REPORT
ON A
WATER SUPPLY
FOR THE
TOWN OF ST. CATHARINES,
BY
THOMAS MONRO,
CIVIL ENGINEER.

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Thorold, 10th June, 1875.

Lucius S. Oille, Esq., M.D., Chairman Water Committee, St. Catharines:

Sir,—I beg to acknowledge receipt of your letter of the 9th April, requesting me to report on the subject of a water supply for the town of St. Catharines, and to submit plans and estimates for the same.

Such measurements and levels as were necessary to enable me to explain my views on this matter having been recently completed, I have now the honor to present the following report.

I may, however, premise that it was understood the committee did not entertain the idea of pumping from Lake Ontario, in view of the expense which it was believed would attend both the construction and maintenance of the necessary works; and my examinations have therefore, been chiefly directed to any feasible scheme of gravitation supply which presented itself.

Having been informed that plans were some years ago prepared and estimates made by Mr. Lesage, of Montreal, of a proposed plan of supply from the existing canal at Thorold, I requested and obtained permission to have access to these documents, inasmuch as it was evident that the merits of his scheme should be compared with those of any other, in order that a fair and satisfactory conclusion might be arrived at.

To enable these matters to be understood, it will be necessary to briefly describe the physical features of St. Catharines and its vicinity.

The town is principally built upon the right bank of the Twelve Mile Creek, which traverses at this place the plain lying between the foot of the Niagara escarpment and Lake Ontario.

The stream rises among the “Short Hills,” in Pelham Township, and in a course of about fifteen miles to Port Dalhousie, drains, together with its tributaries, a large area of country.

The higher branches have an elevation of over 350 feet above the lake; and two of the eastern ones flow from the level of the upper plateau over the edge of the escarpment, forming several rocky falls between these points and their junction with the main valley of the stream.

On reference to the accompanying topographical map it will be seen that the general line of the Niagara escarpment runs about parallel to the shore of Lake Ontario, and from six to seven miles distant from it. It will also be observed that the town of St. Catharines is about four miles from the lake, and at a general elevation of 120 feet above its ordinary surface level, or from 200 to 220 feet below the level of the upper plateau.

Two breaks in the escarpment occur in this vicinity—one to the east down which the Ten Mile Creek flows; and which has been utilized in the location of the new canal. The other, and much more marked indentation, forms the valley of the Twelve Mile Creek, above referred to.

It will thus be evident that if the Welland Canal were not in existence, attention would naturally be directed to either of these creeks or their branches, as a possible source of a gravitation supply for the town.
Before, however, discussing any plan arising from such investigation, it may be well to offer some remarks upon two points which are of vital importance in any scheme for water supply.

First—The sources should be as pure as possible.

In this respect there is a manifest objection to taking water from a navigable channel, fed from such sources as the Welland Canal, if any other practicable means can be resorted to.

On this point I entirely agree with Mr. Lesage, who, in his report, (page 14) makes the following remarks in reference to taking water from the canal:

"In the absence of any proper analysis, I cannot give any opinion as to its fitness for drinking purposes; and were it not for the reason that it is the only water available at an expenditure commensurate with the means of your population, and also for the assurance given me that it will be principally required for the extinction of fires, sprinkling of streets, washing, or any other object but drinking purposes, I would have hesitated to recommend the present project."

It will be observed, however, that the plans and estimates submitted by him are based upon a full allowance per capita per diem, such as has been usually calculated for towns supplied with water for all purposes. In other words, the people of St. Catharines would have to pay for what they confessedly could not get from the source proposed, that is, good wholesome water to drink.

There is also a particular objection to drawing from immediately above the guard gates at Thorold, inasmuch as during the season of navigation large numbers of vessels are often detained there, awaiting their turn to descend the adjacent locks, and consequently a considerable amount of pollution would occur at that point.

The water would also be very much disturbed by tugs, which are almost always in motion there when the canal is open.

Second—The works should be so arranged as to afford the full quantity required with the least probability of the supply being interrupted even for a part only of one day.

On this point Mr. Lesage observes that "the source from where this water is proposed to be taken is from the Welland Canal, at the guard lock at Thorold, which is proved to be abundant, and always constant, as I am informed the water is never drawn out of that section of the canal."

