

REPORT ON THE
ROCHESTER
WATER WORKS

BY

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ASSOCIATED



MARCH 7, 1927



COMPLIMENTS OF
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REPORT ON THE

ROCHESTER WATER WORKS

Department of Engineering
Rochester, N. Y.

March 11, 1927

Hon. Martin B. O'Neil

Mayor

Dear Sir:

On February 23rd, 1926, with the approval of His Honor, the late Mayor Van Zandt, I employed Mr. Allen Hazen, of New York, and Mr. Harrison P. Eddy, of Boston, Water Supply and Sanitary Engineers of international reputation, to advise in the matter of an additional water supply for this city. Mr. Edwin A. Fisher, then Consulting Engineer to the City, co-operated with Messrs. Hazen and Eddy in the investigation.

Mr. John F. Skinner, Deputy City Engineer in charge of Water Works Improvements, also co-operated in the study and furnished the detailed information required.

I take pleasure in submitting the report which covers in detail the investigations and the advice of the Consulting Engineers.

Respectfully yours,

C. ARTHUR POOLE,

City Engineer.

Mr. C. Arthur Poole

City Engineer

Rochester, N. Y.

March 7, 1927

Dear Sir:

On February 23, 1926, you asked us to advise you with reference to the water supply of Rochester, and particularly to aid in determining the most advantageous additional source of supply and the method of its development.

This matter was taken up with you and with Mr. John F. Skinner, Deputy City Engineer, and his assistants. Mr. E. T. Cranch, of his staff, has been in charge of the extended field work and borings that were under way at that time and that have been continued. The studies have been carried on continuously until the present time.

25 Nov. 32-8-27

All the matters to be now reported on have been debated with you and your associates during the course of our studies, and have been considered in much greater detail than can be reflected in this short statement. The maps and records on which our work has been based are all on file in your office, and reference to them is made for further details that may be needed.

CONCLUSIONS

After investigation we find that the present water consumption has reached the safe capacity of the present sources and that steps should be taken at once to provide additional supply. Of the several sources which are available, we believe that the development of a large storage reservoir on Honeoye Creek, near West Bloomfield, will be the best and in the long run the most economical and satisfactory. With the present supply it will be adequate to serve the city until it approaches a population of one million.

That part of the total plant required for early construction will cost about \$12,000,000, and a moderate increase in water rates will be necessary.

PRESENT SUPPLY CONDITIONS

The present water supply is obtained by gravity from Hemlock and Canadice Lakes. These are natural lakes that have been raised to secure storage. They are under good sanitary control and furnish water of excellent quality with abundant head or pressure.

The City of Rochester is mainly built upon comparatively flat ground centering 6 miles from Lake Ontario, and from two to three hundred feet in elevation above it.

The present population of the city is 320,000 within the city limits, and there is a further population of 23,000 in villages and suburban communities not far beyond those limits.

The population has increased steadily for the last forty years, as indicated by the census reports, at an average rate including annexation, of approximately 3% per annum, compounded each year, or 34% per decade. During the last years the rate of growth seems to have been somewhat less. The rate of growth has been fully up to average American conditions.

Water Consumption

The distribution of water from the water works system is well in hand and there is no hope of saving large quantities of waste by stopping leakage. All the services are metered and have been for many years, with the exception that 300 old fire services are inspected only and are not metered. These are supposed to draw no water. School

buildings and city buildings are all metered. Park use has all been metered since July, 1926.

A partial analysis made at our request indicates that of the total output, about 70 % is accounted for by consumers' meters, and of this 8 % goes to city buildings and public services, 25 % to large industrial users, and 67 % for domestic requirements.

The water consumption for the last few years has been at a rate of about 90 gallons per capita daily from the city works, calculated for the population of the city. As will be shown below, several other matters must be taken into account before a correct figure can be reached, but this will serve as a comparative figure. In 20 years the per capita calculated in this way has increased from 80 to 90 gallons.

This is in part accounted for by the fact that formerly some industries were supplied by the City with Genesee River water pumped at the old water works station through special pipes, and water so supplied was not included in the per capita. This service has since been discontinued, and the capacity represented is now all taken from the Hemlock works. It is interesting to note that discontinuing this service had no appreciable effect in increased output from the main supply.

TABLE No. 1—DOMESTIC WATER CONSUMPTION,
CITY WORKS

<i>Year</i>	<i>Consumption Metered %</i>	<i>DAILY WATER CONSUMPTION</i>	
		<i>Million Gallons Daily</i>	<i>Gallons per Capita Daily</i>
1917	65.8	23.30	91.6
1918	63.9	25.27	96.7
1919	60.0	25.44	94.6
1920	59.3	26.63	95.8
1921	60.9	27.41	96.0
1922	64.0	26.02	89.6
1923	68.8	26.01	88.6
1924	70.0	26.46	89.3
1925	68.5	28.00	94.0
1926	70.2	28.10	93.9

The city works does not supply the entire population of the City of Rochester and for a complete statement the Rochester and Lake Ontario Water Company must be included. This company supplies most of the previously mentioned population of 23,000 beyond the city limits and some population that is farther away to the eastward.

It also supplies a substantial population in parts of the city that have been recently annexed and to which the city pipes do not reach.

This company takes water from Lake Ontario and filters it. The present output of roughly 7 mgd is all that can be handled comfortably by the present works. It sells some water to the City and it has been necessary for the City to sell water to the Company from time to time to meet peak loads. Of the total output of the Company's plant about three-fourths goes to industrial takers and railroads. A little more than half its output is sold within the city limits.

Taking Over the Water Company

The City of Rochester may some day take over the plant of the Water Company. If that plant was all within the city limits there would be every reason why this should be done at once.

If the City does take this plant, it should take it all and not split it on artificial lines leaving a smaller plant in the possession of the Company.

If the Company's plant should be absorbed before a new water supply is obtained, it would continue to operate as at present and there would be no reduction in supply and no considerable added load at the moment for the gravity works.

On the other hand, if the Company's plant should be taken over when a large addition to the gravity supply is available, it would furnish additional market for the new water and its revenues would help to pay for it.

The program presented must be elastic enough, as we believe it is, to fit with any contingency likely to arise in this regard.

Eastman Kodak Supply

It is also to be mentioned that the Eastman Kodak Company has a plant taking water from Lake Ontario, with filtration and with an average output of 6 or 7 mgd, used mainly for process water in manufacturing film. The Eastman Kodak Company has special and unusual requirements in regard to quality, which are met by its supply. It may therefore be assumed that this service will be continued and also that various other industries will continue to get process water independently from the Genesee River, and no provision for these uses need be made in plants for future water supply.

Per Capita Consumption

It is always interesting to know the total per capita consumption of a community and the amount of water taken by the industries including railway uses. In this case the information is not as complete as could be desired, but the following schedule gives a rough idea of it.

<i>Works</i>	<i>Total Output</i> mgd	<i>Industrial Uses</i> mgd
City of Rochester	28	7
Rochester and Lake Ontario Water Company	7	5
Eastman Kodak Works	6	6
SUM	41	18

It should be noted that this statement does not include amounts used from the Genesee River and from wells by industries having their own arrangements for supply.

The amounts indicated for the combined city and outside population of 343,000 are equal to 119 gallons per capita total consumption, of which 52 gallons or 44% are used by industries including the railroads. The remaining 67 gallons cover domestic use and also all the leakage and losses of the system.

FUTURE REQUIREMENTS

No one can tell how fast, or for what period a city will continue to grow. At present the best guide is the record of past growth and the experience of other American Communities. With these in view, it is our judgment that works now planned should be adequate to meet an average rate of growth in water output of 3% per annum compounded annually. It is, of course, not to be expected that this rate of increase will go on forever, but in our judgment, it is suitable for an estimate for the considerable period for which provision should now wisely be made.

