CITY OF EVANSTON, ILLINOIS

FILTRATION

REPORT OF SPECIAL COMMITTEE
OF CITY COUNCIL

and

REPORT OF CONSULTING
ENGINEERS

PUBLISHED BY THE ORDER OF THE COUNCIL
September [illegible]

ATTEND

Parents' and Citizens' Meeting

LARIMER SCHOOL
DEWEY SCHOOL
FOSTER ST. SCHOOL

Thursday, Dec. 12, 1912

8 o'clock p. m. sharp

To consider the plan proposed for building a filtration plant to furnish a **clean** and **pure** water supply for **all citizens** of Evanston at **all times.**

Full information will be given on this important subject by competent speakers.

Whether **for** or **against** filtration have an **intelligent** reason for your vote.

Opportunity will be given for questions and open discussion.

A large attendance of parents and citizens is desired.

Ladies Specially Invited

Frank R. Grover, George P. Engelhard, Mayor Paden and others will speak.

ATTEND

CITY OF EVANSTON, ILLINOIS

JOSEPH E. PADEN, *Mayor*

Special Committee of the Council

1911 and 1912

CHARLES B. CONGDON, *Chairman*

PERKINS B. BASS

JOHN W. BRANCH

VICTOR A. ROSSBACH

WILLIAM H. KNAPP

CHRIST WITT

SAMUEL TOPLIFF

Water Committee of the Council

1912 and 1913

WILLIAM H. KNAPP, *Chairman*

CHARLES B. CONGDON

HOWARD M. CARTER

Consulting Engineers

WALTER W. JACKSON

LANGDON PEARSE

REPORT ON FILTRATION BY THE SPECIAL COMMITTEE OF THE COUNCIL

Submitted April 16, 1912

To the Mayor and Aldermen in Council Assembled:

Gentlemen:—

The joint committee to which on Jan. 9, 1912, you referred the question of water filtration, herewith submit a final report of its investigations and conclusions. A preliminary report was made under date of March 5, 1912.

Plants Visited.

The following filtration plants were inspected, to-wit:

Rogers Park, Rock Island, and Moline, Illinois.

Davenport, Burlington and Ottumwa, Iowa.

Cincinnati and Toledo, Ohio.

New Orleans and Algiers, Louisiana.

Niagara Falls, New York.

Louisville, Kentucky.

Kansas City, Kansas.

Detailed information obtained as to size, construction, equipment and operation of the filtration plants visited is contained in forms accompanying this report. The forms were prepared for such use prior to the inspections. In considering this data due allowance should be made for the fact that limited time and varying conditions met with, necessitated omissions and approximations and precluded obtaining as complete records as might otherwise have been secured.

Rapid-sand filters of the "gravity" or "open" type are used at all of the filtration plants visited except Rogers Park and Davenport.

Rapid-sand filters of the "pressure" or "closed" type are used at Rogers Park and Davenport. No slow-sand filtration plants were visited. The large settling basin of the Kansas City, Mo., water supply was visited. Here the method of purification employed is sedimentation with chemicals and without filtration.

Lake waters are dealt with at Rogers Park and Niagara Falls. River waters are dealt with at all other plants visited, except Toledo. The Toledo plant sometimes deals with Lake Erie and sometimes with Maumee river water, depending on flood, wind and ice conditions.

The raw lake waters dealt with at the filtration plants visited are reasonably free from color, odor, taste and objectionable mineral contents. Removal of suspended impurities, including bacterial organisms, is the chief end sought by purification of these lake waters.

The lake waters dealt with at these two plants are analogous to the Evanston supply in that sewage contamination, turbidity due to storm-roils, befoulment from shipping and dredging, and other accidental pollution occasion the demand for purification. These lake waters vary somewhat in their physical, chemical and bacteriological character, but may be classed as quite constant in comparison with river or ground waters.

The river waters dealt with at the several plants named differ widely, one with another, as regards physical, chemical and bacteriological character. Sudden and wide fluctuations frequently occur in the same supply. The fluctuations are due to many variable factors. They are influenced by agricultural and commercial activities throughout the area drained by the river above the intake. Floods are an important factor and their influence varies with regard to season, intensity and frequency of their occurrence. Ice formations and other natural phenoena exert varying influences.

The successful purification of variable river waters is obviously a more complex, difficult and expensive undertaking than would be the purification of lake waters which are fairly constant in character. The physical improvements wrought by filtration of the river waters at the plants visited are therefore all the more striking. Waters, excessively turbid, repulsive to sight and taste at times, and laden with impurities from sewers and various sources are, by the methods employed, rendered clear, attractive and wholesome. Chemical and bacteriological tests, and studies of the vital statistics, confirm an improvement in the hygienic qualities of properly filtered waters no less striking.

Clearness alone is not a safe index to the purity of a drinking water. A strikingly clear water can be laden with disease germs. Such a water by virtue of its clearness will often prove a greater menace to the health of a community than a turbid water free from pathogenic germs.

Clearness is not infrequently a disguise to dangerous pollution in a drinking water. This is especially true if the temperature and taste of the water are agreeable. These attributes frequently occasion disregard of warnings sounded by the health authorities against its use.

Modern sanitary science demands at least two requisites of a water before it can be approved as entirely suitable for drinking, viz:

1. The water must be attractive to the eye, odorless and tasteless.
2. The water must be free from disease producing organisms.

The relation of typhoid fever death rates to a sewage-polluted water supply is so characteristic that these deaths are regarded by sanitarians as a fairly accurate index to the quality of water furnished a community. Dr. McLaughlin states the relation is so well known that it seems unnecessary to dwell upon it.

Due allowance should be made for special and sometimes peculiar local conditions and environments in weighing vital statistics. It often, in fact usually, happens that in a city furnished with filtered water, all citizens do not use the public water supply exclusively. This condition is brought about sometimes by the fact that the system of mains has not been extended to all parts of the city and wells must be depended upon. The drainage system of such a district is usually lacking. Out door privies are used and soil pollution increases rapidly with density of population. Typhoid fever, and other water-borne diseases usually prevail at a high rate in such sections and will discredit the value of the improved water supply if due allowance is not made for the unfavorable conditions existing.

Pittsburgh, Pa., is provided with a modern slow-sand filtration plant which went into service during December, 1907. Dr. Allan J. McLaughlin of the U. S. Public Health and Marine-Hospital service in his paper read before the Illinois Water Supply association at Urbana, Illinois, on March 5, 1912, calls attention to a persistent high typhoid death rate in Pittsburgh attributable to failure to furnish a filtered water supply to certain portions of the city. He states:

"As an instance of high (typhoid) rate due to failure to furnish filtered water to all the people, the experience of Pittsburgh is interesting. The filter plant in Pittsburgh was first put in operation November, 1907. But a small portion of filtered water was supplied at first and this was mixed with the unfiltered supply. The amount of water filtered was increased until October, 1908, when the supply of that part of the city between the rivers—about three-fifths of the total population—was filtered.

"The south side, a little less than one-fifth of the entire population, was supplied with filtered water in March, 1909. The former city of Allegheny, recently annexed, is not yet supplied with filtered water. This part of the city includes a population of about one-fourth of the entire city.

"There was a remarkable decrease of typhoid fever in Pittsburgh progressively coincident with the increase of area supplied with filtered water. In spite of all this remarkable reduction two points stand out prominently: First, the rate is still high (1910), and second, the seasonal distribution suggests water as a prime factor. Explanation of these two points is furnished by a study of the cases as shown in the following table, from which it is clear that this high rate was due entirely to the abnormal rate in Wards 21 to 27, inclusive:

Table.

Total population of Pittsburgh	553,905
Total deaths typhoid fever	115
Death rate per 100,000, entire city	21.3
Death rate per 100,000, wards 1 to 20	13.4
Death rate per 100,000, wards 21 to 27	46.9

"Wards 1 to 20 were supplied with filtered water. The aggregate population of these twenty wards was 401,622. The typhoid fever death rate per 100,000 in 1910 was 13.4. Wards 21 to 27 comprise the old city of Allegheny and have a total population of 132,283. This section received unfiltered water. The typhoid fever death rate per 100,000 in this section in 1910 was 46.9."

Too many citizens will cling to wells and privies long after sewers, water mains, and a wholesome public water supply are available unless there is ample power vested in and exercised by the authorities to compel their abandonment, and to enforce the adoption of safer and cleanlier methods.

There are many street wells to be found in service today in the city of Louisville, Ky. These wells stand near the curb lines.

Street drainage basins and other sewer appurtenances are frequently found within a few feet of the pump. Louisville has an excellent public supply of filtered water. Still the typhoid death rate per 100,000 was 45 for 1909 and 31.7 for 1910.

Toledo, Ohio, has an admirably constructed filter plant which went into service early in 1910 and is operated under expert supervision. The percentage of persons using city water in Toledo is, however, low, compared with most cities. Owing to the appearance and general character of the public water supply before filtration was established many citizens would not use the city water and the number of wells in Toledo has always been large. It is considered probable that one-half of the population were still using well water at the close of 1910.

An analysis of 59 cases of typhoid fever reported to the health officer in Toledo from November, 1910, to March, 1911, showed the relation of cases to source of water supply to be as follows:

Source of water supply.	Typhoid cases.
Wells	41
City water	17
Bottled water	1
Total	59

It is stated in a recent official publication dealing with the Toledo water supply that:

"Unfortunately the board of health lacks or does not exercise full authority over dangerous contaminated wells. After discovery of a dangerous contaminated well the board of health limits its activity to affixing a notice on the pump setting forth the dangerous character of the water. In many cases the householder and the neighbors continue to use the water."

The foregoing citations are ample to illustrate why it is very necessary, in consulting vital statistics for the purpose of learning the benefits derived from the establishment of a filtered water supply, to have the records for several years prior and subsequent to the installation of the filtration plant. Otherwise the statistics may be only coincident and not consistent, and conclusions as to the real value of the improved water supply and its contribution to the health and comfort of the community based on such statistics might prove misleading.

The following statistics relative to typhoid fever death rates in nine American cities before and after the establishment of an improved water supply cover a number of consecutive years before and after the improved supply, and are deemed consistent.

Reduction in Typhoid Death Rate Following Filtration of Water Supply for Nine American Cities.

City.	Deaths per 100,000. Before.	After.	Reduction per cent.
Albany, N. Y.	104	28	73
Binghamton, N. Y.	49	11	78
Cincinnati, O.	69	13	81
Columbus, O.	46	9	81
Lawrence, Mass.	120	26	78
Loraine, O.	91	19	79
Paterson, N. J.	36	9	75
Philadelphia, Pa.	72	21	71
Watertown, N. Y.	97	27	72
General average	76	18	76
Evanston, average for past five years	27	..	..

Reduction in Typhoid Death Rate Following Filtration of Water Supply for Four European Cities.

City.	Deaths per 100,000. Before.	After.	Reduction per cent.
Berlin, Ger.	111	11	90
Hamburg, Ger.	47	7	85
London, Eng.	98	14	86

Zürich, Switz.	76	10	87
Average	83	10	87

Although there is a wide range in the typhoid death rates shown in these tables, nevertheless there is a very striking agreement in the percentage of typhoid death reduction following filtration.

The fact that most of the American plants given in the table deal with river waters may suggest inquiry as to what results might be expected in dealing with lake waters.

The filtration of supplies drawn from the great lakes is not general, nor of long enough duration to afford statistics that are conclusive. Lorain, Ohio, has a lake supply. The percentage reduction in typhoid death rate following filtration is 79 per cent. This is above the general average of the nine American cities given in the table.

Statistics for the years from 1890 to 1896 show the typhoid fever death rates for 100,000 population to be as follows:

For five largest American cities on the great lakes 42
For five largest American cities on rivers 58

Statistics show that for each death from typhoid, at least ten cases of the disease usually occur and entail suffering and financial loss.

Statistics further show that for each life saved from death by typhoid fever through improvement of the water supply there follows a further saving of from three to four lives from other diseases.

The superiority of average European public water supplies over the average American public water supply, with respect to purity, is proverbial.

Dr. McLaughlin, in his paper of March 5, 1912, hereinbefore referred to, gives the following comparison between the average typhoid death rate in the principal European and American cities:

Unit of comparison.	Aggregate population.	Deaths per 100,000 from typhoid fever 1910.
Thirty-three principal cities in Russia, Sweden, Norway, Austria - Hungary, Germany, Denmark, France, Belgium, Holland, England, Scotland and Ireland	31,500,000	6.5
Fifty American cities of 100,000 inhabitants or over	20,250,000	25.0
Excess of deaths from typhoid fever in American cities ...		18.5

He further adds:

"So that on an average in every 100,000 population we had, compared with European results, 18.5 deaths and at least 180 cases of typhoid fever which should never have occurred. A conservative estimate for 1910 will place the deaths from typhoid fever above 25,000.

"The excess of 18 deaths per 100,000 in the urban population alone shows that we have had in the fifty cities mentioned above, at least 3,600 deaths and probably 36,000 cases of typhoid fever which were preventable and should never have occurred. For the whole United States the number of cases for each year preventable by methods within our grasp would probably reach 175,000 and the deaths so avoided would total 16,200. In 1909 there were more cases of typhoid fever in the United States than there were cases of plague in India, in spite of the fact that India's population is two and one-half times that of the United States."

The Evanston water supply is drawn from Lake Michigan through a cast iron intake pipe laid directly on the lake bottom without dredging, except near the shore end.

The inlets on this intake are located one and one-sixteenth mile, or in other units fifty-six hundred feet, off shore. The inlets are thirteen in number and are grouped at the lake-end of the intake pipe. Their position is nearly due east of the pumping station, which station is two blocks south of the U. S. light house. The inlets consist of 42-inch standard cast iron tees, set in the 42-inch intake pipe line. The single-end branch is set vertical. This method of placing the tees brings the openings into a horizontal plane, five feet above the lake bottom. The lake is thirty feet deep at the end of the intake. It will be observed that by this arrangement the water is drawn from a distance of twenty-five feet below the surface, and five feet above the bottom of the lake. Woven wire screens, having a half-inch mesh, are set down inside the bells of the tee openings.

The lake is thirty feet deep at the inlets and thirty-three feet deep three miles off shore.

The bottom of the lake at the end of the intake is covered with cobble, smaller stone and gravel. There is a zone of soft bottom, a few hundred feet in width, that lies with its eastern border some three or four hundred feet west of the inlets.

The depth of Lake Michigan off the pumping station site, shown by U. S. government soundings, is as follows:

In Miles.	Distance off shore in feet.	Depth of lake in feet.
1	5,280	27
*1 1-16	5,600	30
2	10,560	35
3	15,840	33
4	21,120	40
5	26,400	45
6	31,680	55
7	36,960	65
8	42,240	70

*Denotes location of inlets on intake pipe.

Studies by government engineers and various other investigators indicate that freedom from storm-roils or turbidity and wave action cannot be obtained unless the intake inlets are located in from 50 to 70 feet of water.

These inlets are located as follows with reference to sewer outlets:

Sewer.	Size.	Miles.	Feet.
Keeney street	30-in.	2 7-16	12,870
Main street	36-in.	2 2-16	11,220
Davis street	48-in.	1 9-16	8,250
University place	72-in.	1 6-16	7,260
Forest avenue (Wilmette)	54-in.	2 7-16	12,870

These sewers serve a population of 30,000, as shown by the U. S. census of 1910.

It may be of interest to add that there are thirteen main sewers emptying into Lake Michigan between the south line of the city of Evanston and the north line of the sanitary district of Chicago, which district line is the north line of Cook county and approximately the north line of the village of Glencoe. These sewers serve a population of 36,500, according to the U. S. census for 1910. There are three water supply intakes within the same limits serving the same population.

The distance of the Evanston water intake inlets off shore, as compared with the other Illinois supplies taken from Lake Michigan, are as follows:

Supply designated.	Distance off shore. In miles.	In feet.	Treatment, if any, of water.
Chicago, Hyde Park Crib	2 3-8	12,500	Hypo process recommended.
Chicago, Four Mile Crib	4	21,120	Sewage diversion.
Chicago, Carter Harrison Crib	2 5-8	13,860	Sewage diversion.
Chicago, Lake View Crib	1 7-8	9,900	Sewage diversion.
Rogers Park (Chicago)	5-8	3,300	Filtered.
Evanston and Wilmette	1 1-16	5,600	Hypo process recently installed.
Kenilworth	7-16	2,400	Filtered.
Winnetka	9-16	3,000	Hypo process recommended.
Highland Park	3-8	2,000	None.
Lake Forest	1-2	2,640	Filtered.
Lake Bluff	1-2	2,640	Filtered.
Waukegan	3-4	4,000	Hypo process recently installed.

The Evanston water intake inlets are located some four or five miles nearer the shore than the path of lake boats plying between Chicago, Waukegan, Racine and Milwaukee.

The character of the Evanston water supply has been studied for several years by the local health authorities, by chemists and bacteriologists engaged by the city for the purpose, by the Illinois State Water Survey, by the Lake Michigan Water Commission, and by other sanitarians. Many of these investigations were made before the intake was extended in 1908-09, from a point one-half mile to its present distance one and one-sixteenth mile off shore. These investigators agreed in their findings.

The water is considered safe for use without boiling or filtering on many days, but frequently unsafe for use without boiling or filtering.