It is, of course, well understood here that canals like the Welland require to be periodically emptied for repairs, and it is therefore clear that the reservoir capacity of any scheme which depended upon it as a source should be equal to supply the wants of the town for the longest known or probable period of interruption.

Thus, for example, the water was drawn off the reach above the guard-gates on the 8th April, and navigation opened only on the 3rd of May. Mr. Lesage's estimate for ordinary consumption is for 24,000 inhabitants at 60 gallons per head per diem; and for fire service at the rate of 1,152,000 gallons per 24 hours; in all, 2,592,000 per diem.

The reservoir which he proposes is stated to be capable of holding 6,550,000 gallons. Thus, supposing that during the time the supply was cut off, as above shown, a large fire should occur, this quantity would,
according to the estimate, be barely sufficient to afford say four days supply for the town, leaving the inhabitants totally destitute of water from this source for nearly three weeks.

It may be said that this can be remedied by increasing the size of the reservoir to the required capacity. A basin to hold 40,000,000 of gallons, with a depth of 20 feet, would cover 12 or 13 acres of ground, and in order to obtain the proper head, would have to be located in the town of Thorold.

To form some idea of the probable cost of this, it may be stated that the Toronto reservoir, which when full holds 33,473,600 gallons, will cost about $63,000 all complete, and is truly said to be a remarkably cheap construction. I have been informed that the lots covered by the site of the small reservoir in Thorold, proposed for St. Catharines, would cost about $9,600, so that even if the ground could be obtained for one of large dimensions, the outlay for land purchase would be so great as to render this part of the project, on economical considerations alone, very objectionable. Even if permission were granted to draw water from above the guard-gates at Thorold, there would be considerable difficulty in laying over half a mile of conduit through the town, as the streets would have to be torn up, and doubtless large claims for damages would arise on that account.

But it is also by no means improbable that, in carrying out the extensive changes consequent upon the construction of the enlarged canal, it may be found necessary to shut off the water for a much longer period than heretofore; in fact for such a length of time as would prove a fatal objection to any scheme which relied upon drawing water from the Welland canal alone.

Being impressed with the objections above briefly stated, and familiar with the topographical features of this locality, it occurred to me that if the waters of the Twelve Mile Creek, or any of its branches, could be rendered available under sufficient head, a feasible and economical gravitation scheme might be matured.

With this in view, examinations were made of the elevations of both the main stream and its branches.

It soon became apparent that in order to locate a reservoir on the former at such a height as would give the required pressure for all purposes, it would be necessary to ascend to a point considerably south of the village of St. Johns, or about nine miles distant from St. Catharines. This would involve such a length of main as to prove a serious objection to the plan, and therefore the branches discharging from the east were considered.

After considerable investigation, it seemed clear that if the drainage area of the stream called the Beaver Dams Creek would yield the required supply, it would necessitate the shortest main to conduct water from the proper height, which could be laid in the locality; whilst the shape of the valley, height of the banks, etc., appeared favorable for the construction of the necessary works.

This stream has three branches, which pass under the present canal at Marlatt's, Higgins' and Davis's culverts.
Its catchment basin has been approximately estimated at 7,500 acres.

The soil of the country drained is heavy clay, overlying limestone rock, and is almost entirely cleared land, applied solely to agricultural purposes.

The farms are for the most part large—the houses scattered; and the rainfall is, owing to the steepness of the side slopes, quickly thrown into the stream and its tributaries, there being no swamps, and but little bush or fallen timber to retain it, and therefore not much chance of its being contaminated by decaying vegetable matter.

As a consequence of the rapidity of the discharge, it is probable that a much more than ordinary proportion of the rainfall finds its way into the natural channels of outlet in good condition; but in passing quickly over clay soils the water is quite muddy during freshets.

When neither time nor opportunity has been afforded to properly gauge the flow of streams, the water of which it is proposed to store for the use of towns, it is usual to resort to calculations based upon their drainage areas, and the amount of rainfall, in order to ascertain the quantity which they may be safely depended upon to yield.

In this case the estimate is based on a minimum derived from the statistics of rain and snowfall, taken from the most reliable sources; although the information already obtained from some rough measurements places it, in my opinion, beyond a doubt that the creek in question is amply sufficient to give the required supply.