It is not prudent to assume a lower rate, but as far as practicable, the works should be laid out to be built in installments arranged so that there will be no embarrassment if the rate of growth proves to be either more or less rapid.

It must also be borne in mind that if the business now carried on by the Water Company should be taken over, it would be desirable that new works when ready for service should be sufficient to meet all needs.

On this basis the estimated quantities to be provided in millions of gallons per day will be as follows:

<i>Year</i>	<i>Population Supplied by</i> <i>Present City Plant</i>	<i>Entire Population,</i> <i>Urban District</i>
1926	28	35
1930	31	39
1940	42	53
1950	57	72
1960	76	95

CAPACITY OF THE PRESENT WORKS

Canadice Lake and its outlet stream have been made to flow to Hemlock Lake, which is the main source of supply. The combined catchment area now in use is 65.0 square miles. In elevation the catchment area is high, averaging more than 1,400' above sea level. The mean runoff, or water crop, including Hemlock and Canadice Lakes and the Canadice outlet area, based on gaugings maintained for thirty years by the City of Rochester, is 37 mgd.

Your department is to be highly commended for its patient, careful work in making these gaugings without interruption through all these years.

The underlying rock is a tight, impervious but not very hard shale, which is generally covered by a thin layer of clay resulting from its disintegration, but the narrow valleys are sometimes deep and filled with masses of clay and sand.

The catchment area is covered by a rural farming population and a few small villages, amounting in all to about 1,700 people, or 26 per square mile. The average hardness of the water is between 60 and 70.

The City owns and controls nearly all the shores of both lakes and the sanitary quality of the water is well protected. Storage has been secured by raising and controlling the levels of both Hemlock and Canadice Lakes. The gross storage a short time since was 7.27 billion gallons, or 54% of one year's mean flow of entering water.

By arranging the Hemlock and Canadice Lakes records of flow for the period that it has been gauged in the form of a mass curve and treating this in the usual way, it can be shown as a matter of calculation that a draft of about 32 million gallons per day, or 87% of the mean flow, could have been maintained during that period. The flow of Hemlock Lake during this period has been regular in that the dry years have been sprinkled in between wet years, so that under the assumed conditions of draft, the lakes would have been filled in the wet years to take care of the dry years.

If there were no other evidence we should take this calculation as a measure of the capacity of the present works. But experience in other American water supplies shows that the dry years sometimes come bunched together in a way that limits the capacity of a source, and a source must not be rated too highly, for then there is danger of a bad shortage.

We must conclude from the best evidence at hand, that the distribution of wet and dry years is a matter of chance. In this case, wet

and dry years have been well mixed, but in another thirty year period they may be segregated as they have been in other areas, and this possibility, to the extent indicated by all the data that we have comparable and proper to this case, must be brought into the account. Proceeding in this way, it is our judgment that only 70% of the mean flow, or 26 mgd, could be safely counted on with the storage at hand when this investigation was started.

TEMPORARY MEASURES FOR INCREASING THE SUPPLY

Our first studies indicated consumption equal to or above capacity with no margin for growth. They suggested that even now, or in the next few years, before any other works could be built, a very dry time might result in a serious shortage of water. And this led to a study to see what could be done quickly, even though the addition was not large.

Carney Hollow Diversion

Some years ago, without legal authority, employees of the Town Highway Department of Springwater dug a ditch which diverted a part of the flow of the stream at Carney Hollow, with a catchment area of 4.4 square miles through Pokamoonshine Gulf to Springwater Creek, flowing into Hemlock Lake. We did not see this in action, but from an inspection of the locality it is apparent that the diversion must have been relatively small in amount. The dry weather flows would all have gone underground through the gravel at the point of diversion, and the ditch was not large enough to carry the larger flood flows. The diversion, therefore, must have related only to some of the intermediate flows.

At present the Village of Dansville, N. Y., takes its public water supply from a lower point on this stream and the above mentioned diversion by Rochester has been discontinued.

It would be possible to reestablish this diversion by a proper legal taking, and by building adequate diversion works and perhaps extending them to an additional area of 1.8 square miles more or less that can be brought to the same point by extending the ditch.

Whatever is done in this respect would have to be done in a way to not interfere with the water supply of Dansville. That would probably mean that none of the low water flows could be taken.

The flood flows are most important because they represent the greatest volume, and Hemlock Lake will have the necessary storage to hold them when they are needed.

Mr. Skinner has made studies for a storage dam and reservoir on

the Carney Hollow stream to be built in part by Rochester for the use of Dansville, to permit the City of Rochester to take flood flows not required by Dansville.

Complete diversion and storage of all the Carney Hollow water would add about 2.5 mgd to the capacity of the Rochester system. In any event, the diversion will not be complete, and the Dansville service must be maintained. An addition of one mgd can be counted on.

Increased Storage

Another way to increase the supply is to increase the storage. With a larger reserve against a series of dry years a larger percentage of the mean flow can be safely counted on. We first thought of raising Hemlock Lake by 20 feet. This would require a very long dam not on the best of foundations, and expensive changes in present arrangements at the lake outlet; but it was found feasible to raise Hemlock Lake by about four feet to elevation 905 without meeting these difficulties.

We advised this additional storage. Plans for the work were prepared by the City and approved by the State Engineer, and the work is now under way.

At the same time, by some changes in the outlet, arrangements and pipe connections below the outlet of Hemlock Lake, which we discussed with you, and which were found feasible, it will be possible to draw Hemlock Lake at least 3' lower than it has been drawn in the past. These changes, both up and down, will increase the net available storage in the two lakes by 4.26 billion gallons from 7.27 billion at present to 11.53 billion gallons and with some water from Carney Hollow the safe yield will be increased from 26 to 31 mgd.

For the climate and water supply conditions of Rochester, a storage equal to one year's mean flow may be taken as a rough measure of full development. With Hemlock Lake raised as proposed the storage ratio will fall somewhat short of this, being 0.85.

It would be possible to secure additional storage by raising Canadice Lake or by building another reservoir on the Canadice stream below the present lake. A small additional amount of water could be secured in that way, but it may be doubted whether the amount would warrant the expense. We regard the storage now being added as representing practically the economical development of Hemlock and Canadice Lakes.

This increase of 5 mgd, or 19%, in delivering capacity is not great, but it comes at a time when even a small increase will be helpful and

it is fortunate that steps for making it effective could be adopted at once.

For the present purpose we may consider these improvements as effective, and the capacity of the present system to be 31 mgd.

CONESUS LAKE

Conesus Lake is directly west of Hemlock Lake and for more than a generation it has been accepted by the people of Rochester as the next probable addition to the Rochester water supply. We shall not go into the interesting history of the early reports and discussions further than to point out that had this early and excellent engineering advice been followed, the land and rights would have been secured while they were still available, and Conesus Lake would remain the most available additional supply at this time.

Conesus Lake is larger than Hemlock Lake, and it has a greater catchment area, namely 67.0 square miles. But the average elevation of its catchment area is considerably lower, averaging about 1,200' above sea level. The flow from it has been gauged by your engineers in co-operation with the State and U. S. Geological Survey for six years. The indicated mean flow for that period is 29.1 mgd, or 21% less than the yield of Hemlock and Canadice Lakes, including the outlet stream. When the difference in area also is taken into account, the proportionate yield is 24% less. The mean flow from Conesus Lake is thus disappointing.

It is unfortunate that the flow record is not longer. Short records naturally lead to speculation. Thus, it is found that in comparing the flow of Conesus for these 6 years with the same identical years from Hemlock and Canadice Lakes, that the mean flow from Hemlock and Canadice Lakes for these 6 years was only 88% of the mean flow for the 30-year term. If it is assumed that the measured flow from Conesus is in the same proportion to its own long term mean, then the indicated long term mean flow is 33.0 mgd. Not much weight can be given to such speculation but it suggests the idea that the record mean of 29.1 mgd may be low for a true average.