The city now has a complete laboratory of its own. Frequent examinations of the water supply are being made under conditions of sampling and testing more conducive to correct conclusions. These tests indicate that the extension, which cost $88,000, was a necessary improvement.

Evanston's typhoid death rate of 27 per 100,000 population is double that of Chicago. It is two above the average for the fifty American cities given in the preceding table. Typhoid fever is practically nil in Rogers Park, Kenilworth and other Illinois towns supplied with filtered water from Lake Michigan.

Recent outbursts of typhoid and kindred diseases have occurred along the shore of Lake Michigan north of Evanston where unfiltered lake water is supplied. Places furnished with filtered water have escaped typhoid.

The Chicago supply from the Hyde Park or Sixty-eighth street crib is so situated as not to receive much benefit from sewage diversion. Hypochlorite of lime treatment (Hypo process) has been recommended as an emergency treatment of the water supply for this crib. Waukegan has recently installed a hypo plant.

Winnetka has recently recommended and is proceeding to install a hypo plant.

Evanston installed a hypo plant the latter part of December, 1911, as an emergency measure and thereby checked a typhoid fever epidemic. These concrete facts, together with tangible evidence, such as the befoulment of nets spread in the lake at no great distance from the inlets on the water intake, justify and confirm the conclusion that would be forecasted by a study of statistics, namely, that the water supply of Evanston, in common with neighboring supplies drawn from Lake Michigan, is occasionally seriously polluted with sewage.

Artificial purification of all surface water supplies is demanded by advanced standards and knowledge of sanitary science and art. Such treatment is a legal requirement in Germany. Dr. McLaughlin, an eminent authority, says: "When cities have a public water supply polluted by sewage or admittedly exposed to pollution, the obvious thing to do is to filter or treat the water and protect the public from infection."

Numerous methods for artificial purification of waters intended for a public supply have been proposed and tested. Only a few methods have been found feasible and received more or less general adoption. Sedimentation, sterilization and filtration are the methods usually adopted.

Sedimentation is accomplished naturally in large lakes, and artificially in reservoirs and settling-basins. The process is frequently hastened by use of some chemical that will form a coagulant that will collect, entangle and throw down the impurities in suspension. The process is used on some very turbid river waters at plants installed before the successful development of rapid sand filtration. The efficiency of the process is chiefly dependent upon time. A very large storage of water is required. There is no positive evidence to be gained from experience of plants employing this process that it would prove either economical or efficient for service on the Evanston supply. This statement holds whether chemicals may or may not be used as coagulants, and whether hypochlorite of lime or some other chemical or device for sterilization may or may not be employed as adjuncts. As a matter of fact, the process of sedimentation is carried out naturally in the lake before the water enters the intake pipe. Storm-roils occasionally defeat the process and a turbid supply results. Bacteriological tests and the condition of the system of wells and distributing mains attest to the inadequacy of sedimentation as it occurs in the lake at any reasonable distance off shore. Artificial sedimentation should be employed and relied upon only as an adjunct to filtration, so far as the purification of the Evanston water supply may be undertaken.

Sterilization in connection with the purification of public water supplies is accomplished by hypochlorite of lime (as now used on the Evanston supply) and by other chemicals and processes. Ozone and Violet Rays are receiving more or less attention as sterilizing agents. Thus far their development is not sufficient to secure general adoption. Their cost is considered prohibitive. Sterilization by means of hypochlorite of lime is considered the most feasible, economical and effective process now developed for sterilization purposes in connection with public water supplies. It fails to free a water of its turbidity and is not in and of itself a sufficient treatment. Artificial sterilization, like sedimentation, should be employed and relied upon only as an adjunct to filtration so far as the purification of the Evanston water supply may be undertaken.

Filtration is one of nature's methods by which water is purified. It is accomplished artificially in connection with the purification of public water supplies by what are styled

(1) Slow sand filters,
(2) Rapid sand gravity filters,
(3) Rapid sand pressure filters.

A slow sand filter will deliver from 2,000,000 to 3,000,000 gallons of water daily per acre of filter bed.

It is the earlier type of filter. The filter is cleaned by scraping the deposits off the beds. Cleaning necessitates cutting the bed out of service. Hence additional bed space and ample storage is necessary. Its efficiency is not found greater than that of the modern rapid sand filter. It requires a cover in winter climate such as found at Evanston.

Its cost is approximately $75,000 per acre of bed where covering is required.

A slow sand plant sufficient for Evanston would require at least twelve acres of land.

Its size and cost would preclude its adoption for Evanston.

A rapid sand filter of the "gravity" or open type will deliver from 120,000,000 to 125,000,000 gallons of water daily per acre of filter bed.

The filter bed is constructed in an open tank composed, preferably, of concrete, and usually of such area as to deliver 1,000,000 gallons of water daily per bed where the total daily output of the plant is less than 20,000,000 gallons.

The filter is cleaned by reversing the current of water through the sand bed. This insures washing with a filtered water. The rapid filtration is made possible by the use of chemicals, usually alum, to form a coagulant which collects the finer particles in suspension and forms a filtering or entangling medium on the bed. The effluent is frequently sterilized.

Its efficiency has been shown equal to that of the slow sand filter. It is now being quite generally adopted in America, and to some extent abroad. Its size and cost is much less than that of a slow sand plant and varies with size and local conditions.

A rapid sand filter of the pressure or closed type will deliver the same quantity of water per unit area of bed as will a rapid sand gravity filter. The filter is cleaned by reverse washing with filtered water. The filtering bed is constructed in a closed steel tank built to resist the pressure exerted by the pumps. Chemicals are used as a coagulant and the effluent can be sterilized. Its adoption is not general for large supplies. It does not employ, as a rule, any auxiliary pumping plant or storage basins. Its cost is considerably less for small installations than would be that of the gravity or open type.

These advantages are, however, considered offset by some disadvantages and its adoption should not be made without a very thorough consideration of all the conditions to be met in the service.

There is no doubt that a pure, wholesome and attractive water supply can be secured by the city of Evanston from its present source of supply by the construction of a filtration plant. The supply would be safe for use direct from the faucets, without boiling or other household treatment, every day of the year.

This report might not be considered complete if, in dealing with the improvement of the Evanston water supply, it failed to touch on the question of extending the present water works intake; and also the diversion of the sewage of the town from Lake

Michigan to the north shore channel of the sanitary district of Chicago.

There is perhaps no better water supply to be found for municipal purposes than that of Lake Michigan if drawn from a location free from shore and shipping pollutions. From a sanitary standpoint the location of the inlets on the water intake line, with respect to sewer outlets and lake traffic, is important. Unfortunately there are no figures available to show the minimum safe distance between a sewer outfall and a water works intake. The proper location of the water works intake as regards direction from the sewer outlets is not established. A popular notion has somewhat prevailed that inlets of water intakes should be located northward of sewer outlets upon the west and southward upon the east shores of the southern portion of Lake Michigan. Government investigators have, however, determined that there are no fixed currents in Lake Michigan and that the direction and velocity of the currents or drifts are dependent upon the wind. The correctness of this finding can be substantiated in a measure by observing the surface effects of sewage as it drifts into the lake from the sewer outlet. The surface effects of a relatively small sewage pollution can be readily traced with the eye a long distance from its entrance into the lake under favorable conditions for its drifting and detection.

Since the winds on Lake Michigan vary at all times of the year, as regards direction and velocity, it follows that the wind induced currents will vary likewise. Hence the insecurity of relying upon lake current to protect a water intake supply is, or should be, apparent.

The fallacious supposition that winds protect water intake supplies against sewage contamination entails another equally fallacious assumption that sewage pollution is carried only at or near the surface of the lake. The experience of the various cities drawing their water supply from lakes into which their sewage is discharged demonstrates that, at the best, position of the inlet on the water intake affords slight, if any, protection against sewage pollution. Dr. McLaughlin, in his report of July, 1911, on the sewage pollution of interstate and international waters, says:

"The curious dependence upon the fallacious belief that protection was afforded to lake intakes by the position of the intake to the westward of the source of pollution is paralleled by the faith which citizens of towns on the Niagara river had in the position of their intakes to the westward of a known polluted current. Even when it became generally known that, at best, position of their intakes could afford but a slight and insecure measure of protection, seldom was the prompt and obvious remedy, filtration of the water, applied.

"Much valuable time was lost usually by attempting every known scheme for preventing pollution at the intake. Many of these schemes demanded removal of sewage outfalls to a greater distance or sewage disposal of some kind involving serious engineering problems and expenditure of great sums of money.

"In almost every instance sewage disposal of some kind was a consummation devoutly to be wished. But the problem and expenditure made its immediate accomplishment impossible. As at Erie and Niagara Falls, the citizens continued to drink sewage-polluted water for years, and eventually filtration plants will have to be installed to prevent water-borne typhoid, while the sewage-disposal problem is still unsolved."

Major Judson, United States Engineer, in a paper presented to the Lake Michigan Water commission (see first report, page 63), reported lake surface velocities of one and one-half miles per hour by actual measurement. The velocity of storm induced currents would be much greater.

Scientific tests carried on simultaneously, but independently, by Jordan, Zeit and Russell indicated that the typhoid germ survives from three to seven days in polluted lake water.

Russell and Fuller, using Lake Mendota water, practically confirm the findings of Jordan and others. Mason has shown that typhoid germs were carried twenty-six miles by the Mohawk and Hudson rivers in the typhoid outbreak that occurred in these valleys in 1890. Sedgwick has shown that typhoid germs were carried twenty-five miles by the Merrimack river in 1892.

Drs. Bernard and Brewster have shown that the distribution of the sewage from the Calumet river ranges from the Chicago two-mile crib on the west to lake points, opposite Hammond, Ind., on the east, and into the lake as far as seven miles from the shore. Dr. Biehn and other authorities have traced trade wastes and sewage a distance of five miles from the shore.

It would therefore require a four or five mile extension of the present intake to avoid shore pollution of the Evanston water supply. Such extension would not bring the intake inlets into a sufficient depth of water to insure a supply free from turbidity occasioned by storm washing of the banks or scouring of the bottom of the lake. It has been shown that freedom from turbidity so occasioned cannot be attained in a less depth than from fifty to sixty feet.

Extending the Evanston intake beyond shore pollution and storm-roils would bring it directly in the path of lake steamers plying between Chicago, Milwaukee and other northern points. It has been shown that there is a higher percentage of typhoid carriers and typhoid infection among the sailors on lake boats than among the population of shore towns. Therefore the menace of lake traffic, including that of dredging, is worthy of most careful consideration.

Congress passed an act in 1910 prohibiting the dumping of dredging and similar refuse within eight miles from the shore of Lake Michigan unless such material be deposited behind breakwaters. This regulation would be of service, but not a full protection.

To extend the Evanston water works intake would cost at least $100,000 per mile. A raised crib would have to be constructed and manned. This method of obtaining a pure water supply for the city would be much more expensive and less certain than would be that of filtration.

Diversion of the sewage of Evanston and neighboring communities from Lake Michigan to the north shore channel of the sanitary district of Chicago will lessen the danger of contamination from shore pollution. The improvement obtained will be more or less dependent upon the completeness of the diversion. If surface or street waters, as well as house drainage, are diverted, better results will follow than if the house drainage alone is diverted. Diversion of the sewage will not give relief from the shipping, dredging and other pollutions that occur off shore.

The original purpose of the sanitary district of Chicago was to remove the sewage from Lake Michigan to protect the water supply. At the time the charter was granted diversion was deemed adequate. It is common knowledge that the diversion of the Chicago sewage did not prove adequate for the purpose of protecting the water supply. The district was extended to cover the Calumet and north shore extensions.

Intercity, intercounty, interstate and international complications have arisen and are apparently presenting problems that grow more stubborn with time.

In the report of the chief engineer to the president and board of trustees under date of Oct. 12, 1911, will be found this statement:

"At present the water supply of Chicago, with the exception of that from the Sixty-eighth street crib, is in a fairly satisfactory condition. It is, however, open to chance pollution due to shipping, particularly at the cribs nearest to the route of steamers entering the mouth of the Chicago river. At times, also, the water supply becomes turbid. All the intakes are located in water less than forty feet in depth. Whenever a storm occurs the wave action stirs up the bottom in depths of fifty feet or less. The intakes are, therefore, inside the zone of turbid water. Eventually, for sanitary and esthetic reasons, it is believed that the city of Chicago will consider and undertake the filtration of the water supply."

He further states:

"The danger from shipping is a live one, since the health commissioner of the city of Chicago has shown that typhoid fever is far more prevalent on board vessels on the great lakes than in the towns bordering on the lakes, and that steamers are not only carriers of passengers and freight, but of typhoid as well."

He states the following conclusion: "The amount of water available for dilution, if taken at 10,000 cubic feet per second, will be insufficient after 1922, when supplementary methods of sewage disposal will have to be installed."

Dr. McLaughlin, in his paper of March 5, 1912, hereinbefore referred to, has this to say:

"In regard to sewage disposal it must be remembered that no general rule can be formulated which will cover with justice every case. Each municipality becomes a separate problem, and local conditions must be studied. Remedies for correction of improper sewage disposal will differ according to the local conditions.

"Even if all the sewage from our large cities and towns was prevented from reaching the lakes and rivers it would be impossible to prevent pollution from reaching these waterways in times of storm and flood, so that sewage disposal, even carried to the degree of sterilizing the effluent, does not give us a substitute for water filtration or treatment."

He states further:

"These sewage problems are often difficult of solution, present great engineering difficulties, and necessitate the expenditure of large sums of money. This means that much time must elapse before the proper method is selected, and a great deal more time will pass before the works are completed. In the end, though necessary, the sewage purification does not remove all pollution, and treatment of the water supply is still a necessity after the sewage-disposal plant is in operation.

"On the other hand, the dangerous public water supply is a simpler proposition. Immediate protection can be afforded by treating with hypochlorite, using a temporary plant until the method to be finally adopted is decided upon. In a word, there is every excuse for deliberation and reasonable delay in settling the sewage-disposal problems, while there is no excuse whatever for any municipal government to delay in applying the remedy which protects immediately, viz.: treatment, or filtration of the public water supply."

The cost of sewage diversion of a character and extent adequate to afford a measure of protection to the Evanston water supply from shore pollution will no doubt cost in the neighborhood of $750,000 to $800,000, exclusive of the cost heretofore incurred for the north shore channel.

There is no reason for doubting that a pure, wholesome and attractive water supply can be secured by the city of Evanston from its present source of intake supply by the construction of an efficient filtration plant. The filtered supply would be safe, for use, direct from the faucet, without boiling, or other household treatment, every day of the year.

In view of all the facts and findings set forth in this report, your committee has reached the following conclusions, towit:

1. That neither extending the Evanston water intake to any feasible distance off the lake shore, nor diverting the sewerage system of the city of Evanston from Lake Michigan to the north shore channel of the sanitary district of Chicago, will jointly or singly yield a water supply that will be pure, wholesome and attractive for domestic use and purposes at all times.

2. That rapid sand filtration, supplemented by sterilization, of the present water supply between the intake and distributing mains at the pumping station of the city of Evanston will yield and is the most certain, feasible and economical method of obtaining a water supply for this city that will be pure, wholesome, attractive and safe for domestic use and purposes, direct from the faucets, at all times.

And in view of these conclusions your committee recommends that all necessary steps be taken to secure the erection of a rapid sand gravity type filtration plant for the city of Evanston at the earliest possible date.

(Signed) C. B. Congdon,
Perkins B. Bass,
W. H. Knapp,
J. W. Branch,
Christ Witt,
*_____ ______
Samuel Topliff,
Joint Committee.

*Alderman Rossbach absent.

REPORT

ON THE

Filtration of the Water Supply

OF EVANSTON, ILLINOIS

WITH APPENDICES

MADE TO THE

WATER COMMITTEE

By

WALTER W. JACKSON

and

LANGDON PEARSE

Consulting Engineers

August 28th, 1912

REPORT ON THE FILTRATION OF THE WATER SUPPLY OF EVANSTON, ILLINOIS

To the Honorable, the Water Committee, The City of Evanston, Ill.

Gentlemen:—In accordance with your instructions of May 7, 1912, I have made a somewhat extended study of the conditions affecting the water supply of the city of Evanston, and of the several methods of bettering its quality, and respectfully submit herewith my report thereon, together with recommendations and estimates of cost. In this work I have been assisted by Mr. Walter W. Jackson, formerly superintendent of water works, Columbus, Ohio, who signs this report jointly with me. A preliminary report was submitted to your honorable committee on July 2, 1912, touching briefly on the matters herein amplified.

Your commissioner of public works, Mr. J. H. Moore, and his assistant, Mr. C. C. Saner, have furnished the necessary departmental records, and have shown a lively interest in the subject, as well as a very thorough understanding of the same. We are also indebted to your chemist, Professor Lewis, for information as to his bacterial analyses of the water since the establishment of the municipal laboratory in July, 1911.

Your committee has already given some consideration to the question of improving the water supply by filtration, and has acquired certain land adjacent to the present pumping station, part by purchase, and part through a gift from the Northwestern university, to be used as the site for a mechanical filter plant.

From our study of the evidence presented in your records, and our own personal investigation of the existing conditions, we are able to unreservedly endorse your choice of mechanical filtration for the purification of your supply. The water supply can be made entirely satisfactory only by filtration, and under the local conditions the so-called "mechanical" or "rapid" system of filtration is to be preferred, using the open or gravity type of filter.

