 6,000 second-feet from Lake Erie for the purpose of remedying the existing pollution of Niagara River. Washington, 1913.

2. Progress report of the International Joint Commission on the reference by the United States and Canada in re the pollution of boundary waters, whether or not such pollution extends across the boundary in contravention of the treaty of January 11, 1909, and, if so, in what manner or by what means is it possible to prevent the same, including report of the sanitary experts. Washington, 1914.

3. Pollution of boundary waters. Conference with sanitary engineers at New York City, May 26 and 27, 1914. Washington, 1914.

4. Résumé of testimony of consulting sanitary engineers in the matter of the pollution of boundary waters. Conference at New York City, May 26–27, 1914. Washington, 1914.

5. Hearings of the International Joint Commission in re remedies for the pollution of boundary waters between the United States and Canada, held at Niagara Falls, Ontario, Buffalo, N. Y., Detroit, Mich., Windsor, Ontario, Port Huron, Mich., and Sarnia, Ontario, September 25 to October 2, inclusive; Detroit, Mich., November 10 and 11; and Washington, D. C., December 14 and 16, 1914. Washington, 1914.

6. Hearings of the International Joint Commission in re remedies for the pollution of boundary waters between the United States and Canada, being public hearings held at Buffalo, N. Y., and Detroit, Mich., June 21–27, 1916, and Ogdensburg, N. Y., August 25, 1916. Washington, 1917.

7. Report of the consulting sanitary engineer upon remedial measures. March 8, 1916. Washington, 1918.

8. Final report of the International Joint Commission in the matter of the reference by the United States and the Dominion of Canada relative to the pollution of boundary waters. Washington, 1918.

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