It must be remembered that in any event only a part of this flow can be made available by storage.

If Conesus Lake water were to be used, a new conduit from Conesus Lake to the City would be required. Along a direct route for such a conduit, borings showed a deep deposit of sand in a large rock valley below lake level which would make the construction of an outlet tunnel in this location difficult, and so expensive as to be impractical.

ble. Studies followed for another route with more favorable results. An outlet tunnel about 3 miles long to the westward will pass through rock and can be driven to a point where a pipe line will lead to Rochester. The total distance is greater, but the ground is more favorable, and estimates for development must be based on this longer route.

Storage is required. If the storage is limited to about 6 feet, i. e., to a range of six feet between high and low water in the lake, the yield to be counted on is estimated at 20 mgd. Twice as much storage, i. e., twelve feet, would be needed to get a full development up to a possible maximum of about 25 mgd.

Conesus Lake and Hemlock Lake both fully developed would thus produce 56 mgd, sufficient to last that part of the city now supplied by the city works until 1950, or the entire urban district, including that supplied by the Water Company, until about 1942.

From the standpoint of quantity, Conesus Lake does not provide adequately for future growth. When cities build new works, it is desirable to get sources that will maintain service for longer periods.

Sanitary Condition of Conesus Lake

The most important matter in regard to Conesus Lake is its sanitary condition, growing out of a large temporary summer population in cottages upon the lake. The permanent population is moderate in amount, being estimated from the census returns of 1920 at about 2,700 or 40 per square mile. This population is mainly rural, but includes the Village of Livonia.

The summer population is much greater. In 1925, there were 780 camps upon the shores of the lake. The lake water is used for water supply by the Villages of Avon and Geneseo, and the water to be supplied to Avon and Geneseo must be deducted from the amount otherwise available from Conesus Lake if it is used by Rochester. Because of this present use, the lake and its surroundings are subject to sanitary inspection. There is thus available an unusually detailed record of the sources of potential pollution.

In addition to the camps, there are permanent chicken ranches, garages, ice houses, farms, stores, hotels, schoolhouses and creamery. The camps and houses are not permitted to discharge sewage to the lake, but most of them are provided with concrete vaults or with septic tank systems which do overflow to the lake.

From the report of the Inspector, it appears that there are 16 dug vaults, 209 concrete vaults, 36 toilets over 300 feet from the shore, 10

toilets with leaky vaults, 71 toilets with removable receptacles, 212 toilets with tight tank systems, 124 toilets with septic tank systems, 30 septic tanks with permits, 290 toilets cleaned by service man, 434 sinks draining to cesspools, 3 sinks drained to lake, and 23 sinks promised to be abated in 1926.

In 1925, there were reported 499 violations of the rules in regard to pollution, of which 451 were abated during the year and 48 remained unabated at the end of the year.

The septic tanks, which have permits, and are thus duly authorized by law, may present a serious sanitary problem. Presumably, they serve the hotels and larger establishments and those having ordinary water closets as distinguished from old-fashioned privies and dry vaults. By septic tank is meant a closed basin through which sewage flows, and in which the suspended matters are more or less completely deposited. The chamber is supposed to be big enough so that an appreciable period of delay and fermentation of the sewage takes place in it.

The important thing is that after this subsidence and fermentation which make only a moderate change in the fundamental character of the sewage, the liquid portion overflows to the lake. No doubt many bacteria are removed by septic tanks, but many others pass, and as a bacterial removal process it is far from complete. An important part of the danger of pollution that might be found from raw sewage remains after this treatment.

If Conesus Lake were to be taken for a water supply, one of two courses would have to be taken:

1. All the camps and houses and surrounding land would be bought. The camps would be removed and the entire surroundings of the lake brought back to their native wild state. And with this done, a dam at the outlet could be built and the full required storage obtained, equivalent to twelve feet fluctuation in lake level, thus making available the full 25 mgd that this source is capable of delivering. This is the best procedure, but it will be expensive.

2. The camps may be permitted to remain, limiting the draft for storage to 6 feet, so as not to incommode them too seriously, in which event about 20 mgd may be expected. In this case, the least that could be done as protection against pollution would be to filter the water. The analyses of the water which have been submitted to us have shown but little indication of pollution. The camps are occupied, for the most part, in summer only. The lake is large and there is much natural purification, and conditions have not become very

bad as yet. The lake water, if filtered, might be used.

If the shores of the lake remain in private ownership, many more cottages and hotels are sure to be built in the course of years and the pollution will greatly increase. Even if all now unoccupied property were to be purchased by the city, there would still be development of additional and larger cottages and hotels on property remaining in private ownership.

Considering the matter from a standpoint of what we consider to be the inevitable future development, we are not willing to recommend the use of Conesus Lake with the cottages remaining, even with filtration.

The estimated cost of acquiring all the cottages and moving them and developing the lake, so that it would be comparable in its occupation and purity with Hemlock and Canadice Lakes, is clearly greater than is warranted by the amount of water that can be obtained from it.

TABLE No. 2—ESTIMATED COST OF DEVELOPMENT OF
CONESUS LAKE PROJECT

PROJECT A

6' Storage—20 mgd

1. Land for dam at outlet of lake, as sites for all needed works and for right-of-way, but not including the purchase of the marginal land, or cottages, and for water rights.	\$ 500,000
2. Building dam and spillway at the outlet of the lake.	277,000
3. Submerged intake in lake, say 2,000', 54" pipe with crib.	100,000
4. 3 miles of tunnel, about 6' diameter, through rock, at \$65 per lin. ft.	1,030,000
5. Pipe line to city, 23 miles 48" steel pipe, at \$17 per lin. ft.	2,064,000
6. 19,000' vacant lake front at \$20.	380,000
7. 30 mgd Filter Plant, complete, at \$40,000 per mgd.	1,200,000
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	\$ 5,551,000
+ 20% engineering and contingencies.	1,110,200
	<hr/>
	\$ 6,661,200

PROJECT B

12' Storage—25 mgd

Items 1 to 5 inclusive as above.	\$ 3,971,000
Greater dam to cover 6' additional storage, say	300,000
Purchase 900 cottages at \$3,500.	3,150,000
Purchase 84,500' lake front at \$20.	1,690,000
Purchase additional, 6,080 acres at \$100.	608,000
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	\$ 9,719,000
+ 20% engineering and contingencies.	1,943,800
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	\$11,662,800

OTHER SOURCES OF SUPPLY

When it became clear that for various reasons it would be necessary to consider other sources of supply, a rapid canvass was made of everything in sight. We shall first mention briefly a number of the sources that were considered and discarded and afterward discuss at more length the two that were considered more favorably.

A filter plant and pumping station could be placed beyond the limits of the present city where the catchment area of the river is about 2,200 square miles. The water rights in the river would have to be acquired. There are no large cities upon the upper Genesee. The water is substantially free from color but is turbid at times. The project looked fairly promising until it was found that because of the salt industry and other operations on the catchment area, the water contains an amount of mineral matter and hardness that puts a very heavy handicap on its use. It would still be possible to go to the upper Genesee, say above Portage, or to some of its tributaries with a conduit 50 miles long, where water could be obtained free from excessive amounts of mineral matter. The natural flow of the Genesee River at these points would not be sufficient to meet future water supply conditions, and even if it were, it is not to be expected that the City would be permitted to take all of it. In any such case the construction of a large storage reservoir would be necessary. The waters taken would be mainly from flood flows and the ordinary and low water flows would not be reduced.