We recommend, therefore, the construction on the property already secured of a rapid filter plant, comprising primarily:

1. A mixing tank of 500,000 gallons volume, holding one hour's supply at the nominal rate of 12,000,000 gallons per 24 hours, in which the coagulant will be thoroughly mixed with the raw water to obtain a complete reaction.
2. A settling basin in two compartments, having a total volume of 1,000,000 gallons, and allowing two hours for sedimentation when the plant is operating at its nominal capacity of 12,000,000 gallons per 24 hours.
3. Ten filter units having a net sand area of 0.01 acre each, the installation having a gross capacity of 12,500,000 gallons per 24 hours at the ordinary rating of 125,000,000 gallons per acre per day.
4. A filtered water reservoir in two compartments, providing a total storage capacity of 2,500,000 gallons, or five hours' supply at the rated capacity of the plant.
5. A head house providing space for the wash water pumps and the air compressor and tank, for the storage of coagulating chemicals and the making and handling of their solutions.
6. Low lift pumping equipment by means of which the raw water will be lifted from the lake to the mixing tank, comprising two or more centrifugal pumps to be driven either by electric motors or steam turbines, with a suitable house for the same.

The general arrangement of the proposed new works is shown on Figure 1. It will be seen therefrom that the space provided is barely sufficient to receive the necessary construction, and that the removal of the engineer's residence will be essential. Under ordinary conditions space would be conserved by building the filters on the roof of the filtered water reservoir, but in this location we believe it will be safer to reduce the loading on the rather treacherous soil to avoid floor cracks and consequent leakage. For any considerable extension to the plant it will be necessary to provide more land.

You have laid particular emphasis on your desire for a most accurate estimate of the cost of the proposed construction. Instead therefore of following the ordinary practice for such a report as this, and basing our figures on assumed costs of units of volume or capacity, we have made up rough sketch designs, and from these we have carefully estimated all the major items in actual quantities, such as concrete, excavation, piping, re-inforcing steel, etc. Unit prices were then figured on the conditions obtaining in the district, and we believe that the results so determined represent the true cost of the work as nearly as is possible to estimate before the completion of the working drawings. An exception is made, however, in the item of moving the residence of your pumping engineer, for which a merely nominal figure has been used.

TABLE NO. 1.

Estimated Cost of Rapid Filter Plant.

Force main and Venturi meter	$ 4,610		
Mixing tank	13,224		
Settling basins	18,750		
Head House:			
Building and appurtenances ... $12,643			
Wash water pumps, air compressor and tank.. 5,950	18,593		
Filters complete, including filter house and pipe gallery	57,492		
Filtered water reservoir	45,812		
Filtered water conduit and pump well	5,446		
Blow-off line and drains	1,750		
Moving engineer's residence	1,200		
	$166,977		
Engineering and contingencies, 10%	16,698	$183,675	

Cost of Low Lift Pumps.

Low lift pumps, house, piping and appurtenances	$19,000	
Engineering and contingencies, 10%	1,900	20,900
Grand total		$204,575

Cost of Operation:

A liberal estimate of the cost of operating the proposed filter plant, with fixed charges, is given in Table No. 2. The estimates are based on the present consumption of 2,190,000,000 gallons per year, or an average of 6,000,000 gallons per day, with the application of one grain of aluminum sulphate per gallon of water. The cost of power for the low lift pumps, wash water pumps, etc., and the lighting, making together the largest of the several items, is estimated from the quotation of the Sanitary District of Chicago of $26.40 per horse power per year for a 24-hour load. This is on the safe side, because of the method of charging for the use of electricity by the peak load rating. (See Appendix B.)

TABLE NO. 2.

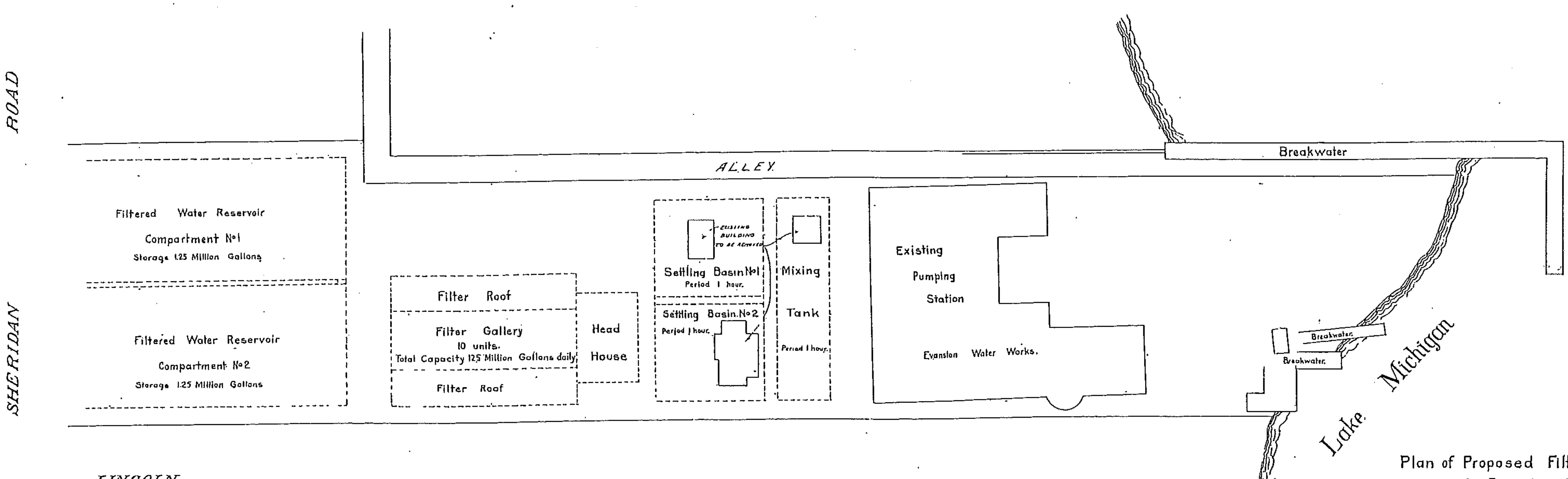
Annual Cost of Maintenance and Operation and Fixed Charges.

Operating Cost.

Chemicals:				
Sulphate of Alumina, 160 tons at $18.00		$2,880.00		
Attendance:				
Two men at	$ 900.00			
One man at	1,000.00			
One man at	720.00	3,520.00		
Superintendence:				
Part time, say		900.00		
Power and Lighting:				
175 horse power at $26.40		4,620.00		
Oil supplies and repairs		750.00		
Operating cost, total			$12,670.00	
Per million gallons				$ 5.78

16A

Interest,
Deprecia



Plan of Proposed Filtration Plant
for Evanston, Illinois.
August 1912. Scale In.=1 ft.

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Fixed Charges.

Interest, 4% on $204,575	$8,183.00		
Depreciation, 2% on $204,575	4,091.50		
Fixed charges, total		$12,274.50	
Per million gallons			$ 5.60
Grand total		$24,944.50	
Per million gallons			$11.38

As will be seen, the total cost per year for filtered water would be $24,944.50 on the basis of 2,190 million gallons per year, or $11.38 per million gallons. Of this the cost for chemicals, superintendence, etc., alone is $5.78 per million gallons.

Should it prove desirable to use lime with the sulphate of alumina, there would be required 400 tons at a cost of $2,600. This would raise the cost of operation to $15,590, and the total per million gallons to $12.90.

These costs are not at all excessive. So far as we can ascertain there is at present sufficient surplus in the earnings of the water department to amply cover our estimated annual charges without any increase in the water rates. It has, however, been the custom in Evanston to provide earnings from the water works sufficient not only to cover the operating and fixed charges of the water works and improvements, but to provide for transfers to other funds to be applied to the maintenance of the fire department and in other municipal expenses. Therefore, the annual expense of the filtration plant will have to be an additional charge. The effect of this on rates is considered in Appendix C.

The capacities recommended for the proposed construction have been chosen after a careful study of the conditions governing the consumption of water in the city of Evanston, and a discussion of this phase of the question, and of the desirability of further regulation of the use of water is included herein. We have also appended a comparison of the cost of pumping by steam and electricity.

Description of Present Pumping Plant and Intake:

The present pumping station is located on the lake front, on the north side of Lincoln street. The equipment includes:

One Holly quadruplex engine, 14"x9"x24", having a capacity of 2,000,000 gallons per 24 hours, erected in 1874. This was the first installation for the Evanston waterworks.

One No. 4 Gaskill-Holly compound fly wheel pumping engine, 16" and 32"x18½"x28", having a capacity of 5,000,000 gallons per 24 hours, erected in 1888.

One No. 7-A Gaskill-Holly compound fly wheel pumping engine, 28" and 50"x29"x38", having a capacity of 12,000,000 gallons per 24 hours, erected in 1896.

One 200 horse power horizontal water tube boiler, with Vicks down-draft furnace.

Two 85 horse power horizontal return tubular boilers. These are to be replaced shortly with two 200 horse power water tube boilers, with down draft furnaces, already purchased.

The two larger engines are apparently in good condition, giving evidence of excellent management in the pumping station. All three are inside packed, the two larger operating with small slippage for this type of machine. But as they had been newly packed shortly before the pitometer tests reported below the average slippage may be considerably greater.

The pressure carried is but 40 pounds per square inch, measured at a gauge 23 feet above Datum, which would be considered very low in any but an extremely flat territory. There is no reservoir and water is pumped directly to the distribution system.

The very first collector of lake water was a crib filled with gravel extending 125 feet into the lake. In 1876 a bar formed outside this crib making it impossible to pump more than one hour at a time. Water was next received through a 16-inch intake pipe extending 1,200 feet into the lake. This was supplemented in 1890 by the construction of a 30-inch intake pipe 2,600 feet long, and in 1908-09 a 36-inch cast iron pipe was laid parallel to the 30-inch pipe to the end thereof, at which point the two were joined into one 42-inch cast iron pipe line, which was extended to a group of 13 screened inlets 1 1/16 miles off shore, in 32 feet of water. The intake pipes are laid on the lake bottom, and without protection. In the spring of the present year the 42-inch pipe was broken, presumably by a dragging anchor.

Equipment for the application of hypochlorite of lime to the supply was installed at the pumping station in December, 1911.

Modern Standards of Quality of Domestic Water Supply:

With the advance of sanitary knowledge during the last twenty years, the necessity of a pure water supply has become recognized in progressive communities. Among the requirements to be fulfilled in a suitable water supply are these:

1. The water must be pure, that is, free from all pathogenic or disease-producing bacteria. Since most processes of treatment do not discriminate between the pathogenic and non-pathogenic bacteria, we say that a water must be low in bacterial content.
2. The water must be clean, that is, free from all mineral or organic particles which tend to cause roiliness or turbidity.
3. The water must be colorless and odorless.
4. The water must be free from microscopic organisms, which, while harmless to man, produce disagreeable odors and tastes.
5. It must be free from injurious material in solution.
6. It must be soft.
7. It must be cool.

Character of the Water:

Lake Michigan water has no injurious substances in solution, such as are frequently found in alkali waters of the west, but is rather hard, requiring much soap to make a lather, and causing soft scale in boilers. In general it is fairly cool. At a distance of ten to twenty miles from shore the water is clear, nearly colorless, and practically free from those microscopic organisms which cause tastes or odors. Near the shore, however, the water is not clear, but at times has a considerable degree of turbidity, and contains large numbers of bacteria, many of which may be pathogenic.

Analyses of the Evanston water supply reported by the Illinois Water Survey are summarized in Table 3, and the results of analysis of samples taken in the vicinity of Evanston made in connection with the sanitary investigation of the North Shore of Lake Michigan, from Evanston to Waukegan, by Prof. Edward Bartow, Langdon Pearse and F. O. Tonney, M. D., in 1909 are shown in Table 4.

Besides the turbidity and color, which are apparent to all users of Evanston water, these analyses point to the pollution of the water supply by the city's own sewage. So long as sewage is discharged into the lake the water supply will be subject to dangerous pollution, depending somewhat on wind and weather. The analyses from the survey of the North Shore show a considerable degree of turbidity even three miles from shore, and extremely high bacterial counts, with the occasional occurrence of B. Coli, taken as indications of fecal pollution, at one to two miles out.

Typhoid in Evanston:

Typhoid fever is one of the most common waterborn diseases. A study of its occurrence and intensity is frequently of great assistance in judging the quality of a water supply, since the effect of the water on the health of the consumers is indicated thereby. Other intestinal diseases may be caused by infected water, such as diarrhoea, winter cholera and the like, but as physicians do not commonly report them, data is not usually available. Typhoid, however, should be and usually is reported to city boards of health.

Typhoid has been for several years quite common in Evanston. The number of cases was greatly increased in 1911 by a mild epidemic late in the year, which was checked by the diligence of the health and water officials in installing the hypochlorite plant referred to above. The figures given in Tables 5 and 6 were taken from a report prepared by Professor, Lewis,

TABLE NO. 3.

SUMMARY OF ANALYSES OF EVANSTON WATER.

COMPILED FROM REPORTS OF ILLINOIS STATE WATER SURVEY,

1897 to 1911.

RESULTS IN PARTS PER MILLION.

Year	Number of Analyses	Turbidity	Color	Residue on Evaporation	Chlorine	Oxygen Consumed	Nitrogen as Ammonia Free	Nitrogen as Ammonia Alb.	Nitrogen as Nitrites	Nitrogen as Nitrates	Alkalinity	Bacteria Per c.c.	Colon Bacillus Per Cent. Positive 10 c.c.	Colon Bacillus Per Cent. Positive 1 c.c.	Colon Bacillus Per Cent. Positive 0.1 c.c.
1897	4	*	**												
Average			0.05	182.8	2.9	4.3	.157		.000	.200					
Maximum			.10	300	3.0	8.3	.612	.360	.002	.400					
Minimum			.03	144	2.7	2.5	.001	.068	.000	.050					
1898	10	*	**												
Average			.02	165.4	3.3	2.9	.013	.068	.004	.189					
Maximum			.06	242	4.8	4.5	.072	.118	.030	.300					
Minimum			.02	136.4	2.9	2.0	.001	.017	.000	.040					
1904	30	*	**												
Average				189.2	3.3	4.1	.037	.163	.003	.248					
Maximum			.20	352	9.3	7.8	.220	.336	.075	2.33					
Minimum			.00	132	1.3	2.6	.006	.092	.000	.04					
1905	34	*													
Average				194	2.71	4.2	.041	.189	.001	.211					
Maximum				458	3.9	15.6	.082	1.48	.007	.360					
Minimum				143	2.2	2.5	.026	.066	.000	.012					
1906	31	*													
Average				201	3.7	4.1	.043	.151	.002	.25	118	1630	59	63	2
Maximum				313	5.0	6.7	.102	.236	.024	.680	146				
Minimum				145	2.0	2.6	.014	.064	.000	.120	74				
1907	11		**												
Average		28	.07	166	4.5	3.7	.021	.108	.001	.247	118	3097	50	60	30
Maximum		100	0.2	205	6	4.7	.054	.160	.002	.520	126	13000			
Minimum		5	.0	144	3	3.0	.000	.010	.000	.040	111	150			
1908	10														
Average		52	7	191	6	2.9	.084	.123	.002	.293	120	1217	80	43	5
Maximum		180	20	281	7	7.1	.510	.260	.007	.680	128	5200			
Minimum		20	0	146	5	1.4	.008	.068	.001	.160	112	180			
Intake extended in 1909 from half mile to one and one-sixteenth mile															
1909	6														
Average		34	7	179	5	2.8	.037	.144	.001	.410	118	700	67	55	36
Maximum		50	10	213	5	3.7	.058	.170	.005	.720	123	1500			
Minimum		15	0	155	4.5	2.2	.008	.110	.000	.240	111	80			
1910	4														
Average		44	5	172	5.5	2.1	.027	.096	.000	.270	134	27600	75	25	25
Maximum		80	10	185	6	2.5	.036	.114		.320	136	60000			
Minimum		5	0	163	5	1.8	.016	.080		.240	132	3000			

* Turbidity was noted. In most cases decided.

** Color is given by old standard.

Note: Odor is often musty.

TABLE NO. 4.

SUMMARY OF ANALYSES FROM SANITARY SURVEY
OF NORTH SHORE OF LAKE MICHIGAN.
November 16 to December 16,1909.
Compiled from Original Analyses for Lake Michigan Water Commission
RESULTS IN PARTS PER MILLION

Distance off Shore. Miles	Number of Samples	Appearance			Chlorine	Oxygen Consumed	Nitrogen as				Alkalinity	Bacteria per Cubic Centimeter	B. Coli Per Cent. of Tests Positive
		Turbidity	Color	Odor			Ammonia Free	Ammonia Alb.	Nitrites	Nitrates			
0.1	7												
Average		62	9	0	3.3	2.5	.014	.081	.000	.000	123	5500	63
Maximum		180	25		4.0	4.7	.020	.050	.000	.000	128	12000	
Minimum		15	0		3.0	1.4	.000	.130	.000	.000	121	384	
1	7												
Average		29	3	0	3.0	1.9	.009	.067	.000	.000	119	2700	14
Maximum		60	10		3.0	2.7	.030	.080	.001	.000	122	12000	
Minimum		0	0		3.0	1.4	.000	.060	.000	.000	115	43	
2	4												
Average		18	1	0	3.0	1.9	.012	.062	.000	.000	117	8900	0
Maximum		30	5		3.0	2.5	.030	.070	.000	.000	118	18100	
Minimum		0	0		3.0	1.4	.000	.050	.000	.000	116	100	
3	4												
Average		12	0	0	2.9	1.6	.002	.058	.000	.000	119	5800	0
Maximum		20	0		3.0	2.1	.010	.070	.000	.000	121	20000	
Minimum		5	0		2.5	1.2	.000	.050	.000	.000	117	100	
4	3												
Average		7	0	0	2.8	1.6	.003	.067	.000	.000	119	3100	0
Maximum		10	0		3.0	1.8	.010	.070	.000	.000	120	6140	
Minimum		0	0		2.5	1.4	.000	.060	.000	.000	118	30	
5	3												
Average		5	0	0	2.8	1.3	.000	.060	.000	.000	118	300	0
Maximum		10	0		3.0	1.6	.000	.070	.000	.000	118	760	
Minimum		0	0		2.5	1.0	.000	.050	.000	.000	118	30	

published in the 1912 Proceedings of the Illinois Water Supply association.