The proportion of the total precipitation which can be made available, varies, of course, very largely, and is dependent upon the shape of the ground, the nature of the soils, and other causes.

In Europe the subject has been minutely investigated, as many of the principal towns are supplied by collecting the rainfall. Mr. Hughes, in his valuable treatise on Water Works, states that an average, based upon a large number of cases in England, shows that 62$$\frac{1}{4}$$ per cent of the whole precipitation passed off in streams.

In the annual report of the Cochituate Water Board, for 1871, the average available portion of the rainfall for 17 years which was received into the lake was 46 per cent. This lake drains 11,400 acres, and is said to afford a daily supply of ten millions of gallons to the city of Boston.

At Rochester, which is on a continuation of the “ridge,” the annual rainfall for the past 22 years was found to average 32.2 inches yearly. The chief engineer of the works (which are now in course of construction) estimates the average yield of the 27,554 acres drained by Hemlock Lake, from which the gravitation supply will be derived, at 30,000,000 gallons per day.

The minimum yield of the basin supplying the city of Brooklyn is stated by Mr. Kirkwood at 0.77 cubic feet per second per thousand acres; and at Rochester this standard has been applied to the drainage area of Hemlock Lake, showing 12,000,000 gallons per day as the probable yield during the driest months.

In the report of the Board of Water Commissioners for Hartford, Ct., for the year ending 1st March, 1875, it is proposed to extend the gravita-
tion works by which that city is supplied. The water shed of the new reservoir to be built for that purpose was found to be 3,616 acres, and the estimated yield 5,494,609 U. S. gallons per day, which, it is stated, is a larger amount than the city, with over 40,000 inhabitants, ever used in any one day.

It will be observed that the drainage area of the Beaver Dams Creek is more than double that of the proposed reservoir at Hartford.

Taking the statistics of rainfall as observed at Toronto, it appears that the average total precipitation for 33 years was 35.956 inches. The rainfall, composing a part of this varied from 43.555 in 1853, to 18.588 inches in 1872.

In 1872, the year of least precipitation, the rainfall was as above stated, 18.558 inches, and the snowfall reduced to rain, 6.750 inches; or together 25.338 inches nearly. The average monthly rain and snowfall for 33 years is as follows:

<table>
<thead>
<tr>
<th>Month</th>
<th>Rainfall</th>
</tr>
</thead>
<tbody>
<tr>
<td>January</td>
<td>2.912</td>
</tr>
<tr>
<td>February</td>
<td>2.714</td>
</tr>
<tr>
<td>March</td>
<td>2.871</td>
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<tr>
<td>April</td>
<td>2.718</td>
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<tr>
<td>May</td>
<td>3.190</td>
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<tr>
<td>June</td>
<td>2.915</td>
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<tr>
<td>July</td>
<td>3.181</td>
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<tr>
<td>August</td>
<td>2.969</td>
</tr>
<tr>
<td>September</td>
<td>3.659</td>
</tr>
<tr>
<td>October</td>
<td>2.491</td>
</tr>
<tr>
<td>November</td>
<td>3.232</td>
</tr>
<tr>
<td>December</td>
<td>3.104</td>
</tr>
</tbody>
</table>

35.956

It will be seen from the above that the average amount of rainfall is very equitable in the vicinity of Toronto, as during the five warmest months of the year about 44 per cent of the whole was observed. Suppose, however, we take the year of least precipitation, namely 1872, and reckoning only 45 per cent of the 25.338 inches as having passed off in the Beaver Dams Creek, the matter would be as follows:

Drainage area 7,500 acres. 7.500 x 43.560 x 25.338 x 0.45 x 6.25 gives 1,878,055,244 Imperial gallons, which, divided by 365 days, gives over five millions of gallons per day.

An average yield calculated on the same basis would be from seven to eight millions of gallons per day.

In short, one inch of available rainfall over the drainage area of the creek would yield 172,156,250 gallons.

From the above it is apparent that an abundant supply can be reckoned upon, even making the highest allowance for loss by leakage, evaporation, infiltration, etc.; and it is, therefore, not considered necessary to go into minute calculations on the subject; the question being simply that of the economical establishment of a large, deep pond or lake, where the rainfall may be impounded, and the sediment brought down by the stream during freshets permitted to subside, so that the
whole may become perfectly clear, whilst the depth will both preserve coolness and prevent the growth of aquatic plants in the reservoir.