A reservoir above Portage has been proposed for water power purposes and it may be built some day. Storage on one of the tributaries is already under way for water power purposes. The project as a whole is larger and would produce much more water than there is market for in Rochester in any time now under consideration, but if it should be built at some time for power purposes, the City of Rochester, on proper arrangements being made, might become a partner in the enterprise and take such quantities of additional water as needed from this source.

An attractive modification of this project would be to take the water by way of Hemlock Lake which is only a little longer than a direct route. The conduit from Portage to Hemlock Lake would be 25 miles long, most of it in tunnel. If the Honeoye Reservoir were in existence the water would flow through natural channels from Hemlock to it and the intake would then be at the proposed Honeoye dam as will be described below in this report.

For the present, this source is too large and too distant and the first installment would cost too much money to permit its serious consideration at this time, but looking to a remote future, it is not at all impossible that it may be part of Rochester's ultimate supply.

Canandaigua Lake

This lake is much larger than Hemlock Lake and has a catchment area of 186 square miles. Canandaigua Village is at the outlet. If the lake were used for water supply, sewage from the village would be kept out of the lake. The remaining population amounts to 40 per square mile. The lake is more than 200' lower in elevation than Hemlock Lake, and only 50' higher than Cobb's Hill Reservoir. Theoretically, this 50' might be made to bring the water as a gravity supply, but practically the fall is too little. It would be better to pump it.

The works would consist of an intake, a pumping station on the shore of the lake, raising the water to an elevation where it could be filtered and from which it would flow through a pipe or aqueduct to Cobb's Hill Reservoir.

No satisfactory gaugings are available for computing the yield of Canandaigua Lake. The elevation of the catchment area is low, averaging only 1,130 feet, and the runoff may be low in proportion. Assuming that the water level could be controlled through 5 feet and all the water taken, it is our estimate that a yield of 60 mgd might be obtained.

It is to be noted, however, that the lake is used for navigation, has many cottages upon its shores, and that the City of Canandaigua, on its outlet, with a population of 7,686, depends upon the flow for its water supply and to dilute its sewage.

A supply from Canandaigua Lake would not be satisfactory unless strong measures were taken to control both the quality and quantity of the water, and the present uses of the lake for other purposes are such that full control would be very difficult.

A rough preliminary study indicated that works would cost much more than for other possible sources.

Having now considered several possible sources that cannot be recommended, we proceed to take up the two that were found most promising, namely:

1. Lake Ontario.
2. An upland gravity supply based upon an enlargement of Honeoye Lake.

LAKE ONTARIO

Lake Ontario is an obvious source of future water supply. The quantity of the water to be obtained is adequate for all possible needs. The water is colorless and relatively clear, and harder than

gravity water from Hemlock Lake. The lake water is subject to pollution, especially by water entering from the Genesee River and from the Rochester sewage outfall near its mouth. With reference to these pollutions, it would be well to have the water works intake as far as practicable to the westward. An intake going well out into the lake would avoid much of the pollution found in shallow water along the shore. The hardness of the water would be from 95 to 100. Water now taken from the Lake by the Rochester and Lake Ontario Water Company, and by the Kodak Works, is slightly harder, due to the proximity of the intakes to the mouth of the Genesee River.

Position of Intake

We have selected as the best position for an intake, after inspecting the ground and maps, a point near Bogus Point, where there is also space for the convenient location of the filters and pumps that would be needed. At this location for the first mile out from shore the water is relatively shallow, being only 40 feet deep at the end of the first mile. After that it gets deeper more rapidly and a depth of 100' is reached at about two miles from shore. The intake would probably be built as a tunnel in rock extending out for a certain distance, where connection would be made through a temporary crib and shaft to a steel pipe laid in trench below the bottom of the lake for the rest of the way.

We think that the intake should go out to water 80 feet deep which is found by your surveys to be 9,670 feet from shore.

Difficulties in Intake Construction

Getting a satisfactory water supply from the Great Lakes presents a problem of some difficulty. Along the shore the water is more highly polluted, and the intake must extend out to cleaner water. It must also be deep enough to avoid troubles with anchor ice and frazil. If a large pipe is laid above the bottom of the lake, it may be crushed by ice accumulations in winter, even in a considerable depth of water.

Tunnels driven beneath the beds of the Great Lakes for intakes have advantages, and have often been used where tunneling conditions were favorable, although many difficulties have been met in driving them. At the location of the proposed intake, rock is exposed on the shore of the lake, but there is not sufficient information as to materials to be encountered under the lake. Such information would be secured by borings as a preliminary to going ahead with the project.

The proposed location off a point is subject to strong wind action

and it will not be easy to hold either the barges needed for preliminary borings or the dredges needed in the subsequent operations. The intake can be built. It is simply suggested that it is a matter that requires mature study and very careful, competent supervision, and in any event the cost of an adequate lake intake would be large.

Filtering Lake Ontario Water

With an intake eleven miles from the Rochester sewer outfalls and nine miles from the mouth of the Genesee River, and a mile and three-quarters off shore, in 80 feet of water, and with no other major source of pollution within 60 or 70 miles, and with predominating currents along the shore from west to east, it might be thought that water would be obtained that could be used with chlorination and without filtration.

It is certain that most of the time the water at the proposed point of intake would be of excellent quality, and that numerous samples could be taken from this position for analysis.

The reason why this water cannot be used without filtration is because there are occasional combinations of wind and current that carry the polluted river water and the city's sewage for long distances in any direction, and once in a while this direction will hit the intake.

We have had more or less experience with these intakes and with the sudden and unexpected changes in character of water obtained from them, and we believe that if this supply were to be taken the water should be filtered as is now done at Toronto and Cleveland, and that this project should not be otherwise considered.

Pumping

One great handicap in the use of Lake Ontario water is the pumping. The cost of pumping will be much greater in this case because of the unusual elevation of the city above the lake. Most of the cities that use lake water are elevated but little above the lakes, and it is necessary to pump only against the pressures actually required for ordinary service.

But Rochester is on a shelf high above a lake. The service reservoirs which provide the necessary pressure are 390 feet above lake level. Add to this the friction losses in the intake and in the pipe lines to the city, the head required to operate the filters, and we find that, depending upon the size of equipment provided, and the quantities of water drawn, the total pumping lift will ordinarily range between 430 and 550 feet. A fair estimate for average working conditions is perhaps 470 feet, or 203 lbs. This is two or three times the head actually

pumped against in most of the lake cities, and this means that at Rochester the pumping cost will be correspondingly greater than elsewhere.

Size and Arrangement of Plant

We have in mind a plant to accommodate ultimate peak loads of 100 million gallons daily which would be suitable in connection with Hemlock Lake to maintain service and meet peak loads with the aid of the present service reservoirs until the average daily consumption reaches about 100 mgd. The filter plant and pumps and pipes may be provided at first for about one-third the ultimate capacity, and additions made from time to time as the growth of the service requires. The required works without going into particulars would be as follows:

TABLE No. 3

ESTIMATED COST OF ADDITIONAL SUPPLY FROM
LAKE ONTARIO

	<i>Whole Proposed Plant</i>	<i>First Installment</i>
Intake consisting of tunnel and 7' steel pipe, extending a total distance of 9,670' to 80' of water, at \$200	\$ 1,934,000	\$1,934,000
Allow for intake, shafts, etc.	500,000	500,000
Land for filters and pumping station and for right-of-way for pipe line for about 10 miles (the last part of the way in public streets)	305,000	305,000
For filter plant, complete	4,000,000	1,500,000
For pure water reservoir, covered, being only large enough to permit convenient pumping, equalization being maintained by present service reservoirs, 20 mgd cap.	600,000	200,000
Pumping station including both low lift and high lift pumps, with reserve units, electrically driven centrifugal pumps	1,600,000	600,000
Rising main extending from pumping station on a diagonal line across country to the old Erie Canal, and thence extending toward the center of the city connected with present pipes, and ultimately with additional pipes, leading to the present service reservoirs, 15 miles, 3 lines of 48" pipe, averaging \$24.50	5,800,000	1,940,000
SUM	\$14,739,000	\$6,979,000
Add for engineering administration, contingencies and overlooked items, 20%	2,947,800	1,395,800
Total estimated first cost	\$17,686,800	\$8,374,800