TABLE NO. 5.

Typhoid Deaths per 100,000 in Chicago and Evanston.

Year.	Chicago.	Evanston.
1907	17.5	21.
1908	15.0	32.
1909	12.5	28.
1910	13.0	24.
1911	10.8	28.
Average of 5 years	13.8	26.6

WATER CONSUMPTION.

Records:

An interesting comparison of the quantities of water delivered into the distribution system is shown in Table No. 7, compiled from the pumping station records from the year 1901 through 1911. The fluctuations in the rate of consumption for the period are, however, brought out to better advantage in the curves shown in Fig No. 2. It is interesting to note that your commissioner of public works has checked, to a large extent, the waste of water,

TABLE NO. 6.

Distribution of Typhoid Cases in Evanston, by Months.

Year	January	February	March	April	May	June	July	August	September	October	November	December	Total Cases	Total Deaths	Cases per 100,000	Deaths per 100,000
1909 ..	12	7	9	1	0	2	0	1	4	8	4	2	50	7	200	28
1910 ..	7	8	19	4	5	4	4	5	3	8	2	0	69	6	276	24
1911 ..	4	1	1	0	3	0	4	2	4	9	22	49	99	7	396	28

During the 1911 epidemic all possible sources of infection were examined, and all indications pointed to the responsibility of the water supply. Over 90 per cent. of the cases were those of users of raw city water. Professor Lewis states: "The water supply of Evanston varies from 5 to 200 parts per million in turbidity, with a total bacterial count on agar at 20° C. of from 400 to 5,000 colonies per cubic centimeter, and gas producers vary from 5 to 20 in ten cubic centimeter quantities."

The data given in Tables 5 and 6 indicate that Evanston is subject to typhoid in amount much greater than Chicago. The concentration of the major portion of the cases in one or two months, usually in the winter, points to an infected water supply. The sudden decrease in the typhoid cases in December, 1911, and January, 1912, subsequent to the application of hypochlorite of calcium, confirms our belief that the typhoid is largely due to infected water.

holding the average rate of consumption nearly constant since 1903, despite the considerable increase in the population served.

Slip.

All the quantities in Table No. 7 have been calculated from plunger displacement, without correction for slip. There is ordinarily a very appreciable loss through valve leakage and especially with inside packed pumps, from plunger leakage. The commissioner kindly ascertained this slip through pitometer tests conducted by Mr. W. D. Gerber, whose report is appended hereto. Mr. Gerber fixes the slip of the three pumping units at:

5.4% for the 12,000,000 gallon pump
5.2% for the 5,000,000 gallon pump
27.9% for the 2,000,000 gallon pump (one plunger measured). Revised figures in the calculation of displacement factors would increase the apparent slip for the

5,000,000 gallon pump to 10 per cent., and for the

2,000,000 gallon pump to 30 per cent.

These figures are less than were expected, and as the two larger machines were newly packed, and were said by the chief engineer, Mr. Wadsworth, to be in better shape than for some years past, it is probable that the average station slip for past years would be in the neighborhood of 15%. The quantities used for our studies, however, have not been corrected, except where specifically noted.

Except in extremely hot or very cold weather, the demand for water in the small hours of the night is insufficient to permit the operation of the large engine under the governor, and with this machine running it has been the practice to waste a sufficient quantity to hold the gross pumping rate up to about 4,000,000 gallons per day. During the period of our observation, in June of the present year, this wastage amounted to apparently a rate of one million gallons per day for perhaps 4 hours per day, or about 167,000 gallons per day. This correction of course does not appear at times when the draft is heaviest.

Population:

TABLE NO. 8.

Population Served, from U. S. Census.

	1890	1900	1910	Increase 1900-'10
Evanst'n	13,059	19,259	24,978	29.7%
Wilmette	1,458	2,300	4,943	115.0%
Total	14,517	21,559	29,921	Av. 38.3%

The Wilmette district has been served by the Evanston water works since 1893. The growth of Evanston during the past decade has been comparatively slow. The trend toward the increased construction of apartments is very evident, and it is probable that future building development will be largely of this character.

Per Capita Consumption:

The per capita consumption of the combined cities has been reduced in the last ten years from 240 gallons to 187 gallons. This, however, relates to the average for the year. The per capita consumption for the maximum day rises to about 400 gallons, and the maximum hourly rate to 567 gallons.

TABLE NO. 7.

Summary of Pumping Statistics, Evanston, Ill., 1901 to 1911.
Compiled from Records Furnished by C. C. Saner.
Gallons Pumped in 24 Hours.

Year	Average for Year	Average for Max. Month	Average for Min. Month	Average for Max. Day	Average for Min. Day
1901	5,320,200	7,940,000	3,717,400	10,155,100	3,365,200
1902	5,297,700	6,760,600	4,392,400	8,679,700	3,667.000
1903	5,738,500	7,660,500	4,429,800	9,742,600	4,002,600
1904	6,367,700	7,360,900	5,652,000	9,694,300	4,658,300
1905	6,183,400	7,104,900	5,118,500	8,859,100	4,485,200
1906	6,474,400	9,095,600	4,973,800	11,358,300	4,461,600
1907	5,956,500	7,691,500	4,087,300	10,571,000	3,657,600
1908	6,063,700	8,755,700	4,186,300	12,745,900	3,732,300
1909	6,056,500	8,670,000	5,068,300	11,587,800	4,032,640
1910	6,217,800	9,300,400	4,933,000	12,034,800	4,196,700
1911	5,777,000	9,154,000	4,642,000	12,072,800	4,135,300

While these rates have not been corrected for slip, it is still true that the consumption is undoubtedly excessive and far greater than in most other cities of like character and approximate size.

A comparison of the per capita rates in Evanston and Wilmette is instructive, the figures here used being calculated from the 1910 records, using the population figures of the U. S. census.

June 15. 5 million gallon pump running alone, midnight to 6 a. m. and 11 to 12 p. m.
5 and 2 million gallon pumps running 6 a. m. to 11 p. m.
Hot. Light rain.
Temperature, Maximum, 81° F.
Mean, 72° F.
Precipitation, 0.16 inch.

July 6. 12 and 2 million gallon pumps running.

TABLE NO. 9.

Comparative Consumption of Water in Evanston and Wilmette.

		Consumption in gallons.			
	Population.	Daily Average.	Per Capita uncorrected.	Slip.	Per-Capita corrected for slip.
Evanston	24,978	5,820,600	233	15	190
Wilmette	4,943	397,200	80	26	108

A comparison of the rates of consumption in various cities will be found in Table No. 11 in Appendix C. It will be seen that in a great number of residential cities the per capita consumption is less than one-half the average in Evanston.

Hourly Fluctuation:

A knowledge of the variations in the demand for water through the day is important in determining the size and proportions of a purification works, and also in the study of the manner in which the water is used. Beginning in May of the present year, readings of the counters on the pumps have therefore been recorded at hourly intervals instead of but once each day as heretofore.

NOTE. To accompany Fig. 3.

The weather conditions on the dates of observation are taken from the records of the meteorological station of the Evanston Board of Public Works (C. C. Saner, observer).

June 11. Hot and dry.
Temperature, Maximum, 84° F.
Mean, 70° F.

June 14. 5 million gallon pump running alone 9 to 12 p. m.
12 million gallon pump running balance of day.
Cool and rainy.
Temperature, Maximum, 66° F.
Mean, 59° F.
Precipitation, 0.47 inch.

Hot.
Temperature, Maximum, 93° F.
Mean, 83° F.
Precipitation, Trace.

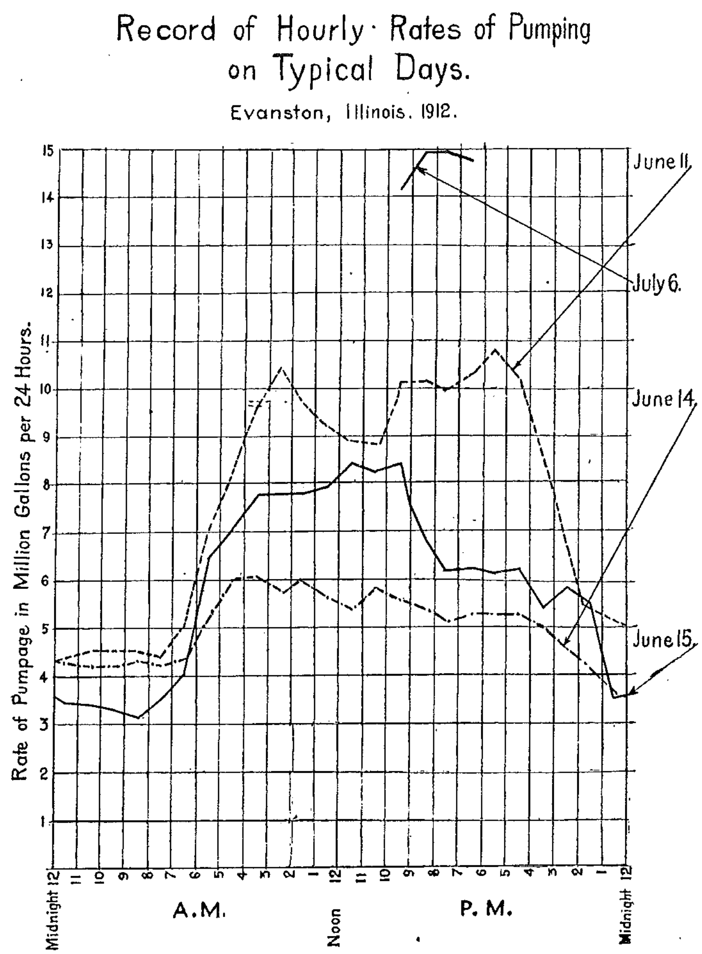
The effect of hot and dry weather is illustrated by the increased pumpage on June 11, over that on June 14 and 15, when light rains were falling.

The effect of hot summer weather is illustrated by the few hours observed on July 6, when an extremely high pumpage occurred.

The curves for several typical days are shown on Fig. No. 3, and while the observations have not as yet been carried over the four seasons, there is ample proof that the extraordinary consumption during the warm weather is due to the excessive sprinkling of lawns and gardens. Great wastage from leaky fittings is also indicated by the exceedingly high rate of one hundred gallons per capita per day during the late hours of the night, when in a residential town there is practically no actual demand.

While there is no record of the hourly rates in the past, the chief engineer is of the opinion that a gross rate of 17,000,000 gallons has been maintained for a period of about four hours, all three machines have been operated simultaneously at their nominal capacities. The highest rate reported during the past year, or since hourly counter readings have been taken, was reached on July 6, when a gross rate

Fig. 5


Record of Hourly Rates of Pumping
on Typical Days.
Evanston, Illinois. 1912.
Rate of Pumpage in Million Gallons per 24 Hours.
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
June 11.
July 6.
June 14.
June 15.
Midnight 12
11
10
9
8
7
6
5
4
3
2
1
12
11
10
9
8
7
6
5
4
3
2
1
12
Midnight
A.M.
Noon
P.M.

of 14,775,300 gallons per day was held for four hours with a rate maintained over a 5-minute period of 15,800,000 gallons per day, or corrected for slip, of 14,400,000 gallons per day.

Maximum Momentary Rates:

Though our observations have been limited to little more than one month in the year, it would appear that the maximum hourly rate of pumpage will run about forty per cent. above the average for the day, and the maximum momentary rate of discharge around fifty per cent. above the average for the day. These ratios will hold for the hot weather, when the quantities are greatest. They are the rates determining the capacity of the projected filter plant.

Treatment of Water.

The Evanston water supply is unsatisfactory in that the bacterial count is high, showing strong evidence of sewage pollution. In addition it is not clean, especially during and after storms, the turbidity ranging from zero to 180 parts per million. Color is frequently present to the amount of twenty parts per million.

So long as sewage is discharged into the lake by Evanston and neighboring municipalities, the water supply is always subject to dangerous contamination, depending on wind and weather. The diversion of the sewage will not prevent the possibility of chance pollution from passing vessels, and will not remove the cause of turbidity or cloudiness. In other words, diverting the sewage will not clarify the water.

Extension of Intake:

Cleaner and less polluted water than that in use at present can be obtained by extending the intake line, but the expense of tunnel construction would be great, and an exposed pipe line laid on the lake bottom, while also expensive, would be at all times in danger of breakage from dragging anchors, and the like, as instanced by the experience of the past spring, when very dirty and polluted water entered the system from the broken intake pipe.

Under the conditions existing at Evanston, we do not favor the extension of the intake, but advise filtration as the best and surest means to obtain a clean, pure water above all suspicion.

Sterilization:

Sterilization of water by calcium or sodium hypochlorite is a very practicable emergency measure, and was used to good effect in the winter of 1911-12 to check an incipient typhoid epidemic. We do not consider this treatment alone to be a sufficient corrective in the case of the Evanston supply. It does not remove turbidity, and a clean water would therefore not be obtained through its use. In the quantities permissible for use it does not remove tastes or odors. And further, the success of the treatment depends on the continuous application of correct quantities of the chemical. The possibility of human negligence as a factor is high. If an orifice box is stopped up, or a solution tank empties, and the attendant is not watchful, a dose of untreated water may pass. Again the process is selective in that it attacks the weaker bacteria, while the more virile may pass unharmed or be merely stunned. A filter plant, however, when running with reasonable supervision, is always at work impartially removing 95 to 99 per cent. of all the bacteria, whether weak or strong.

Other sterilizing processes have been discussed by various cities, here and abroad, particularly the use of ozone and the ultra-violet ray. In both filtration is absolutely necessary to secure a clean water. While ozone is theoretically an excellent sterilizing agent, the results so far obtained in actual practical operation do not seem to warrant the recommendation of its use today, chiefly owing to the cost and the mechanical difficulties of the process. The ultra-violet ray is also said to be an efficient sterilizing agent, but for its successful application an absolutely clear filtered water is required. Hence, neither ozone nor the ultra-violet ray need be considered further with reference to your situation.

Supplementary to filtration, the hypochlorite treatment makes an excellent finishing process, assuring a water as bacterially free and clean as is possible to secure. We have therefore included in our estimates the cost of the necessary apparatus for such treatment.

Filtration:

Either of the two established systems of filtration will give satisfactory results from the standpoint of efficiency with Lake Michigan water. Under the local conditions, however, we believe the "rapid" or "mechanical" filters are preferable to the "slow sand" type.

Rapid or mechanical filtration is accomplished by the formation of an artificial filtering medium in the upper layer of the sand bed. This layer consists of aluminum or iron hydrate, and the suspended particles entrained therewith. It is customary to provide a settling basin through which the water passes prior to filtration, in which much of the suspended matter collected in coarse clots by the gelatinous coagulant drops out, relieving the sand beds of a great part of the burden. The ordinary capacity of well designed rapid filters is rated at 125,000,000 gallons per acre per day, and thus the area required for an output of 12,500,000 gallons per day would be but one-tenth of an acre. When choked or clogged the mechanical filter is cleansed by washing with a reverse flow of filtered water, accomplished in a few minutes with the use of perhaps three per cent. of the filtered water.

The so-called "slow sand" process depends for its efficiency on the formation of a bacterial jelly in the upper layers of the sand bed, which retains the bacteria and suspended particles. Slow sand filters are operated at the low rate of 3 to 5 million gallons per acre per day. A plant of 12,500,000 gallons capacity would require about four acres of sand surface while the same settling and filtered water storage basins would be necessary as in the rapid type. When the sand bed becomes clogged it is cleaned by scraping and removing the top layers of sand. This expense, together with the heavy fixed charges on the greater first cost (2½ to 3 times that of the rapid filters) would more than offset the cost of the coagulant and attendance required for the operation of the rapid filter in your case.

Rapid Filters Preferable:

On account of the desirability of locating the filters near the present pumping station, and the restricted area available, because of high land values, at the proposed site, as well as the necessity of limiting the expenditures for construction, we have approved the conviction held by yourselves and the Commissioner of Public Works that the Evanston water should be purified in a mechanical filter plant. The use of sulphate of aluminum, in the treatment of water for domestic use, is recognized today as entirely harmless. The amount used is extremely small, from ¾ to 2 grains per gallon, or about one pound in 56,000 pounds of water. The alkalinity of Lake Michigan water, that is, its contents of the carbonates of lime and magnesium, is sufficient to always insure the complete reduction of the sulphate of aluminum to the insoluble hydrate, there being present approximately 116 parts per million of alkalinity whereas but 16 parts are necessary for the reaction with two grains of coagulant per gallon. This coagulant is used extensively in water putrification plants at Columbus, Ohio; Louisville, Kentucky; Little Falls and New Milford, New Jersey, and many other cities. Altogether several million people now consume daily, water treated by sulphate of aluminum.