<i>Estimate of Annual Operating Cost</i>	<i>Whole Proposed Plant</i>	<i>First Installment</i>
Electricity to pump 70 mgd maximum average output to be reached by the proposed plant, 470' lift, 65% average pumping efficiency, 58 million K. W. H. per annum at 0.9c.	\$ 522,000	\$174,000
Labor and supplies for pumping	130,000	43,000
Filtering lake water @ \$5.	128,000	43,000
	<hr/>	<hr/>
Total cost of filtering and pumping . . .	\$ 780,000	\$260,000
4¼ interest on first cost	752,000	356,000
1% depreciation or sinking fund charge, either but not both	177,000	84,000
	<hr/>	<hr/>
Annual cost of water	\$1,709,000	\$700,000
Average daily output running at capacity . .	70 mgd	23 mgd
Cost per million gallons	\$67	\$83
Maximum or normal capacity in mgd	100	33
Suitable for average output and to meet the peak loads in connection with an average output of	70	23
Capacity of whole combined system, including present works. Good for average annual rate of	100	54

Actually, most of the time the load factors would be lower and the cost per million gallons would be higher; and through a term of years the average cost of water would be materially above these figures.

From our studies, we believe that this is a thoroughly practical and reliable method of water supply.

The first installment of works would cost \$8,400,000. The heavy pumping cost is a great handicap to this project.

HONEOYE CREEK

Honeoye Lake has been considered as a possible source of supply and has attractive features, but by itself is not large enough. Honeoye Lake is a comparatively small lake in a valley that is as large as that which holds Canandaigua Lake. Possibly in Honeoye valley there was once a large lake, but if so it has been drained by a natural

wearing away of the barrier in the course of ages. By replacing the barrier, that is to say, by building a dam, the valley can be again flooded, making a lake four or five times as large as the present one. The new lake would be as long as Canandaigua, but somewhat narrower and capable of producing quite as much water. The City of Rochester might build this lake and own and control it for the purpose of water supply.

Mendon Ponds Reservoir

It is proper to record at this point that Mr. James P. Wells suggested to us at the outset of this investigation a plan to utilize the water that will be secured under this project in a somewhat different way. Mr. Wells proposed to carry the flood flows of Honeoye Creek by a pipe line to a point in Mendon, where a large reservoir would be built, and from which the water would be taken as needed to Rochester.

The topography is favorable, for there is a natural basin almost at the top of a wide, flat ridge of sand hills.

We studied this proposed reservoir, with inquiries as to the levels of water in the wells of the various farm houses in the neighborhood, and also with the aid of a most useful paper by Herman LeRoy Fairchild, Sc. D., on the "Mendon Kame Area." We noted the numerous dry "kettles" with their evidence of underground seepage.

The results of these studies did not reassure us as to the tightness of the soil strata. At any rate, we think it better to develop the water in another way and more completely than could be done by the proposed Mendon Reservoir.

The plan that we propose is to build a reservoir, or, in reality, a lake that would include and raise Honeoye Lake. The dam would be a short distance above Factory Hollow, on a site that has been surveyed and bored by your assistants.

Catchment Area

This dam will control a catchment area of 187 square miles which includes all the catchment area now used for water supply by the City of Rochester and also Honeoye Lake and a very considerable area downstream from it.

The added catchment is 122 square miles, or nearly twice the area now controlled. It is east and southeast of Hemlock and Canadice Lakes, and has hills higher than those in the present catchment area, although a part is lower and less hilly and may produce less water

relatively. The average elevation of the added area is 1,160' above sea level, or somewhat less than that of Rochester's present catchment area.

The population per square mile on the added area is 26, which is practically the same as it is upon the present catchment area and there would thus be no lowering of present standards with respect to freedom from pollution.

Dam

At the point selected for the dam, Honeoye Creek flows through a deep cut between hills that are made up of lenses of clay and sand and gravel. A dam less than 60 feet high to the flow line and 800 feet long will be required.

Borings extending to a depth of 200 feet did not reach rock. In general, the higher material is sandy in character and that underneath is clayey, but there is much mixing and sand is frequently found beneath clay. The sand is usually cemented to a more or less stiff structure by a small admixture of clay.

It would apparently be possible to build a puddle cutoff to a clay deposit found by the borings deep enough and extensive enough to be tight, but we think it will be better, instead of doing this, to form a dam of very large section of gravel and clay brought down from the banks close at hand, and to puddle the whole upper face.

It is the intention to make the dam large enough and heavy enough and thick enough so that any possible seepage through any sand lenses, that may possibly be continuous, will be so slow as not to be important in amount, or involving any risk to the dam.

When the dam is built and the water raised, the banks of the stream immediately above the dam will be too steep to be stable against wave action in the reservoir, and it is proposed, probably by means of pumps on a floating barge in the lake and monitors on shore, to cut down those steep banks to slopes that will be stable.

The result of these operations will be to considerably fill up the reservoir immediately above the dam and to puddle it. Much of the excavated material will be clay, and the operation of leveling and puddling should be continued after the dam is filled with water until it is demonstrated beyond doubt that it is entirely tight.

A dam built in this way to raise the present level of Honeoye Lake by 30 feet, will contain not more than 700,000 cubic yards, and with breaking down the steep banks and puddling the total required earth work will not exceed 900,000 cubic yards. This is a very small dam to hold so much water.

Spillway

With a lake as large as that proposed, any flood that needs to be provided for can be absorbed in the lake by a temporary rise in water level, and this can be done without a burdensome increase in free-board at the dam. A flood that raised the water 10 feet at the dam would amount to 27 billion gallons, equal to a runoff from the entire catchment area of more than 8 inches.

The works required for the spillway will therefore be outlets of sufficient capacity to lower the lake level at a reasonable rate after such floods.

It is proposed to build a very substantial masonry conduit cut deep in the right bank of the stream, containing one passage for water to be drawn for use, and another for water to be wasted after flood flows. A third conduit will probably be added for the accommodation and relocation of the present pipe lines from Hemlock Lake to the city.

The water to be wasted will be taken in by a circular morning glory spillway built on a very large block of concrete, so that in case of possible settlement, all will settle together without damage. At the discharge end it is proposed to take the water through a hydraulic jump or other velocity reducing apparatus before returning it to the stream. A capacity of 5,000 cubic feet per second is proposed, which, running at the maximum rate, would remove the above mentioned flood quantity in eight or nine days, or otherwise would continuously discharge runoff equal to about one inch per day from the entire catchment area.

Reservoir

The reservoir to be formed by this dam will have an area of 12.5 square miles, being 15 miles long and averaging $\frac{3}{4}$ of a mile wide. The average depth of water, not including the water now in Honeoye Lake, which cannot be drawn, will be 26 feet, and the capacity 68 billion gallons, of which 45 billions are in the upper 20 feet, and considered available.

To determine the area and capacity of the reservoir at various elevations, surveys that had previously been made at different times by the Engineering Department of the City of Rochester were found and combined, and to them was added such new topographical work as necessary to fill in the gaps and make possible a map of the entire reservoir site, sufficiently accurate for this purpose.

The areas and capacities shown in the following table have been calculated from this map:

TABLE No. 4—AREA AND CAPACITY OF
PROPOSED RESERVOIR

ELEVATION		Area in square miles	Capacity in billions of gallons excluding	Average
Above Sea Level	Rochester w. w. datum		water now in Honeoye Lake which cannot be drawn	depth in feet
785	277	0.7	0.4	3
790	282	1.4	1.5	5
795	287	2.3	3.4	7
800 (a)	292	3.3—6.6	6.3	8
805	297	8.0	13.9	9
810	302	9.0	22.8	12
815	307	10.1	32.8	15
820	312	11.0	43.8	19
825	317	11.5	55.5	23
830 (b)	322	12.5	68.0	26
835	327	13.7	81.7	29
840 (c)	332	14.7	96.5	33

(a) Present level of Honeoye Lake.

(b) Proposed flow line of reservoir.

(c) Proposed extreme possible flood height.

Bil. Gals.

The proposed range to be used for water supply, 810-830, holds.....	45.2
Add storage in Hemlock and Canadice Lakes when present proposed arrangements are complete.....	11.5
Total net storage in proposed system.....	56.7

This amounts to more than one year runoff from the tributary of 187 (or 219) square miles.

In appearance the upper 11 miles of the new reservoir, ranging in width from three-quarters of a mile to a mile and a half, will be similar to the natural lakes in this neighborhood. The sides will be nearly straight and the hills will rise abruptly to a great height from the water. For a mile above the proposed dam the valley is narrow and the width of the reservoir will be only one-fourth of a mile. For three miles intervening, beginning about one mile above the dam, the reservoir lies in sandhill country which has been much eroded by

small tributaries of Honeoye Creek, and in this distance the sides are less abrupt and there will be a dozen bays, some of them a mile long, with narrow peninsulas between. This is spoken of as sand-hill country, but in reality there is clay mixed with the sand. The peninsulas, of course, would all be owned by the city, and, as far as they are not now wooded, should have a forest planting.

Except in the sandhill country, the banks of the reservoir would be everywhere steep and free from shallow flowage.

The large swampy area above Honeoye Lake would be covered to a depth of slightly less than 30 feet of water and the larger swamp area extending for about three miles below Honeoye Lake would be covered by little more than 30 feet.

Roads

The state road at Honeoye Village is to be carried across the lake on an embankment extending well above high water, which will divide the lake into two parts. The next state road to the northward, passing through Lima and West Bloomfield, is a mile and a half below the dam.

Between these two state roads there are two present road crossings of Honeoye Creek that will be submerged and abandoned. North and south crossroads must be built, both east and west of the lake, using in large part existing roads and making connections with the State roads at both ends and, between, connecting with all the country roads that will need to be retained for service after work is complete.

At the southern end of the lake relatively small relocations of existing roads will result in a marginal road. No important change in the present road system is here involved.

Land

A large amount of land will be required. This should be bought liberally to the end that the city may completely control its source of water supply, and hold it free from centers of population that will tend to impair its quality.

The land to be submerged is mainly the bottom of the old lake valley which is now swamp land, uninhabited, undrained, more or less covered with forest, and not of great agricultural value. All the land to be flooded must, of course, be secured at the outset either by purchase or by eminent domain, and also a certain margin of minimum width around the lake. In addition to this, and somewhat optional, it is our recommendation that the city buy, as far as it can at fair prices, large areas of land to protect the quality of the water. In

some cases, buying farms that would be left inconveniently situated with respect to roads will remove the necessity for building roads leading to them. The land to be submerged must all be secured before the dam is built, but acquiring other areas may extend over a long series of years.

We believe that the marginal areas bought and held should be much wider than have been taken in the past, to the end that the great new lake to be now formed may be completely protected in its sanitary quality for water supply for all time.

Camps on Honeoye Lake

Honeoye Lake has not been used for camps to as great an extent as Conesus Lake, but, in the last years, there has been a rapid development and nearly two hundred camps, most of them small and inexpensive, must be bought and removed, and all unoccupied lake front lots acquired.

Villages Submerged

The very small village of Richmond Mills will be submerged and must be taken and destroyed. Honeoye is a larger village, having 424 inhabitants. About half the village would be submerged and the rest of it would be left so close to the water that it would be more satisfactory to buy and remove it. There may be some exceptions to occasional houses in the higher part of the Village, but practically, we may assume the complete removal of this village.

Cemeteries Near Reservoir

There is a large cemetery in the southern limits of Honeoye Village with about 750 graves and another cemetery a mile or more north-west of Honeoye Village with 242 graves, and five other small cemeteries with a combined total of about 200 graves at various places in the neighborhood of the proposed reservoir.

On present information all of these cemeteries are entirely above the proposed flow line and need not be disturbed. Their presence will not impair the quality of the water, but for future use it would be better to use other cemeteries farther away from the proposed flow line.

Submerging Old Pipes

Four or five miles of present pipe lines leading from Hemlock Lake to Rochester would be submerged by the proposed reservoir. It is our thought that these pipe lines should be looked over critically before filling and any defects repaired.

It will not do to build a heavy dam over the present pipes where they cross the site, for they would then be crushed and broken. Provision must be made for rebuilding them in a new location where they will be safe. With this done, the pipes will continue to operate as at present after the reservoir is filled. This will permit Hemlock Lake water to be drawn directly to the city without mixing with the water in the new reservoir. This is important for in this way the superior quality of Hemlock water as compared with the water in a newly filled reservoir will be made available to the extent of its quantity at all times.

There is every reason to think that the pipes submerged in this way will continue to be serviceable for many years. If they develop defects and leaks, the water will pass to the new reservoir and will not be lost.

Ultimately all the water can be drawn from the new reservoir and no harm will result if the present pipes cease to be serviceable after a term of years.

If it should be thought that it would always be desirable to maintain this direct service from Hemlock, a new pipe line could be laid along the left shore of the reservoir to replace the submerged portions of the present pipes and connected with the remaining portions at both ends, and this could be done at any future time when it became desirable. At present, there is no reason to think that it would ever be needed.

The present pipe lines would continue to be used below the new reservoir as long as they were fit for service. The new reservoir is very near the hydraulic grade line from Hemlock Lake to the city, or to Rush Reservoir, and cutting off the upper ends of these pipes and substituting the new reservoir as the source of supply at some future time would only result in a comparatively small reduction in carrying capacity.

Ganargua Creek Catchment

At some future time an additional area of 32 square miles of excellent high catchment may be diverted to the proposed system. The stream is "Mud Creek," one of the head waters of Ganargua Creek, a tributary of the Oswego River. A small dam three-quarters of a mile above South Bloomfield would hold the water back over a large flat meadow. There is a chance to build a large reservoir, but it would be better to divert the flow to the proposed Honeoye Reservoir where all needed storage can be secured. A tunnel five miles long, with an

available fall of 33 feet, would carry the water to Honeoye Reservoir, reaching it about a mile south of Allen's Hill. A tunnel 6 feet in diameter on this slope will carry 100 mgd and will be large enough. The dam need be only high enough to hold back flood flows for a few days, or at most, weeks, until the water has time to pass through the tunnel running at capacity.

The purchase of a few farms would secure enough land to control this additional source of supply and hold it until needed.

Elevation and Distance

It is 27 miles from Hemlock Lake, or rather from the outlet structure at Whitebridge Overflow where the pipes start, to Cobb's Hill Reservoir, and the head available, with Hemlock full, is 269 feet, or 10 feet per mile. This ample slope permits smaller pipes than would be needed in flatter country. The outlet of the proposed Honeoye Reservoir is on the pipe line route from Hemlock Lake to Rochester, and the present pipe lines go directly through the proposed dam site.

The new Honeoye Reservoir is 9 miles, or one-third of the distance toward Rochester, and the pipe line distance will be only 18 miles or two-thirds of that from Hemlock Lake. With the reservoir full, the proposed elevation is 194 feet above Cobb's Hill, equal to 10.8 feet per mile. The slope per mile is a little more than from Hemlock, and it is ample for economical pipe construction.