Summary:

The present water supply is unsafe being subject to gross unexpected pollution, and is frequently excessively turbid, judged by modern standards for municipal water supplies. Therefore a filtration plant should be constructed for the Evanston water supply:

1. To insure a pure water at all times, and especially pending the diversion of the sewage to the North Shore Channel of The Sanitary District of Chicago. However, even with the entire dry weather sewage flow diverted, there will be the probability of storm flow or surface wash reaching the lake, and there will still be the danger of pollution by shipping.

2. To insure a clean water at all times. The present intake is located in the zone of muddy water, when stirred by wind. The diversion of sewage will not make the water clean.

3. To protect the supply against probable contamination and certain turbidity, due to possible breakage of the intake pipe.

Coagulation:

In Bulletin 8 of the Illinois State Water Survey, Messrs. Bartow and Birdsall have published a study on the coagulation of Lake Michigan water. Their conclusions point to the desirability of the use of lime in connection with the application of sulphate of aluminum as a coagulant, to increase the speed of flocculation. The turbidity of the water samples is not given, nor the method of manipulation, but it is probable that the tests were made under quiescent conditions.

In a series of tests made by us early in June on lake water, ranging in turbidity from 10 to 30 parts per million, our own observations indicate that rapid flocculation is obtained with applications of coagulant as low as ¾ grains per gallon if the sample is agitated, but that it is slow if produced under quiescent conditions. The flocculation is facilitated by the addition of two or three grains per gallon of lime, and further, if the full quantity of lime is added with the coagulant to a portion of the water, overtreating the same, and a few minutes allowed for reaction before the addition of the untreated remainder, the reaction is more rapid and a heavy flock is produced which settles rapidly, clarifying the water much more effectually than when sulphate of alumina alone is used.

The addition of lime also partially softens the water, reducing the alkalinity or temporary hardness about eight parts per million for each grain per gallon used.

DESIGN OF FILTER PLANT.

Character of Construction:

The filter plant proposed for your consideration would be of first-class construction throughout. The mixing tank, settling basins and filtered water reservoir are to be of concrete, reinforced with steel whenever necessary, with groined arch roofs, over which two feet of earth will be placed, to be covered with grass. The head house and filter gallery will be built of suitable brick, with stone trim, tile roof, and reinforced concrete floors, to be fireproof throughout. The filters will be of reinforced concrete with suitable air and strainer systems, enclosed controllers, and operating tables, with spacious filter and pipe galleries affording easy access to all parts. With the small filter units no wash water storage is contemplated, the wash water pumps being of sufficient size to deliver the required amounts. These, together with a small air compressor, may be motor-driven. In short, the plant will be up-to-date, with all necessary mechanical devices, of first-class permanent construction, and built at moderate cost.

Capacity of Plant:

The average daily water consumption at the present time is approximately 6,000,000 gallons, the maximum daily draft being reported at 12,000,000 gallons, and the highest hourly rate observed, 17,000,000 gallons per 24 hours, this last having been maintained for a period of four hours.

Appreciating the present wasteful use of water in Evanston, and counting on the effect of the proposed general introduction of meters, your Committee has suggested that the proposed purification works should be designed for a considerably lower capacity than that demanded by the present maximum daily consumption. This would be counting the chickens before they are hatched, however. In so important and vital a project as a pure water supply, we believe it unsafe to consider the lesser capacity. The plant must be designed for the expected maximum daily draft, for consumers may continue to use water freely on a hot summer day during a drought even though the ordinary use is restricted by the use of meters. The effect of any such reduction in the waste of water may be discounted, however, in the omission of reserve capacity which would ordinarily be provided for the natural increase in the demand due to the growth of population.

We have therefore determined the rated capacity of the proposed construction at 12,500,000 gallons per 24 hours. In view of the present excessive rate, and the possibility of further control, and considering that the maximum demand on the Evanston water works is made in the summer months, when the turbidity of the water is ordinarily so low that an overload capacity may reasonably be demanded of the filters, we believe it unnecessary to provide in the original construction reserve capacity to cover future growth in population.

It is proper to provide for the excess draft, occurring in the daylight hours, by the storage of filtered water. The efficiency of filtration is largely dependent on maintaining the uniformity of rates. It is therefore decidedly improper to omit the filtered water reservoir and depend on changing the rate of filtration to meet the demand. Besides, this would require a capacity in filters fifty per cent. greater than when the draft is balanced by a sufficient filtered water storage.

Mixing Tank:

One fault of the earlier filter plants was the absence of facilities for the thorough mixing of the coagulant with the water, and the shortness of the period allowed for coagulation. To obviate the poor sedimentation resulting from this cause, we have provided for the construction of a mixing tank or reaction basin of generous proportions, to be thoroughly baffled, so that the cross currents created therefrom produce the mechanical agitation necessary to thorough mixing, insuring rapid and complete coagulation. The enlarged aggregate formed by accretion on the gelatinous hydrate, kept in suspension by the rapid velocities in the mixing tank, is more easily removed in the settling basins than the fine particles of suspended matter carried through with incomplete coagulation.

Settling Basins:

The settling basins proposed are somewhat smaller than would be desirable without the preliminary treatment of the water in the mixing tank, but being well baffled and provided with properly designed inlet ports and collectors, the following efficient coagulation they will remove a large percentage of the impurities from the water, and reduce in proportion the burden on the filters, and the amount of wash water required for their operation. Consideration has also been given to the fact that the raw water is seldom high in turbidity during the seasons of heavy draft, and that during periods of high turbidity the quantities treated are not more than half the rated capacity of the plant.

Lime Solutions:

As our laboratory tests showed conclusively the improvement in coagulation and sedimentation effected by the use of small quantities of lime with the coagulant, we have made provision in the estimates for a lime slacking rig and solution tanks. It is expected that the quantities of the coagulant required will be lessened by the use of lime, and of course the softening effect would be advantageous. It is estimated that the soap necessary to completely soften one million gallons of water, of the composition of Lake Michigan water, is approximately worth $1,000.00. Soft water is also much more agreeable than hard in the bath, and is highly desirable in the laundry.

Filters:

A filter unit of small capacity has been proposed largely because it was understood that objections existed to the building of an elevated wash water tank on the property. Larger units would require larger wash water pumps, the operation of which would be more troublesome, and with electric power, much more expensive. If the objections to the elevated wash water tank are withdrawn, it will be quite feasible to substitute for these ten units of 0.10 acre area each, six units, each having a net sand area of 0.0167 acre, and a nominal capacity of 2,080,000 gallons per day. With the wash water tank, and the small wash water pump then required, the cost of the six unit plant will be about $3,000 less than that of the ten unit installation upon which our estimates are based. A somewhat shorter filter gallery would be required and a somewhat greater area would be made available thereby for future extension.

Filtered Water Reservoir:

As stated above, it is necessary to provide suitable and sufficient storage of filtered water to equalize the varying demands by the City, and to obviate varying the rate of filtration, a procedure that is undesirable. We have fixed the size of the filtered water reservoir at a total of 5 hours' supply, based on the rated capacity of the plant. More storage would be desirable, but space is lacking on the proposed site. Adequate storage conserves economy of operation and maintenance of continuous service. The reservoir will be divided into two separate compartments by a tight dividing wall. This facilitates inspection whenever required. Baffles are also proposed to insure thorough displacement of the stored water and the circulation of fresh incoming water.

Wash Water Pumps:

The estimate covers the installation of two motor-driven centrifugal pumps each of sufficient capacity to wash one filter unit, 0.01 acre in size at the nominal rate of 12 inches vertical rise per minute. Since continuity of service depends on a prompt washing of a clogged filter, the duplicate installation is essential. The wash water pumps are to be installed in the basement of the head house. While it is feasible to wash beds of area 0.0167 acre, as proposed in the six filter unit alternative, the size of pumps and piping is considerably increased, and the cost also. But if no aesthetic objection is made to the presence of an ornamental elevated tank, a smaller pump can be used with the six filter unit plant, decreasing the cost as noted under *"Filters."* From the standpoint of operating cost, this is desirable, as the peak load is materially lowered. This, however, is a detail which can be decided at the time of design as the estimate will cover both schemes.

Air Compressor:

The use of air under pressure is proposed in this plant to insure means for thorough cleansing of the sand bed, in connection with the low rate of wash proposed. To minimize the cost of air, a small air compressor will be installed, which will work continuously, feeding a steel storage tank of sufficient size to supply enough air for the washing of two filters. The tank will be placed in the roof of the filter gallery, the air compressor being located in the basement of the head house.

Head House:

The head house is to be a neat building with basement and two upper stories. In it will be stored the sulphate of aluminum, lime and hypochlorite of calcium. Apparatus is provided for making the necessary solutions, which will be stored in solution tanks, from which the solution will be fed automatically into pipe lines connected to the grids which will distribute the chemical in the flow. An office is provided, as well as a locker room for the attendants, with complete sanitary appliances.

Low Lift Pumping Equipment:

We propose to utilize the existing pump wells as far as possible for the service of the raw water or low lift pumps. These will raise the water and deliver it to the inlet of the mixing tank. Centrifugal pumps will be used, direct connected to steam turbines or electric motors. They will be housed in a lean-to built on the north side of the present pumping station. A Venturi meter will be included in the force main, in order to show definitely the amount of water being treated. This is absolutely necessary in order to determine the correct amount of coagulant, lime, or hypochlorite.

Character of Buildings and Substructures:

The head house and filter gallery will be treated architecturally to harmonize with the buildings on the adjoining property of the Northwestern University. Neat face brick will be used, with stone trims and tile roofs. The substructures will be entirely of concrete, reinforced with steel wherever necessary. Owing to the nature of the soil on the proposed site, considerable reinforcing will be required, particularly in the floor of the filtered water basin. The filtered water reservoirs, settling basins, and mixing chamber will be entirely hidden from view by the grassy lawns and banks, which can be laid out with paths, steps and shrubbery to make an attractive setting.

Comparative Cost of Plant:

Several factors operate to raise the cost of the proposed works above that of a similar construction under general conditions elsewhere. In Chicago and Evanston both skilled and unskilled labor receive high wages. All material must be teamed to the site of the work, direct access to a railroad being out of the question. The character of the soil at the site demands somewhat more expensive footings than are ordinarily used. And in consideration of the gift of the land by the Trustees of the Northwestern University, the building must be architecturally attractive and the grounds neatly planned.

Extension of Present Pumping Equipment:

The present capacity of the pumping station is none too great, and the units are so divided that, in case of a complete breakdown of the 12 million gallon pump, in warm weather, the city would quickly be short of water. We, therefore, believe that immediate consideration should be given to the installation of additional equipment, and the removal of the old 2 million gallon unit. This subject is treated more fully in Appendix B, as it does not necessarily belong to the filtration scheme.

Operation of Proposed Plant.

In previous pages attention has been called to the polluted and turbid condition of the lake water, and to the absolute necessity of mixing the coagulant thoroughly with the raw water early in the progress through the plant in order to secure the greatest degree of purification.

Mixing of Chemicals with Water—Use of Lime:

Low lift centrifugal pumps will take the lake water from the existing intake wells and pump it through a Venturi meter. The coagulant should be added ahead of the meter in order to take advantage of the increased velocity, at the constricted throat, a condition which favors mixing. The water then enters the mixing chamber within a minute after the addition of the aluminum sulphate. The reaction between the coagulant and the alkaline carbonates will not be complete until the water has passed through about half the chamber.

Should it prove desirable to employ lime, the lime will be added in the mixing chamber, not only to insure thorough mixing by the baffles but also to allow sufficient time for the reaction to take place between the lime and the half bound carbonic acid. The element of "time for reaction" is all important, especially during cold weather, since low temperatures delay the reactions.

As previously noted, the result of adding lime will be to hasten the change of the sulphate of aluminum present into the insoluble aluminum hydrate. The reaction will occur more rapidly and completely, forming larger flocks than when lime is omitted. Large flocks settle much quicker than small, so that the settled water will be clearer.

Sedimentation:

Leaving the mixing chamber, the water enters the settling basin. There the velocity of flow is lowered to such an extent that the flocks of coagulant, precipitated carbonates and suspended matter sink, falling to the bottom of the settling basins. These are arranged so that both can be used simultaneously to secure a low velocity, or in tandem to give more thorough mixing when desirable, or finally, either basin can be cut out and cleaned. The period between cleanings will depend on the turbidity of the water. Such an arrangement of the basins makes the system highly flexible, thus aiding the operation materially, with the further advantage that most of the work of purification is done by the settling basins, thus reducing the load on the filters.

Washing Filters:

The settled water passes onto the filter beds. These are divided into ten units to reduce the size of the washing devices, and the cost of wash water pumps and pumping. However, a plant containing six units can be worked out to advantage, if a wash water tank be allowed in the aesthetic treatment of the grounds. Filter beds require occasional washing to remove the fine flocks, residual sediment, and bacteria carried over from the settling basins and deposited in the upper layers of the sand. The frequency of washing is affected very largely by the action of the settling basins. In plants where the basins are small, filters have to be washed every 10 or 12 hours, increasing the expense for labor, wash water and power. With the settling basins planned for this plant the beds should not require washing so frequently, and if the runs can be lengthened to two or three days, the operating expense will be somewhat reduced.

The reverse current of wash water raises the sand in the bed, separating the grains and removing the foreign material which has accumulated. The blowing of compressed air through the bed churns the sand, with a scrubbing action, thus increasing the efficiency of the wash.

Efficiency of Filters:

Filter beds of sand remove bacteria because these organisms, though living, from a mechanical standpoint are simply particles of suspended matter. Although bacteria are naturally exceedingly minute, they are flocculated by the coagulant and entangled sooner or later on the sticky gelatinous coating of the sand grains. The filtering action is so thorough that lake water containing several thousand bacteria per cubic centimeter should, when filtered, contain less than 100. A small amount of hypochlorite of calcium added to the filtrate will remove the few bacteria remaining.

Filtered Water Supply to High Service:

From the filters, the effluent passes to the filtered water reservoir. The importance of adequate capacity has already been commented upon, to insure efficient operation, not only as a safeguard against sudden changes in the rate of filtration (which are detrimental to the quality of the effluent) but also to reduce the number of attendants to a minimum.

The filtered water will then flow to a new pump well to be built outside the existing pumping station. From this the high service pumps will force the water into the present mains.

SUMMARY.

Our conclusions are:

1. At certain seasons of the year the water supply of Evanston is both polluted and turbid.

2. The diversion of the sewage will undoubtedly remove most of the pollution, but it will not make a clean water.

3. The extension of the intake is inadvisable for Evanston.

4. Filtration will afford permanent relief. A sterilizing agent such as hypochlorite of calcium should be used as a finishing process.

5. A filtration plant of the rapid gravity (or open) type is required of normal capacity 12 million gallons per day.

6. The proposed site is adequate for such a plant.

7. The cost of a 12 million gallon rapid filtration plant will be $183,675. Low lift pumps will cost an additional $20,900.

8. The use of water in Evanston is excessive, and wasteful. A yearly average of 100 gallons per capita daily should prove ample.

9. A complete system of meters will reduce the waste, and allow ample water for every reasonable use.

10. The present pumping equipment is inadequate, not only in capacity and flexibility, but principally in lack of reserve.

11. The continued use of steam for the high and low lift pumping is economical.

Our recommendations are:

1. That a rapid filter plant (of the gravity or open type) of 12 million gallons capacity should be built on the proposed site at an estimated cost of $204,575, including the low lift pumping equipment, provided immediate steps be taken toward the reduction of excessive rates of pumpage.

2. That immediate steps be taken to install two additional 5 million gallon centrifugal pumps, driven by direct connected steam turbines. These are to run on the high service.

3. That the meter system be extended to all services so that the entire city may be metered as soon as possible.

We trust that we have made our position clear in the matter at hand and that our conclusions will meet the approval of your honorable committee.

We take occasion here to thank you for your courtesy to us and the uniform readiness with which your staff has afforded us information.

Signed:

W. W. JACKSON,
LANGDON PEARSE,
Consulting Engineers.

Chicago, Ill., Aug. 28, 1912.

APPENDIX A.

Report giving results of Pitometer test of pump slippage on the three pumping engines at the Evanston waterworks pumping station, June 17 to 22, inclusive, 1912.

Test on 12 Million Gallon Pump:

There are four water cylinders, the dimensions of each being:

Plunger diameter 29 inches, area 660.52 square inches.

Rod diameter 5½ inches, area 23.76 square inches.

Stroke, 38 inches.

Plunger displacement per revolution
=98593.28 cu. in.
= 57.05 cu. ft.
= 427.9 gallons

Slip Test Number	Speed Revolutions per Minute	Slip. Per Cent.
1	18.4	4.1
2	18.8	3.3
3	13.3	5.2
4	13.1	7.3
5	9.4	4.9
6	9.6	7.6
Average,		5.4

Test on Five Million Gallon Pump:

There are four water cylinders, the dimensions of each being:

Plunger, west side, diameter 18 1-16 inches, area 256.24 sq. in.