Quality of Water

Water from Hemlock and Canadice Lakes will be delivered as at present, to the limit of the capacity of the source and of the present pipes. For some years, most of the required supply will come from them. Additional water will be taken from the new reservoir as needed.

The water entering the proposed reservoir will be in every respect equal to the water entering Hemlock and Canadice Lakes, and it may be expected that after some years of service the water to be drawn from it will equal in quality that of the present supply.

But it must be recognized that in the early years of use of a new reservoir, the water drawn from it will have unpleasant tastes and odors at times, due to organic growths supported in part by the organic matter of the soil of the flooded area. These will decrease rapidly in the first years and then more gradually, but such growths and tastes and odors as are now found in the present Rochester water supply will persist indefinitely.

In addition, some turbidity must be expected because of the steep banks of clayey material in the lower part of the reservoir that will sometimes be washed by wave action and make the water turbid; and it may stay turbid for weeks after being stirred up in this way.

The water may be cleaned of tastes, odors and turbidity by filtration, if it is desired. A site for filters has been surveyed. It is conveniently situated with reference to present and proposed pipe lines. On it a plant may be built to filter all of the water both present and additional. Or, if desired, the water from the new reservoir may be filtered by smaller works, and Hemlock and Canadice water continued without filtering.

Looking at the matter broadly, the water to be expected from this system will be of as high quality as could be obtained from any possible source for the supply of Rochester. It will be softer than Lake Ontario water. Hemlock water is two-thirds as hard as Ontario. The new supply may vary somewhat from Hemlock and it cannot be told in advance just what it will turn out to be. At present the hardness of Hemlock is the best indication of what may be expected.

Quantity of Water to be Obtained

The capacity of Hemlock and Canadice Lakes at the beginning of this investigation was 26 mgd. This is being increased by works under way, to 31 mgd. With Honeoye Reservoir built as proposed, the safe capacity of the combined system is estimated at 85 mgd, sufficient to last as the assumed rate of growth for the entire city, including the area in and outside the city now supplied by the Water Company, until 1957.

The addition of the headwaters of Ganargua Creek above South Bloomfield would add a further 15 mgd, bringing the total to 100 mgd.

It is to be noted that these streams have not been gauged, but we have intended to make conservative estimates, based upon the thought that the runoff from the additional areas may be somewhat less than from the present ones.

TABLE No. 5—SCHEDULE OF RUNOFF ESTIMATES

	<i>Present sources</i>	<i>Present sources and Honeoye Reser. added</i>	<i>Present sources, Honeoye Reser. and Ganargua Creek added</i>
Total catchment area, square miles	65	187	219
Of this water	4	16	16
Estimated mean flow, mgd. .	37	92	111
Estimated safe net yield, mgd.	30	85	100
Storage in billion gallons . . .	11.5	56.7	56.7
Runoff in inches	11.9	10.4	10.6
Storage ratio, gross	0.85	1.69	1.39
Percentage runoff assumed available	81	92	90

Filters

We regard getting a proper and fully adequate source of supply as of primary importance to Rochester, and the question as to whether or not it is to be filtered is secondary.

We do not propose to discuss the advantages of filters, but merely to point out that there is an adequate site for the construction of filters for the entire proposed supply including the present supply, located so that water will flow to them from present and proposed reservoirs by gravity and, in turn, from the filters to the present service reservoirs through existing pipe lines which pass close to the proposed filter site, and also through additional pipe lines laid in future as they may be required.

As an early procedure, the city may continue to use the water of Hemlock and Canadice Lakes in the manner described above, without mixing with the additional water and without being filtered. It can use more of it than the rated capacity of the source because most of the mean flow of 37 mgd can be used in this way in all years but the driest ones. All the water from Hemlock that the pipes would carry, and they will carry nearly all of it, could be used in maintaining service. The amount of make-up water from the new reservoir used to meet peak loads and carry the services through droughts in the early years would be relatively small.

Under these conditions it may be that using the water of the new reservoir with heavy chlorination and depending simply on dilution with Hemlock water would produce results that would be reasonably

satisfactory. Later on, the water in the new reservoir will clear and without filtration will approximate Hemlock water in quality. The proportion of water from the new reservoir in the mix and the frequency of the times when it was needed would increase as the years go by. But at any time when the conditions made it desirable, the filters could be added.

With this in view and to avoid the contingency of the land now available for filters being bought and put to some other use, which would stand in the way of constructing filters, it is our recommendation that the filter site be bought as one of the essential parts of the original site.

TABLE No. 6—ESTIMATED COST OF GRAVITY SUPPLY

Estimate of Cost

The estimated cost for the proposed Honeoye Reservoir, with land and rights, is as follows:

Land and water rights, including village property, camps about Honeoye Lake, the land to be submerged, filter site, right-of-way and a large area of farm land surrounding the reservoir.	\$ 4,050,000
Dam and spillway construction, complete.	1,375,000
Clearing reservoir, 9 sq. miles @ \$40 per acre.	230,000
Roads, including one State road crossing, and 16 miles more or less of other roads.	1,300,000
Houses for keepers, fences and miscellaneous small structures.	130,000
	<hr/>
SUM.	\$ 7,085,000
Add for engineering administration and overlooked items, 20%	1,417,000
	<hr/>
TOTAL for Reservoir.	\$ 8,502,000

The cost of the whole project, and of a first installment for early construction, are estimated as follows:

	<i>Total</i>	<i>First Installment</i>
Proposed reservoir, complete as per above schedule, including 20% overhead.	\$ 8,502,000	\$ 8,502,000
Add for diversion of Ganaragua Creek, complete.	3,000,000	100,000
Filter plant for all additional water, including 20% overhead.	4,800,000	
Pipes, two lines of 60" steel pipe from the new reservoir to the filters and thence to the city, 18½ miles @ \$28, including 20%.	6,600,000	3,300,000
	<hr/>	<hr/>
TOTAL estimate.	\$22,902,000	\$11,902,000

The estimate of annual cost is as follows:

	<i>Total</i>	<i>First Installment</i>
Interest, 4¼ %	\$ 970,000	\$505,000
Depreciation or sinking fund, 1 %	229,000	123,000
Operation of filters, \$5 per million gallons @ 70 mgd	128,000	
Care of catchment area and upkeep, addi- tional	51,000	17,000
Total annual cost	\$1,378,000	\$645,000
Cost per million gallons	\$54	\$77
Maximum or normal capacity in mgd . . .	100	33
Suitable for average output and to meet the peak loads in connection with an average output of	70	35
Capacity of whole combined system, in- cluding present works. Good for aver- age annual rate	100	66

If the water of the first installment should be filtered, there would be an additional cost of \$16 per million gallons of the delivered water.

It is to be noted that the \$77 per million gallons stated above for the first installment for this supply is computed on an average daily output of 23 mgd, this figure being selected to make an exact comparison with the Lake Ontario estimate. As a matter of fact, the capacity of the proposed system to this point is limited only by the capacity of the pipe line; and the size shown in the estimate is good for an average use of 35 mgd, in addition to the capacity of the present works or to a total of 66 mgd. There would therefore be but little additional cost for a greater quantity of water within this limit, and the cost per million gallons would become less as the quantity increased.

Covering Distributing Reservoirs

Distributing reservoirs used for holding filtered water are best covered. It may be taken for granted that the present Rochester distributing reservoirs at Cobb's Hill and in Highland Park will ultimately be covered.

Introducing a new water supply as proposed either from Lake Ontario or from Honeoye Creek can be carried out in such a way that

the water stored in these reservoirs will continue to be, for the most part, as at present, unfiltered water from the present sources. The new filtered water can be taken into the pipes and used to meet the needs of the moment.

The reservoirs are so situated and connected that it will be possible to divide and cover them when the time comes while maintaining service.