Rod, west side, diameter 3 inches, area 7.07 sq. in.

Plunger, east side, diameter 18⅛ inches, area 258.02 sq. in.

Rod, east side, diameter 3 inches, area 7.07 sq. in.

Stroke, 28 inches.

Plunger displacement per revolution
=28402.64 cu. in.
= 16.436 cu. ft.
= 123.28 gallons

Slip Test Number	Speed Revolutions per Minute	Slip. Per Cent.
1	18.5	5.6
2	17.3	6.2
3	27.5	5.4
4	27.5	3.7
Average,		5.2

Test of Two Million Gallon Pump:

(Only one plunger measured)

Plunger, diameter 9 1-16 inches, area 64.49 square inches.

Rod, diameter 2 inches, area 3.14 square inches.

Stroke, 24 inches.

Plunger displacement per revolution
=13080.64 cu. in.
= 7.57 cu. ft.
= 56.77 gallons

Slip Test Number	Speed Revolutions per Minute	Slip. Per Cent.
1	32.4	28.8
2	28.7	27.05
Average,		27.9

Report of results of Pitometer test on the two 6-inch Crown meters located at the intersection of Sheridan Road and Hill street, Evanston, June 21, 1912.

Meter No. 137450 located in Sheridan Road north of Hill street:

Test lasted one hour.

Volume of water registered by Pitometer =1760. cu. ft.
Volume of water registered by Meter =1380. cu. ft.

Slip = 380. cu. ft.
Slip = 21.6%

Meter No. 141182 located in Hill Street just off of Sheridan Road:

Test lasted one hour.

Volume of water registered by Pitometer =1981.2 cu. ft.
Volume of water registered by meter =1380. cu. ft.

Slip = 601.2 cu. ft.
Slip = 30.3%

In both cases the meters read too low.

(Signed) W. D. Gerber,
Engineer of Tests.

APPENDIX B.

Cost of Pumping With Steam and With Electric Power.

With Reference to Proposed Additions to the Equipment of the Evanston Waterworks.

In the preceding pages we have described the present equipment, and have shown that it is necessary to increase the pumping capacity of the Evanston Waterworks pumping station, to provide a desirable reserve. The condition of the pumping equipment is accurately indicated by the tests made by Mr. Gerber (Appendix A). The 2 million gallon unit is very wasteful and might be removed to advantage, making room for more economical pumps of greater capacity.

To properly equip your pumping station for all contingencies (unless the number of metered services be rapidly increased), we would recommend the installation of two centrifugal pumps, each of five million gallon capacity, to work against a nominal lift of at least 120 feet. Steam turbines or electric motors may be used to drive these pumps, direct connected.

For this extension electric power has been favored by some, and in addition the conversion of the entire equipment has been urged. We have therefore gone into the relative merits of steam and electric drive for your conditions.

Cost of Additional High Service Equipment:

Two centrifugal pumps, direct connected to electric motors, with pumping capacity of 5 million gallons daily against 120 feet head, will cost about $6,000 each, including motors, transformers, wiring, etc. Steam turbine units could probably be installed for about the same figure, but the condenser, piping, etc., would add about $3,500 additional for the two units. This makes a lower first cost for the two electrically driven units of $12,000, compared with a cost of $15,500 for the two steam turbine driven units. However, other factors must be considered in making a choice, since operating cost and regularity of service may carry as much weight as low first cost.

By removing the old two million gallon Holly pump, and remodeling the entrance gallery, sufficient floor space can be made to readily care for two centrifugal units of either type and may cost about $1,500. their appurtenances. These changes

In order to make our comparison more thorough we have also considered an alternative installation of two 5 million gallon pumping engines, of high duty type. It is possible that one unit can be installed in the space proposed, but the second unit would require an extension to the pumping station. The cost of the high duty units would be about $15,000 each or $30,000 for the two, including condensers. An additional amount of $2,000 would be required for remodeling and piping besides about $5,000 for extension of building and foundations. This makes a much greater first cost, although

TABLE NO. 10.

Average and Maximum Daily Pumpages by Months, 1910 and 1911. With Calculated Peak Ratings.

	PUMPAGE Million Gallons Per Day						Peak Rating in Horse Power Based on 50% Efficiency	
	Average Daily		Average Maximum Daily		Calculated Peak Rate			
Months.	1910	1911	1910	1911	1910	1911	1910	1911
January	5.73	5.29	6.77	6.20	9.5	8.7	399	365
February	5.71	4.87	6.38	5.19	9.0	7.3	378	307
March	5.19	4.64	5.82	5.00	8.1	7.0	340	294
April	5.41	4.78	5.78	5.26	8.1	7.4	340	311
May	5.20	6.06	5.78	9.97	8.1	14.0	340	588
June	7.87	7.06	11.52	10.74	16.1	15.0	676	630
July	9.30	9.15	11.82	12.07	16.5	16.9	693	710
August	8.42	6.42	12.03	8.65	16.8	12.1	706	508
September	6.05	5.92	7.32	9.09	10.2	12.7	428	533
October	5.58	5.33	6.21	6.21	8.7	8.7	365	365
November	5.21	4.98	6.59	5.61	9.2	7.8	386	328
December	4.93	4.82	5.49	5.56	7.7	7.8	323	328
Average	6.218	5.777	7.625	6.779	10.67	10.45	448	438.9

providing somewhat more economical pumping machinery.

Cost of Pumping:

In the case of very small pumping stations in which the cost of labor is very high for every million gallons pumped, there is little doubt that true economy has resulted from the use of electric power purchased at two, three, and even five cents per kilowatt hour. But as the load or pumpage of the plant grows, the balance in favor of the motordriven pumps declines and disappears. The rate at which power is bought and the manner of computing the amount used materially affect any general discussion.

The entire cost of operating the pumping station in Evanston during the year 1910 amounted to $21,240.47 exclusive of fixed charges, or deducting expenditures on intake, wells and well house, residence and grounds, and the salary of the advisory engineer, none of which is directly applicable to the cost of pumping proper, the charge for pumping was $17,271.92. Allowing a slippage of 15 per cent on the total displacement of 6,217,782 gallons per day, and a lift of 120 feet, the total output of the plant would amount to 974,270 water horse power hours per year produced at a cost of 1.8 cents per water horse power hour. A similar analysis for 1911 give the charge for pumping $16,318.39 on an average displacement of 5,777,008 gallons per day. The cost per water horse power hour is practically the same.

The electric power may be purchased in Evanston from the North Shore Electric Company or from The Sanitary District of Chicago. The price made by the latter is a rate of $26.40 per electric horse power per annum, the amount used in each month being charged for on the basis of the peak load during that month, with an additional charge based on the interest and depreciation charges on the prorated portion of the cost of the transmission line between Chicago and Evanston.

Although the efficiency of a centrifugal pump under the most favorable conditions may exceed seventy per cent, we estimate that fifty per cent for the motor driven pumping unit is as high as can safely be allowed under working conditions. The average peak load in 1910, based on fifty per cent efficiency of the pumping units (Table 10), would amount to 448 electrical horse power. Exclusive of the fixed charges on the line this would cost $11,827.20. The interest and depreciation on the power line (10 per cent on $16,500, half the cost of the line), would increase this to $13,477.20.

Assuming that the operating force required for the motor-driven equipment would comprise the present Chief Engineer and the two assistants for the three tricks, with one helper in the day shift, the salaries would amount to $3,775 per annum. Repairs and supplies, heating, light, etc., would cost approximately $1,000, making the total annual expense exclusive of any fixed charges on the equipment:

Current	$11,827.00
Charges on transmission line	1,650.00
Salaries	3,775.00
Repairs and supplies........	1,000.00
	$18,252.00

On the actual load of 974,270 water horse power hours an electrical load of 1,948,540 horse power would be required on the basis of fifty per cent efficiency, or 1,453,611 kilowatt hours. The current costs 0.92 cents per kilowatt hour of actual use.

The operating costs for steam under the present conditions are therefore lower than for the electrical power, on the basis of handling the entire pumpage. Operating costs, alone, however, are not the sole criterion. Annual costs, including fixed charges, would be considered in an entirely new proposition, where a pumping station is built from the ground up. This is not the case here, for a plant already exists which cannot be wiped out.

If a complete electrical installation is planned with reserve, the existing steam plant being removed, then the fixed charges on the machinery must be considered. This scheme, however, is not advisable, as the present pumps, with the exception of the 2 million gallon Holly pump, are in shape to stay in service.

If, however, a sufficient electrical installation be made only to act as reserve capacity, then the first cost would nearly balance the cost of steam driven units, so that fixed charges would not materially affect our comparison. In this case, the electric pumps might be carried only as a reserve or to help care for the peak load. Although this might prove economical if current could be bought at a low rate per kilowatt hour actually used, we do not believe it would prove so if the bills are rendered on the basis of monthly peak load. For it can readily be seen that a pump might be operated only a few hours yet the charge would cover the load as though used through an entire month.

Comparison of Service on Extension:

To show more concretely the effect of the method proposed for peak load charges, we have estimated the cost of pumping under an assumed basis of actual work. The pumps are supposed to be installed in the present station, working as a reserve, taking the peak load as well, and running occasionally on the full load.

The figures given for the steam turbines are based on a duty of 50,000,000 foot pounds per 1,000 pounds of steam and an evaporation of 8 pounds of steam per pound of coal. The cost of boilers and appurtenances have been taken at $30.00 per boiler horse power. For the electrically driven outfit an efficiency of 50 per cent is assumed. The cost of electrical power is taken at $26.40 per horse power per year for 24 hour service, figured on the monthly peak load.

For sake of comparison we shall assume that the two units pump 500 million gallons during the year, at a maximum rate of 5 million gallons per day. To pro-rate the boiler room charges we shall assume that a total of 2190 million gallons was pumped during the year and charge off to the steam turbines their proportion of the boiler room expense. The use of the electrical power is based on the peak load, in this case 5 million gallons per day. With an efficiency of 50 per cent this requires 210 electrical horse power, if used every month in the year.

Steam Turbine Driven Pumps, Operating Cost and Fixed Charges:

Fuel, 625 tons at $3.75 per ton, delivered	$2,343.75
Firemen, 500 ÷ 2,190 x 2,775.00 pro-rate expense	633.56
Supplies and repairs on pumps	150.00
Supplies and repairs on boilers, 7% on $9,000	630.00
Interest on pumps and equipment, 4% on $15,500	620.00
Depreciation on pumps and equipment, 5% on $15,500	775.00
Interest on boiler equipment, 4% on $9,000	360.00
Depreciation on boiler equipment, 5% on $9,000	450.00
	$5,962.31

Electrically Driven Pumps, Operating and Fixed Charges:

Power, 210 H. P. at $26.40	$5,544.00
Supplies	50.00
Interest on depreciation power line, 10% on $16,500	1,650.00
Interest on pumps and equipment, 4% on $12,000	480.00
Depreciation, 5% on $12,000	600.00
	$8,324.00

From this comparison it will be seen that the cost of electrical pumping is very much higher than for steam when the pumps are not run continuously on constant load. Over 1,000 million gallons would have to be pumped with the steam turbine unit before the cost of steam would nearly equal the cost of electrical pumping. This is about 50 per cent of the total yearly pumpage. With the present pumping equipment running, the centrifugal pump sets would probably not be called on for any such service. Even if run during 8 months of the year, the comparison favors steam, particularly as the total pumpage assumed is fairly high for a reserve service.

Reliability of Service:

In a plant of your size without any reservoirs or standpipe on the distribution system, it is essential to have a source of power as reliable as possible, to insure the continuous operation of the waterworks, not only for sanitary reasons, but above all for fire protection. Fire protection is required twenty-four hours of the day throughout the year. Steam power generated in place is considered reliable, when sufficient reserve is provided. Electrical power generated at a distance and brought in by transmission lines is not so safe, unless several sources of power are available and are connected. To guarantee this reliability of electrical service, any power company would require an additional payment, regardless of actual use. Hence, with one source of electrical power, steam reserve is definitely required, in a plant where continuity of service is so vital.

Flexibility of Operation:

For mechanical reasons we believe that the steam turbine driven pumps will be superior under your conditions, particularly for the low lift service of the proposed filtration plant. Alternating current motors are built to run at practically constant speed. Flexibility of operation is much reduced and more pumping units are required. The steam turbine, on the other hand, will run at varying speeds, giving a range in deliveries, and permitting the use of a few pumping units on the low lift service.

Service for Filtration Plant:

Most of the foregoing applies equally well to the low lift service, if the filtration plant be built. We do not, however, expect such wide variations of rate in the low lift pumping, since the peaks of the high service would be carried by the storage in the filtered water basin. This would be more favorable to the application of electric power. It is not probable that any particular economy would accrue, and the criteria of reliability and flexibility would still apply.

Nevertheless there is a use for the electric power in operating the auxiliary machinery in the filter plant, comprising the wash-water pump, air compressor and stirring apparatus. In their use, we have provided storage which should tide over any ordinary interruption of electrical service. Electric light can be used also. About 60 kilowatt hours will be required for all this auxiliary service.

Conclusions.

From our study of this problem with reference to your conditions, we believe that no increase in economy is to be gained by the substitution of electricity for steam, particularly for intermittent service. For the extension of your equipment we would, therefore, recommend the use of steam turbines direct connected to centrifugal pumps, each unit having a capacity of five million gallons per 24 hours, through a lift of not less than 120 feet. We believe sufficient space will be provided by the removal of the existing two million gallon Holly pump.

For the low lift service of the filtration plant, we believe steam turbine driven pumps suitable. Electric power, however, will be desirable for the auxiliary machinery such as the wash-water pumps, air compressor and stirring apparatus, as well as for the lighting.

APPENDIX C.

WASTE PREVENTION.

Per Capita Consumption.

The total amount of water delivered into a distributing system, whether economically used or wasted through broken or leaky pipes or mains, is known as the "consumption." Usually it is stated in terms of the average daily consumption throughout the year on the basis of the total population of the town or city. In Evanston and Wilmette, as in most larger cities, this factor is equitable, as the number of consumers approach very nearly the total population. Thus a suitable basis exists for the comparison of the per capita consumption with that of other and larger cities. With a combined population of 29,921 by the United States Census of 1910, the consumption in Evanston and Wilmette was 208 gallons per capita for the yearly average based on gross pumpage, or with an allowance of 15 per cent for slip, 177 gallons. The maximum daily consumption of 12,034,800 gallons represented a per capita consumption of 402 gallons, or, deducting 15 per cent for slip, 342 gallons net.

Different Uses of Water.

Evanston is essentially a residential city; thus the commercial use of water is limited. All services of this class are metered, the registration amounting to about 15 per cent of the total consumption or approximately 30 gallons per capita. It is believed, however, that a considerable portion of this would ordinarily be classed as purely domestic.

Water is used very freely for public purposes, though with the extension of the oiled roads the use in street sprinkling has been checked. Drinking fountains and horse troughs flow freely, and the small parks are sprinkled lavishly. Twenty four sprinkler nozzles have been observed operating simultaneously in the park south of the Life Saving Station, three at the public school in Sherman avenue, and seven on the small grounds surrounding the Public Library. A considerable quantity is also used in flushing sewers, blowing off dead ends, etc. Though no measurements are available, we estimate the consumption of water for public purposes, by comparison with that in other cities, to be ten gallons per capita daily.

We are advised by the line foreman in the Evanston Water Works that leaky joints or services cannot escape notice, as mere drips will always show at the surface. Unless, therefore, such leakage finds its way undetected to sewers or drains close by, the loss from this cause would seem to be inconsiderable. The allowance of 2,500 to 3,000 gallons per mile of pipe, suggested by Mr. Emil Kuichling, for use in ordinary conditions, would amount in Evanston to about seven gallons per capita. In Washington, D. C. (E. S. Cole, American Water Works Ass'n, 1912), a leakage of 27,265,000 gallons daily from 2,600 leaks in the distribution system was found prior to October 28, 1911 amounting to about 82 gallons per capita, none of which showed above ground. It is improbable, however, that unaccounted for losses will ever approach this high figure in Evanston. We shall assume that the allowance of 15 gallons per capital per day represents the unavoidable loss from the distribution system. This is derived from very careful studies made by Mr. Dexter Brackett on the distribution system of the Metropolitan Water Board in Boston and its environs.

The consumption through domestic or residential services may be determined by deducting the above estimated quantities from the total consumption. The total average consumption for the Evanston and Wilmette, 1910, the year of the last decennial United States census, may be apportioned as follows:

	Gallons per day.
Average daily consumption for 1910	6,217,800
Less 15 per cent slip in pumps (estimated)	932,670
Net	5,285,130
Total consumption in Wilmette (Corrected for underreading of meters	536,755
Net consumption in Evanston, gallons per day	4,748,375
Net consumption in Evanston, gallons per capita per day	190

The net daily consumption in Evanston may be distributed as follows:

	Gallons per day.	Gallons per capita per day
The use for commercial purposes	750,000	30
The use for public purposes	250,000	10
The unavoidable losses	375,000	15
Domestic consumption	3,373,375	135
Total	4,748,375	190

Variable Demand.