Covering these reservoirs is recognized as a probable future expenditure in connection with the development of a water supply. The situation does not call for carrying it out at once or during the period of heaviest load from the capital charges growing out of the construction of the proposed new works. In other words, this work may be prudently postponed for some years and it is therefore not brought into the present schedule of estimates.

Remote Future

It may be asked what will be done for water supply when the consumption exceeds 100 mgd, or 3 times the amount supplied by both the City Works and the Rochester and Lake Ontario Water Company.

This relates to a future so distant that only a most general consideration can be given.

One possibility would be to secure additional water from the Genesee River above Portage with a catchment area of 950 square miles, taking it by tunnel to Hemlock Lake from which it would flow to Honeoye Lake, and, after storage, to the City. The required tunnel would be about 25 miles long. Either a pressure tunnel or steel pipes would be used for about two miles under the Canaseraga Valley where the present ground is lower than the proposed water level. There is ample fall, some 200 feet, so that a moderate sized tunnel would carry a large quantity of flood water. Full storage would be required and the storage in Honeoye Lake could be increased by raising the dam above the level now proposed if it were then necessary.

Another possibility would be to take water from Keuka Lake. This would require a tunnel only about 20 miles long, but pumping would be required. The catchment area of Keuka Lake is 178 square miles.

Some of the upper water of Chemung River, a tributary of the Susquehanna, as for example, some 292 square miles above Bath, are within feasible tunnel distance and at ample elevation, so that there will be a choice among several sources when the time comes.

FINANCIAL CONDITION OF THE WORKS

The next question is to consider whether the works are in a position to carry the charges on the added investment. A few figures taken from the Auditor's report are shown in tabular form below:

TABLE No. 7—FINANCIAL CONDITION OF ROCHESTER WATER WORKS

COMPTROLLER'S REPORT FOR 1925

(1) Capital (p. 13)	
Cost of entire system to date	\$14,781,275
Depreciation reserve	4,724,422
	<hr/>
Net value	\$10,056,853
Bonded debt	\$11,269,000
Sinking fund	2,684,902
Net debt	<hr/> 8,584,098
	<hr/>
City's equity in present works (book)	\$ 1,472,755
Actual value and equity on a fair valuation would prove probably much greater	
(2) Operating for 1925 (p. 59)	
Water rents	\$ 1,163,072
Water used by city buildings, etc.	185,839
Frontage tax	15,641
Sale of Meters, etc.	37,535
Penalties, etc.	18,968
	<hr/>
Total water revenue(— \$4.42 per capita)	
(— \$144 per mg output)	\$ 1,421,055
Expenses (p. 68)	
Personal Service	\$337,723
Other Service	27,422
Materials and supplies	162,695
Rent, Insurance, Contributions	24,645
Taxes	44,899
Pensions	12,505
Rights, obligations	335
Equipment	653
	<hr/>

Total Expenses	610,877
Net operating revenue	810,178
Interest on bonds (average 4.09%)	461,593
Sinking Fund (average 1.83%)	206,060
Payment on bonds \$2,500 is not included.	
Surplus after charges (excluding construction)	142,585

The income shows fair but not excessive rates both per capita and for the volume of output. The actual value of the plant if it could be determined by an appraisal would, no doubt, amount to much more than the \$10,000,000 at which it is carried. This is only about \$30 per capita. Fifty or sixty dollars per capita would come nearer to representing the value of a gravity system of the kind found in Rochester.

The bonds outstanding were mostly issued long ago and for long terms and at low rates of interest, ranging from 3½% to 5% and averaging 4% for those now outstanding. They fall due from 1927 to 1955. Some cities have paid off bonds more rapidly, but in this case, if the payment for interest and sinking fund or principal amounting in 1925 to \$670,153 were continued at the present rate for 18 years, on a 4% basis, it would pay the interest and liquidate the principal. The present rate of payment is therefore fully adequate and required future payments will be rapidly reduced with a reduction of the remaining outstanding bonds.

The surplus of 1925 is sufficient to pay interest on more than \$3,000,000 of new construction. This surplus will increase with the natural increase in the business, and also with the payment of existing bonds and reduction of interest, but not fast enough to meet the needs.

The exigencies of the situation require that the construction program of new works be carried forward rapidly. We have not attempted to work the matter out in detail, but a moderate increase in present water rates will apparently be necessary under these conditions.

After some years when the present outstanding bonds have been paid off, as they will be by continuing present arrangements, a return to the present rate level may be possible.

COMPARISON OF TWO PROJECTS

It will be seen from that which has gone before, that the only two projects that need to be further considered at this time are:

1. A supply pumped from Lake Ontario.

2. A gravity supply from a great new reservoir on Honeoye Creek.

The estimates that have been set up for these two sources may now be compared. Two comparisons may be made. One for conditions of early years with a first installment only of those parts that can be divided and the other for the ultimate proposed plant.

TABLE No. 8—COMPARATIVE COSTS

	<i>Lake Ontario</i>	<i>Gravity supply Honeoye Reser.</i>
<i>First Installment</i>		
First installment for early construction, including land, reservoirs and lake intake of full capacity. No filters on gravity supply. Suitable to maintain service until average output is 54 mgd to be anticipated in 1940.	\$ 8,375,000	\$11,900,000
Total annual cost, including interest and 1 % depreciation.	700,000	645,000
Cost per mg additional water, 23 mgd. . .	83	77
<i>Entire Plant</i>		
Cost of entire plant to maintain service until average annual output reaches 100 mgd; all water filtered; to be anticipated in 1962.	17,700,000	22,900,000
Total annual cost, including interest and 1 % depreciation.	1,709,000	1,378,000
Cost per mg additional water, 70 mgd. . .	67	54

In the comparison of the first installments, Lake Ontario water, with filtration, is compared with an unfiltered gravity supply from a new reservoir, it being assumed in both cases that Hemlock Lake water would continue to be used without filtration.

In first cost, the gravity supply will be considerably more expensive, 42 % more for the first installment, and 30 % more for the complete plant on the basis of these estimates.

In operating expenses, the gravity plant would be much less costly. The only expenses are for the care of the catchment area, and are almost nominal. Contrasted with this the cost of filtering and pumping water from Lake Ontario for the first installment would amount to more than a quarter of a million dollars per annum. The

saving in operating expenses on the gravity supply will more than make up for the increased capital charges.

If it should be decided that the water from Honeoye Reservoir is to be filtered at the start, there might be temporary exception to the above statement during a few early years when filtered gravity water would cost as much or a little more than filtered Ontario water.

The operating expenses with Lake Ontario water will increase in direct proportion to the quantity; and the farther the comparison is carried into the future the larger the annual differences become and the more favorable does the gravity supply appear from a financial standpoint.

For the last stage shown in this estimate, with a total output of about 100 million gallons per day, the entire charges including both operating expenses and capital charges will be decidedly less for the gravity supply.

The Lake Ontario project has the advantage of deriving its supply from an inexhaustible source. It has the disadvantage that pollution of Lake Ontario will tend to increase in the future. The water from the Honeoye development will probably be somewhat softer than that from Lake Ontario.

In the case of the Lake Ontario project, all of the water will be pumped against relatively high heads, whereas the Honeoye supply will be delivered by gravity. Consequently, the hazard of interrupted service is somewhat greater in the case of the Lake Ontario project because of possibilities of failure in power, failure of pumping machinery and other interruptions incidental to pumped supplies.

Recommendation

Taking all the conditions into consideration, we recommend that the City adopt the development of a gravity supply on Honeoye Creek substantially as outlined in this report.

Respectfully submitted,

HARRISON P. EDDY
ALLEN HAZEN
EDWIN A. FISHER

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This report is accompanied by two plans, namely:	
Possible Supply from Honeoye Creek, dated 1, 25, 27.	
Possible Supply from Lake Ontario, dated 1, 13, 27.	