The fluctuation in the rates of consumption, both seasonal and hourly, is very violent. The chart (Fig. No. 2) indicates a daily average demand for maximum months exceeding the average for the year by upwards of 50 per cent, whereas this maximum rarely exceeds the average by more than 25 per cent, even in metered cities. The heaviest consumption is always found in Evanston in the hot summer months, the cold weather peak being comparatively insignificant. The maximum daily pumpage exceeds the average for the month in which it occurs by about 30 per cent, and the average for the year by nearly 100 per cent. The minimum daily pumpage in 1910 amounted to 4,196,700 gallons, or about two-thirds of the average, and one-third of the maximum day.

In the city of East Orange, N. J., with a population of 34,400, living in detached houses, the average daily consumption in 1910 was 3,165,200 gallons. The maximum daily pumpage reached 4,200,000 gallons in July (122 gallons per capita) and the minimum fell to 2,200,000 in January (64 gallons per capita).

The hourly variations in Evanston are known for a short period of two months only, in the early summer of 1912. Curves plotted (Fig. No. 3) for the hourly pumpage rates on June 11, 14, 15 and July 6 show clearly the effect of temperature and weather conditions.

The maximum hourly rate is about 40 per cent greater than the average for the day. A still closer separation on observations made at intervals of five minutes shows momentary rates 50 per cent above the average for the day. The average for the 24 hours at the same time is kept up by a high night rate, the consumption for the small hours of the night holding to a rate of 100 gallons per capita during the moderate weather.

The exceedingly high summer demand is of course due to the very large quantities of water used for lawn and garden sprinkling, which extends over the daylight hours and far into the night, and is by many consumers continued throughout the 24 hours. There is also a considerable steady demand through the 24 hours caused by losses from leaky plumbing and fixtures.

Regulation of Water Consumption.

The cities bordering on the Great Lakes are fortunate in having an inexhaustible supply of water at their doors. They have, therefore, been slow to recognizze the necessity of preventing waste or the extravagant use of the water supply. Heavy production costs have been tolerated, and equipment has been provided to meet the demand, without question. With no necessity for husbanding a limited supply there has been a disposition to let the people have what they wanted so long as the public was willing to pay.

There has been and is now a widespread impression that the reduction of waste necessitates a restriction in the use of water. This has made it difficult in many cities to so reform the relations between producer and consumer that the individual owners of properties as well as the city as a whole would be financially benefited, without depriving any person of the right to take as much water as can properly be used.

Under the "readiness to serve" or fixture schedule for water rates there is no individual responsibility on the part of the consumer. It is the fault of the system under which water has been distributed and sold that carelessness or heedlessness on the part of the consumer will permit the continuance of a known leak. Leaky fixtures will be found on the majority of premises served on schedule rates. Few consumers, moreover, are able to appreciate the amount of loss from an apparently negligible leak. In a personal investigation at Augusta, Me., in 1903, Langdon Pearse found a consumption of 1,200 gallons per day for a household of six persons, with barn, horse and cow. A leaky ball cock on a water closet flush tank was repaired by a plumber at a cost of 50 cents, and the consumption then dropped to 300 gallons per day or less, showing a clear leakage of 900 gallons or 150 gallons per capita daily directly traced to leaky fixtures.

The waste of water may be somewhat reduced by frequent inspections and policing on the part of the authorities, but, while the imposition and rigorous enforcement of many petty regulations may be acceptable in many European cities, the system would be resented under the conditions obtaining in American cities. This method, too, will be productive of good results only so long as it is vigorously followed up.

The alternative is in the general use of meters. This has proved successful in many cities in reducing unnecessary waste to a minimum. It provides for that individual responsibility which is required to produce in the consumer a personal interest in the stopping of leaks and waste on his premises. Moreover, as important a point is this, that the general use of meters distributes more equitably the burden of the maintenance of the water works system by proportioning the charges assessed to the service rendered.

In an opinion by Vice Chancellor (now Supreme Court Justice) Pitney in 1906, in a case involving the city of East Orange, N. J., the following statements are made bearing on the subject of meters and the waste of water:

"Moreover, since it is the duty of the city to equalize as nearly as practicable the burden of the maintenance of the water plant, much may be said in favor of the position that such duty involves the establishment of a universal meter system. . . .

"Moreover, I will venture the observation that it is a serious question whether it is entirely consistent with a sound public policy and true civic virtue to encourage and persist in such a wanton waste of potable water as is now the fashion in many cities, and was exemplified in that of East Orange."

The East Orange supply is taken from wells. The per capita consumption is about one-half that of Evanston.

Experience is the most reliable guide by which to judge of the effectiveness and permanence of the waste prevention methods. It is illuminating to note that in no case where meters have been introduced has a city ever gone back to former methods, and in no one has there failed to be a steady increase in the percentage of water sold by meters. All have endorsed the method by rapidly extending it. The results of the introduction of the meter system in a large number of American and German cities is summed up in a report on the "Waste of Water in New York, and its Reduction by Meters and Inspection," made to the Merchants' Association of New York, in 1906, by Mr. James H. Fuertes, C. E., as follows:

"First. Wastage and leakage can be quickly stopped and permanently suppressed without depriving any citizen of the use of as much water as that to which he has been accustomed. That the question of the suppression of the greater part of the wastage is to all intents and purposes merely a hunt for leaks followed by the watching of the different consumers and the insisting that they keep fixtures from leaking.

TABLE NO. 11.

Per Capita Consumption and Other Uses.

Place.	Business Use Per Capita Per Day. Gals.	Other Use and Unaccounted For. Gals.	Total Use. Gals.	Census Population	Per cent of Taps Metered
Woonsocket, R. I.	10	23	33	38,125	87
Brockton, Mass.	13	24	37	56,878	100
Bayonne, N. J.	66	41	107	55,545	99
Cleveland, Ohio	56	42	98	560,663	98
Lowell, Mass.	3*	48	51	106,294	79
Newport, Ky.	12	48	60	35,000†	31
New Bedford, Mass...	27	54	81	96,652	48
Taunton, Mass.	8	54	62	34,259	50
Rochester, N. Y......	24	56	80	218,419	99
Harrisburg, Pa.	73	57	130	64,186	83
Worcester, Mass.	14	58	72	145,986	96
Utica, N. Y..........	26	62	88	74,419	100
Toledo, Ohio	30	63	93	168,497	78
Battle Creek, Mich...	17	65	82	25,267	95
Milwaukee, Wis.	44‡	65	109	373,857	98
Yonkers, N. Y........	41	61	102	78,803	100
Wilmington, Del.	46	72	118	87,411	34
Cincinnati, Ohio	32	96	128	364,463	33
Jersey City, N. J.....	57	105	162	267,779	9
Detroit, Mich.	50	108	158	465,766	9
Washington, D. C.....	30	147	177	331,069	25
Erie, Pa.	59	148	207	66,525	3
Buffalo, N. Y.........	62	251	313	423,715	4

*Business use said to be very little, but the figure 3 is the estimate of the writer.

†Population is of district supplied.

‡Thirty-six gallons are known to be used by manufacturing plants and railroads, and probably eight by store, saloons, etc.

"Second. That sale of water by measure has no tendency to restrict the use of water, but does notify the owner when the leakage from the faucets and other fixtures is serious enough to require attention. That wastage from domestic premises is rare, but that leakage is prevalent. That tenants do not wilfully waste water, and that the blame for the present condition in New York rests not upon the hundreds of thousands of users of water, but upon the relatively few owners who neglect to keep their plumbing in order as required by the city ordinances. That the responsibility for this state of affairs rests primarily with the system under which the water is sold. That the sale of water by meter does not work a hardship on owners of property rented to tenants; in practically all cities from Berlin to Asbury Park, the water taxes are liens on the property, and yet in no city where the system has been adopted permanently, and where the rates have been properly adjusted, would either the water works managers or the inhabitants of the city go back to the old system."

Our own experience leads us to differ with Mr. Fuertes in this, that we have found many cases of owners living on the premises, as well as tenants, entirely unmindful of any responsibility to prevent totally useless and uncalled for losses of water.

Comparison with Other Cities:

The comparison of the use of water in Evanston with the consumption in other cities will show how unreasonable is the present condition in Evanston. Although the needs of cities vary, many are in the same class, being residential towns, built up with detached houses. Typical cities are listed in Tables 11 and 12, which were taken from a paper by Edward W. Bemis, printed in the Engineering Record, December 2, 1911. Table 11 illustrates the variation in the use of water whereas Table 12 is designed to show the direct effect of meters in reducing the consumption per capita.

In Table 11 considerable variation in business use appears, ranging from 3 to 66 gallons per capita. This of course depends on the characters of the industries. The "other use and unaccounted for" covers the domestic consumption, leakage from mains and all other uses. In most of the cities listed this is much lower than in Evanston, for which we have calculated the business use of 30 gallons per capita, others use 160 gallons, and a total use of 190 gallons per capita in 1910. Wellesley, Mass., and Madison, Wis., might readily be compared with Evanston, in residential character, with a college campus and buildings. Yet Wellesley uses only 46 gallons per capita and Madison 56. The per cent of services metered, however, is 100 in Wellesley, 99 in Madison, and only 19 in Evanston.

Table 12 shows very clearly the effect of thorough metering in reducing the daily consumption on both residential and in manufacturing cities of all sizes. In every city listed therein the total consumption is far less than that of Evanston, and several cities even consume less than 50 gallons per capita.

Table 13, however, is most instructive, being a compilation of the water consumption of eight towns supplied by the Metropolitan Water Board in Massachusetts. This board is a State Commission, controlling the water supply of Boston and the surrounding towns, with a total population close to a million. The eight towns selected are all residential suburbs of Boston, largely inhabited by commuters. The conditions closely resemble those at Evanston. From this table it is readily seen that by thorough metering, accomplished during three years, the consumption per capita has been cut 29 per cent to a very reasonable figure—54 gallons per capita daily.

Ownership and Care of Meters.

In order that the meter system should operate to best advantage, it is necessary that the meters should be under the absolute control of the management of the water works. And to this end it is highly desirable that the meters be purchased and owned by the municipality. Meters require inspection and testing as well as cleaning, repairs and renewals. The consumer is naturally suspicious of any "monkeying with his meter because the bill was not big enough"

TABLE NO. 12.

Meters and Daily Consumption in Gallons, Per Capita. (New England Waterworks Association.)

Place.	Population	Per Cent. of Service Metered	Gallons Daily per Capita
Attleboro, Mass.	18,000	100	45
Framingham, Mass.	13,000	100	43
Watertown, Mass.	12,630	100	60
Wellesley, Mass.	7,035	100	46
Brockton, Whitman and Hanson, Mass.	63,400	99	36
Fall River, Mass.	115,097	99	46
Madison, Wis.	29,906	99	56
Reading, Mass.	5,760	92	32
Ware, Mass.	9,000	93	48
Lawrence, Mass.	62,000	90	43
Newton, Mass.	39,750	88	59
Woonsocket, R. I.	35,809	86	36
Burlington, Vt.	21,500	85	46
Westerly, Mass.	13,500	85	50
Winchendon, Mass.	6,200	85	23
Harrisburg, Pa.	70,000	78	143
Lowell, Mass.	96,380	77	54
Marlboro, Mass.	14,200	67	40
Springfield, Mass.	88,397	58	120
Arlington, Mass.	11,500	55	74
Dover, N. H.	15,000	53	49
Taunton, Mass.	30,967	50	70
Chelsea, Mass.	35,475	48	81
Somerville, Mass.	75,500	43	84
New Bedford, Mass.	95,000	38	79
Metropolitan Water District	965,490	28	124
Cambridge, Mass.	103,000	27	98
New London, Conn.	22,000	16	122
Haverhill, Mass.	45,000	15	106
Reading, Pa.	101,210	14	126
East Orange, N. J.	35,000	10	89
Detroit, Mich.	440,618	9	167
Holyoke,, Mass.	54,698	9	103
Louisville, Ky.	260,000	8	82
Gloucester, Mass.	3,800	5	48
Woburn, Mass.	14,400	3	126

and his judgment is not good when the conditions demand its replacement. The cost to the community is no greater and probably less than when the individual buys and sets his meter. If necessary, a small rental can be charged or covered by the minimum rate.

Expected Reduction in Consumption.

There is no doubt that a considerable reduction will follow the general and complete metering of the City of Evaston, as this has followed wherever the system is tried out. The degree or percentage of reduction cannot be accurately determined in advance, though a study of the quantities used in other cities similarly situated and which are more or less completely metered, indicates a cut of 40 per cent to a rate of little more than 100 gallons per capita per day. Neither can it be accurately determined to what extent the hourly and seasonal fluctuations will be reduced, and it is therefore unsafe to consider reducing the capacity of the proposed filter plant to such a degree that it would be unable to take care of the present maximum daily consumption, with a suitable margin for safety.

No direct ratio exists between the per capita rate and the percentage of services metered. In various cities the conditions produce different results. Built up with detached houses, with large lawn areas, and with no fear for the permanence and adequacy of the source of supply, the City of Evanston will of course demand much more water than will a German city in which the conditions of living are directly the reverse.

To meter only those services for which a meter is requested by the owner will be disappointing, if decrease of consumption or increase of revenue is to be expected. The consumer who wants the meter is generally the user of small quantities, who naturally plans to save expense by the change. It is the wasteful or free user whose service should be regulated for the public good. This can be accomplished only by the general and compulsory installation of meters.

Results of Waste Prevention.

It is not necessary in Evanston to conserve the water supply through any fear for the adequacy of the source. And if the burden of cost is properly and equitably distributed there is perhaps no objection at this time to the free use of water by those who stand ready to pay for it. But by reducing the quantities through the elimination of waste and extravagance, the cost of operating the department would be reduced by a considerable saving in fuel and labor, and with the inauguration of the proposed filter plant this saving would be multiplied.

Under present conditions the distribution system is overloaded, and water mains must be enlarged or duplicated in order that satisfactory pressure shall be maintained in certain parts of the city. With proper regulation of consumption such mains might perform their functions for several years to come. The pumping station equipment is inadequate and must be supplemented by the installation of new pumping engines to provide a suitable reserve, and thus the fixed charges on unnecessarily large plants is added to the annual operating costs.

Objections to Meter System.

Opponents of the meter system have urged that the tendency with metered services will be to reduce the use of water below the quantities necessary for hygienic purposes. With a very few this might be the case, but by the establishment of a suitable minimum term payment, this possibility is avoided. The minimum charge of $3.00 per half year in the Evanston tariff of water rates allows at the rate of 12 cents per 100 cubic feet one hundred gallons per day for each service, which is sufficient for all sanitary purposes for an ordinary family.

Other objections are more or less fantastic, such as the alleged influences of meters in increasing typhoid and other water-born diseases.

TABLE NO. 13.

Consumption in the Eight Most Completely Metered Places in the Metropolitan Water District.

Places.	Population	Per Cent. of Services Metered 1907	Per Cent. of Services Metered 1910	Per Capita 1907	Per Capita 1910
Belmont	5,600	100.00	100.00	73	59
Malden	44,730	96.10	96.28	47	42
Medford	23,330	13.29	94.42	105	61
Melrose	15,790	30.85	100.00	118	64
Milton	7,970	100.00	100.00	46	39
Swampscott	6,960	68.25	99.12	74	59
Watertown	12,960	100.00	100.00	67	68
Winthrop	10,290	3.37	95.94	117	63
Totals and averages	127,630	60.01	98.64	76	54

There is no connection between the use of meters and the prevalence of typhoid, and other intestinal diseases, that can be traced in the records of any city.

The city of Berlin, Germany, completely metered and with a per capita water consumption of 18 gallons has a lower death rate from all causes (and but a fraction of the typhoid) than New York and Chicago with their water consumption of 135 and 234 gallons per capita.

Metered Services.

At present most of the services metered are domestic, ⅝-inch meters being the most numerous. There are two large individual consumers, the Mark Manufacturing Co. and the Chicago & North Western Ry. Combined, these two concerns use as much water as the entire domestic metered servive at present, 877 meters. Table No. 14. In the metering of the entire city, the probability is that over 95 per cent of the meters will be ⅝ inch. This will keep the cost of metering down.

Cost of Meters.

In Evanston the cost of ⅝-inch meters has been $8.40 with a charge of $15.00 installed. Practically all the meters are placed in basements. This cost is somewhat higher than that at Cleveland, Ohio, where the basement settings cost less. In the annual report for 1909 of the Cleveland Water Department, the entire cost of all the 74,116 publicly owned meters, of which 69,435 were ⅝-inch, and 1,809 were ¾-inch, averaged for all sizes of meters in 1909 only $8.21 per meter and $9.17 for the setting, or a total of $17.38. It is noteworthy that only 26,298 were in the cheaper basement settings, while 31,077 were in brick vaults and 16,741 were in sewer pipe settings. Other data confirms our belief that $15.00 is a safe price for Evanston, and will probably be reduced when purchases and settings are carried on on a larger scale than heretofore, especially following a policy of complete metering. Setting in vaults is not very desirable in cold climates. It is cheaper and better to set in cellars as heretofore in Evanston.

Cost of Maintenance.

The annual expense of metering comprises the interest on the cost of the meters, a depreciation charge sufficient to replace the meters at the end of the assumed life (20 years), the cost of inspection, repairs, renewals of parts and testing, and the cost of reading the meters, delivering bills, etc. In Evanston collections are made

TABLE NO. 14.

Analysis of Present Certification of Water Taxes
Spring Term, 1912. Six months.

Item.	Customers.	Certification	Total Cu. Ft. Registered.	Certification Per 100 Cu. Ft.
Flat Rates	4,636	$35,832.40		
Metered				
Domestic‡	877	5,008.00	*3,857,338	13 cents
Business§	221	8,904.44	†14,066,829	6.3
Wilmette		4,688.75	8,212,900	5.8
Mark Mfg. Co...		1,102.29	2,172,580	5.07
C. & N. W. Ry...		810.78	1,589,560	5.1
Total Gross	5,737	$56,382.66		
Metered	1,101	$20,514.26	29,899,207	6.86 cents

§This includes fraternity houses.
*Equivalent to 181.5 gallons per day per meter.
†Equivalent to 2625 gallons per day per meter.
‡315 customers pay minimum rates.

semi-annually, so that the expense of reading and billing will not be so high as elsewhere. However, we would recommend quarterly readings to check possible waste. More frequent readings are sometimes made as, for instance, in Columbus, Ohio, where bi-monthly readings were taken to check waste even though bills are rendered semi-annually.

Annual Cost of Meters.

Interest on cost of meter, installed, 4% on $15.00	$0.60
Depreciation, 5% on $15.00	.75
Maintenance, renewals, testing, repairs, etc.	.50
Reading meters, billing, etc.	.50
Total cost per meter per year	$2.35

Total cost yer year for 5,737 meters, $13,482.

This is a reasonable figure, but slightly higher than the average for 13,407 ⅝-inch meters set in Cleveland up to 1904. The cost there was $2.27. (E. W. Bemis, American Water Works Association, 1904.) In many cities the cost of repairs, maintenance and reading is much higher.

The 1,101 meters already in place, however, include all meters used for business purposes, and therefore cover nearly all the larger services. The additional cost of the newly metered services would be much less than the above figure.

In Columbus, Ohio, meters are read every second month, excepting those for the larger services which are read monthly. Each reader cares for about 2,500 meters. The total cost of reading, repairing, etc., and of the work in the office in excess of that required for assessments accounts, is one dollar per year for each meter.

Under present conditions and with the existing plant this amount, $13,482, could not be saved from the direct annual operating expenses of the department, though a considerable saving in fixed charges on construction cost would be effected, the amount of which we have not the data to estimate. But with the filtration proposition before you the balance will be in favor of the meter system. Had the question of compulsory metering not been under consideration a larger filtration plant than that proposed would have been recommended, to cost approximately $300,000. The estimate of cost of operation is very liberal, and with the expected reduction in consumption, the labor may be cut about $2,000, the coagulant $1,400, and the power $2,000.

The probable saving would then be:

Fuel	$3,000.00
Labor	2,000.00
Electric power	2,000.00
Coagulant	1,400.00
Interest and depreciation, 6 per cent on $100,000	6,000.00
	$14,400.00

If a complete meter system were installed at once, the purchase of additional pumping engines, necessary under present conditions, recommended also in the report of the Fire Prevention Committee of the National Underwriters' Association (July, 1912), might be postponed for several years, as well as the construction of certain new mains now necessary to increase the pressure in several sections of the city during hours of heavy draft.

Revenue.

The total cost of all services performed by a municipal water works must be borne eventually by the community. There is in the United States no universally established practice governing the distribution of the burden.

Except for a small reimbursement item, no part of the income of the Evanston Water Department is derived from general taxation. The expense of supplying water for private consumption, for fire protection and other public uses, as well as the cost of extensions to the distribution system and other construction, is provided in the water tax collections. And in addition a large sum is transferred annually to the general fund to be applied to the maintenance of the Fire Department and to other running expenses of the municipal administration. The revenue of the water works amounts to about one-third the total income of the city.

The total certifications, collections, and expenditures of the water works are shown in Table No. 15, from which it will be seen that the revenue has increased regularly each year, despite the fact that the gross

TABLE NO. 15.

Compilation of Earnings, Expense, and Distribution of Surplus.
Evanston Water Works.

Item.	Period.	1909, Year.	1910, Year.	1911, Year.	1912, 6 Months.
Water tax—					
Certifications		$100,294.26	$119,257.08	$128,247.53	$56,382.66
Receipts		93,697.63	105,491.51	113,013.39	
Gross receipts†		102,776.64	114,617.37	116,225.68	
Expense		*72,288.78	45,083.85	54,114.44	
Transferred		38,900.00	46,050.00	49,138.00	
Balance		543.24	24,026.76	37,000.00	

†This includes water tax, water permits, miscellaneous receipts, as well as transfers from different departments.
*This includes $27,552.60 for new intake. Net expense, $44,736.18.

total water consumption has remained practically stationary.

Table No. 14 analyzes the certifications for the water tax collections during the spring term of 1912, showing the present distribution of the sources of revenue. This period of time covers the cooler months only, when the consumption is at a minimum. The certification for the Wilmette account averages 25 per cent higher for the November term, and the domestic metered accounts would be increased in the same or greater proportion.

It is not our purpose to discuss the financial policy of the Evanston Water Works further than to assist in determining a meter rate which will distribute the burden as equitably as practicable, returning to the management the revenue necessary for the suitable maintenance of the water works, and conserving the water supply without the imposition of any hardships on the consumer.

The Commissioner of Public Works is of the opinion that the present revenue is fairly well balanced to the needs of the department, and that the determination of a meter rate schedule is desired which will bring the same returns from an universally metered system as is now collected. In the event of the construction of a filter plant, it is desired that the collections shall be increased by an amount sufficient to defray the total annual operating expense and the fixed charge against the filter plant.

Present Rates.

The meter rates now in force in Evanston are established as follows:

A minimum charge, semi-annually, of $3 per service.

For the first 10,000 cubic feet per six months, $0.12 per 100 cubic feet.

For the next 10,000 cubic feet per six months, $0.10 per 100 cubic feet.

For the next 10,000 cubic feet per six months, $0.08 per 100 cubic feet.

For the next 10,000 cubic feet per six months, $0.06 per 100 cubic feet.

And for all over 40,000 cubic feet per six months, $0.05 per 100 cubic feet.

No discount is allowed on the meter rates.

In the year 1910 the average water tax collections, based on the total consumption of the cities of Evanston and Wilmette, corrected for 15 per cent pump slip, amounted to five and one-half (5½) cents per 1,000 gallons. Columbus, Ohio, with 92 per cent of the services metered, has a base rate of 12 cents per 100 cubic feet, the same as in Evanston, with a sliding scale for large quantities, bringing the minimum to 9 cents per 100 cubic feet, and in addition allows a time discount of 10 per cent. The water collections in 1911 amounted to an average rate of 8¼ cents per 1,000 gallons, based on the total pumpage corrected for a slip of 3 per cent.

The charges certified for the May collection of 1912 averaged:

For the 221 business services, excluding the accounts of the Mark Manufacturing Co. and the C. & N. W. Ry..........$40.29

For the 877 metered domestic services $5.71
For the 4,636 consumers on flat rates—gross 7.73
For the 4,636 consumers on flat rates—net 6.96

Analyzing the charges according to the metered quantities, we have for the certifications in the spring term of 1912:

Metered Service—	Certification for Sp. T'm 100 cu. ft.	1,000 gals.
Domestic	13 cents	17.3 cents
Business	6.3 cents	8.4 cents
Wilmette	5.8 cents	7.75 cents
Mark Mfg. Co.,	5.07 cents	6.77 cents
C. & N. W. Ry.	5.1 cents	6.8 cents

Of the domestic consumers, 315 customers already pay minimum meter rates, that is, they use less than 5,000 cubic feet per year, or 103 gallons daily. This corresponds roughly to 25 gallons per capita, if four persons be assumed to a customer. The effect of these 315 minimum rates is to increase the earnings to 13 cents per 100 cubic feet, although the base rate is 12 cents.

It is very probable that the consumers who have already elected to install meters are those who would naturally be the most careful in their use of water. The domestic metered registration shows an average consumption of 181.5 gallons per service daily, or approximately 45 gallons per capita, on the basis of four persons to a customer.

There is, however, little or no sprinkling in the six-month period covered by the May collection. The consumption would probably be increased 25 per cent for the summer term, and the average collection would rise to $7.14, or an average for each term of $6.42. It is fair to assume that the consumers now on the "Flat Rate" roll are more free in the use of water, and that their assessments on the meter rates would average higher than those already metered.

Future Rate Policy.

After analyzing the probable earnings of the water works with several scales of meter charges, on a reduced total consumption, we have concluded that, inasmuch as the installation of meters would be spread over several years, it is best to use the present meter rates for a trial during the first year of the extension of the meter service. The income can then be analyzed in appropriate classification with more abundant data, and satisfactory rates made, if a change is found necessary. We believe, however, that the present sliding scale of meter rates is reduced rather too abruptly for the large quantities, and that the base rate of 5 cents per 100 cubic feet might be raised to advantage as well as the next lower rate.

The minimum charge of $3 semiannually is reasonable for a trial. It is possible that a "readiness to serve charge" may prove advisable in the future, that is, a fixed amount payable in addition to the charges on the basis of quantity used. It does not seem advisable at present to introduce this modification.

The inauguration of a filter plant will make an increased charge to the consumer of from 2 to 2.4 cents per 100 cubic feet registered on the meter. This would necessarily mean an increase in the water rate. We do not, however, believe that the increase on this account should be made prior to the operation of the filter plant, or until the effect of the general introduction of meters has been tested. Then, when the filter plant is put into service, one change can be made to cover all the needs for revision.

Conclusions.

Our conclusions on the meter question are as follows:

1. It is advisable that immediate steps be taken to reduce the waste by the installation of a complete metered system. This can readily be done in from three to five years. The quicker it is accomplished the better.

2. The meters should be owned and installed by the Water Works Department of the city of Evanston.

3. The meters should be read preferably every two months, or at the most every three, the readings being carefully checked. Continued excessive use can then be investigated and stopped.

4. The small meters should be tested every six years at least, and me-

ters one inch and larger should be tested every year.

5. The water rates should be left unchanged for the present, subject to the following program:

If a Metered System Be Installed.

If a metered system be installed complete within a space of three to five years, and a filter plant be not constructed, we advise leaving the meter rates at the present schedule for a while. The effect of further metering can then be studied in detail, with more accurate analyses of each class of service. At the end of one or two years the rates can then be adjusted. The probability is that a slight increase in rates may then be required, although even with such an increase a large number of customers may pay a less sum annually than under the present flat rates. The present meter rates seem very fair, our only suggestion being that the rate for large quantities might be somewhat higher.

If a Filtration Plant Be Installed.

The capacity of the filter plant recommended herein was determined expressly on the assumption that a continued effort would be made to reduce the waste of water by thorough metering. There will, therefore, be the expense of metering as wll as the expense of filtering the water. Here we advise, as before, that the meters be installed at once, while the filter plant is under construction, and that the present rates be left unchanged during at least a year or until the filter plant goes into operation. In the meantime the working of the rates can be further studied, with increased numbers of meters in service.

The operation of the filter plant will add about one cent for every 100 cubic feet of water pumped into the mains. The increase for every paying customer will, however, be greater, since a generous portion of the pumpage is not registered by any meter.

With the expected reduction in consumption, it is probable that the increased cost of the water to the customer will be from 2 to 2.4 cents for every 100 cubic feet registered on the service meter. Such an increase will have to be added to the present meter rates at the time the filtration plant goes into operation, if the present surplus is to be retained in the earnings of the water works.

APPENDIX D.

EXTENSION OF INTAKE.

The question has arisen—Why spend money on a filtration plant? Why not extend the intake to a point where pure, clear water will be assured? To answer these queries this appendix has been prepared, in order to point out all the elements involved.

Sanitary Aspect.

With the growth of the lake cities, the unsanitary condition of the water near shore has increased, in many cases, particularly where sewage is freely discharged into the lake near the intake. There has, however, appeared a better realization of objectionable features, already existing, and the intakes have been pushed farther from shore. However carefully this matter is followed up, the quality of the water taken from such sources, particularly when sewage is discharged therein, must always be weighed with reservations.

At present Chicago has intakes from two to four miles off shore, yet the protection of the intakes from shipping has been seriously discussed, and also the possibility of filtration. Cleveland, with an intake four miles off shore, is considering filtration. At Erie, Pa., a broken intake pipe is supposed to have caused a typhoid epidemic. Filters are now being planned. At Milwaukee the filtration of the water has been recommended by a commission of engineers, as well as the removal of the discharge of sewage to a point remote from the intake.

Your present intake is located 5,600 feet out in the lake. The only available tests on the character of lake water at various distances from shore are those obtained in 1909 by Messrs. Bartow, Tonney, and Pearse, abstracted in Table No. 4. While this survey shows no B. Coli present in water four miles out, the total bacterial count is very high, ranging up to 6,140 per cubic centimeter. The turbidity is also sufficiently high to be objectionable at times. At five miles out the showing is better.

From the chart of the U. S. Lake Survey, it is apparent that Evanston is opposite the end of a shoal. The present intake is in 32 feet of water, and is thus inside the zone of wave action. To reach a quiet zone, 60 feet depth or more is considered desirable. For this an intake over five miles long would be required. At a distance of four miles 48 feet of water is reached.

The existing data, therefore, seem to indicate that a very considerable extension of the intake would be required on sanitary grounds, and that sterilization of the water taken therefrom would still be necessary at times.

Protection of Intake and Pipe.

Aside from the present possibility of sewage pollution reaching a more distant intake, there is also the possibility of pollution from shipping, the more real in your case because the intake is unprotected, there being no crib or light house to mark the location. And, in addition, there is always the possibility of a break in the intake line, when it is laid on the bottom of the lake, unprotected. Through such a break, turbid or polluted water would speedily enter. The occurrence of such breaks is not remote, as your experience last winter indicates.

Capacity, Present Intake.

The present intake lines have a capacity of about 22,000,000 gallons daily under a head of 6.5 feet. The head available is limited by the elevation of the connections at the pump wells and settling well, and at times may be somewhat less. If the intake pipe were extended even one mile the friction would be increased, with such a reduction in capacity that the remodeling of the pump wells would be absolutely necessary, and the shore connections and portions of the existing intake pipes would have to be lowered, at considerable expense and consequent danger of interruption of service.

At present the service is subject to occasional interruption by anchor ice, during periods of exceptionally cold weather, the supply having been reduced during one day for a period of two hours to a rate of 1,500,000 gallons per day. The National Board of Fire Underwriters, in their report of July, 1912, call attention to this weakness, and suggest that steps be taken to provide against such interruption. This would mean either an intake crib, with a permanent keeper, or an equalizing or storage basin on shore, which would involve double pumping, or an excessively large standpipe. If a filter plant be built, however, storage would be provided by the filtered water basin to serve this purpose.

New Intake.

The cost of a tunnel, run out from shore, would probably be prohibitive for Evanston. A five-foot tunnel is as small as is usually driven, for such lengths, that size being required so that work can be carried on reasonably. Roughly, the cost would range from $15 to $20 per linear foot. For three miles this cost would be from $238,000 to $317,000, to say nothing of intake and shore connections.

Even the cost of a three-mile extension of 42-inch cast iron pipe would be greater than the cost of a filter plant. The three-mile extension would cost around $250,000, with the lightest pipe, including engineering and contingencies. Properly, a pipe exposed in a situation like yours, should be laid in a trench dredged in the lake bottom, and covered. This would add to the expense.

For a permanent improvement, to compare with the filtration project, it would be better practice to consider a 48-inch intake pipe throughout, to reduce the friction losses. With an equalizing reservoir, however, the 42-inch pipe would be sufficient. This, however, only serves to increase the first cost.

The capital cost, therefore, of any considerable extension of the intake are higher than for the filter plant. Extension of the intake into deeper water will undoubtedly lessen the chance of interruption by anchor ice troubles, but on the other hand, when difficulties occur, they will be harder to meet and clear away promptly.

The annual cost of the project of extending the intake may be worthy of consideration, but with the need of sterilization, the possibility of occasional turbid water, and the occurrence of accidents to the pipe line, with consequent expense for repairs (in 1912, $3,000), the advantage is not so great as would appear.

There is, perhaps, a financial advantage in extending the intake, in that it suggests the possibility of constructing the improvements piecemeal, in order to ease the financing of the project. On the other hand, this would require the continued use of hypochlorite of calcium to sterilize the water, and for several years the water would be turbid at times as heretofore. The fixed and operating charges probably would be somewhat case the cost of a keeper and his as- lower, unless a crib be built, in which sistant would reduce the difference.

Advantages of Filtration.

Aside from the question of cost, which we have previously covered, the installation of a filter plant would furnish clean water and a positive insurance against typhoid or other water-born disease, regardless of the diversion of the sewage, or accidents to the intake pipe. And it would postpone indefinitely any extension of the intake or remodeling of pump wells which would be consequent thereto with the present rate of pumping. It would also furnish storage against interruption of service by anchor ice, and if a wash water tank be built would secure thereby a possible means for back-flushing the intake pipe to dislodge ice.

The sanitary dictum is growing that all surface supplies should be filtered. The wisdom of this is supported by the remarkably low typhoid death rates recorded abroad, ranging from 2 to 4 per 100,000 where filtered water is used. Sanitarians have endeavored to illustrate the saving to the community by assuming that a human life is worth $5,000. If five typhoid deaths a year can be saved in Evanston, this would amount to $25,000, or the annual cost of the filtration project.