To effect this object, it is proposed to throw a dam across the valley of the creek immediately above the road at De Cew's Falls, and in the position shown upon the accompanying plan No. 2.

This will set the water back for about a mile, and create a pond or lake nearly 60 acres in extent, the general depth of which will be from 15 to 20 feet.

The available head which it is intended to use will, however, be only from 10 to 12 feet, representing say 165 millions of gallons, or a three months supply for 50,000 to 40,000 people.

The banks of the creek approach each other closely at the site of the proposed dam, and the material forming them is excellent clay, suitable for the construction of water-tight works.

The foundations of the valve-house will be upon rock, which forms the bed of the creek, and material can be had on the spot for covering the front slope of the dam with macadamized stone six inches in depth, as shown on the sketch, as well as for certain other portions of the work. It is intended to lay a light wrought iron pipe from the valve house through the lower part of the pond, to the dividing dam where shown. This will enable the supply for the mill to be drawn from the upper portion during freshets, thus preserving the clear water of the lower portion for the town supply. By an arrangement of gates, valves and pipes, the lower reservoir can be drawn down, if necessary, to make repairs, whilst the supply is taken from above the dividing dam. This dam would also serve as a guard in case of accident to the lower one; but there is little chance of a break or bad leak occurring, if the works are faithfully carried out as represented.

About 1,800 feet above the site for the lower dam, in the left bank, is a depression, which seems at one time to have been the bed of a branch of the creek. When the water of the pond is raised as proposed, it would flow through this, and discharge into the Twelve Mile Creek, as shown on the plan.

This dry ravine can be utilized for passing off the surplus water during heavy freshets, by placing a regulating weir where marked. The lower portion of the gully, near the edge of the escarpment, being rock, would not wear away with the rapid current of the stream; and but little damage would be done to property by carrying out the plan.

The general direction of the pond above this weir, would set the current or movement towards it, and probably effect the intended object very satisfactorily.

There are two objections, however, which may be urged against the plan now proposed, by persons who have not given the subject due consideration.

In the first place, it may be said that the water supplied to the town would be muddy during freshets. Experience shows that although the waters of creeks which flow swiftly through a clay country bring down large quantities of solid matter in the spring, yet almost immediately on reaching slack water, this begins to be deposited, and is found to be a
great source of trouble and expense in the maintenance of harbors situated at the mouths of such streams. For example, at Ports Stanley, Burwell, etc., it has been found necessary to dredge frequently inside the harbors to keep the channel clear, considerable quantities of mud having been deposited there even before reaching Lake Erie.

These are, of course, extreme cases, and only serve to illustrate the principle, as the quantity of clay brought down by the Beaver Dams Creek would be very small in comparison.

The distance from the upper end of the proposed pond or reservoir to the point from which the supply would be drawn is, as before stated, about a mile; in slowly traversing which, there would be ample time, under ordinary circumstances, to render the water perfectly clear.

The dividing dam above alluded to, will, however, secure this in the lower reservoir, as during times of freshet it can be cut off from the pond above, intercommunication being resumed when these shall have subsided.

A low dam and filter bed might also be constructed across the upper end of the pond; the main portion of this dam to be formed of rough stone, which can be had in abundance in the bed of the creek itself. The up-stream side to have a flat slope covered with layers of gravel and sand, and with such a surface as to permit of all the water running through it. It is not at all likely, however, that this will be necessary, as will be shown hereafter.

Second—It may be objected that during the hot and dry months of summer the water may become stagnant, and its quality deteriorate.

It will be seen from the foregoing statement of rainfall that the average yield during the five summer months was about 44 per cent. of that for the whole year, and therefore a constant circulation will be secured by the natural flow of the stream. In cases of extreme drought, however, this would be maintained by the movement induced by drawing off the supply to the town, as well as that for the mill at De Cew's Falls.

Whilst on this part of the subject it is considered proper to quote the following remarks from a paper on the "Sources and Quality of Water," written by the Hon. W. J. McAlpine, one of the ablest hydraulic engineers in the United States.

He says that "water from wells in cities is always unfit for drinking, and in most cases very deleterious to the health. The contaminations are not the less real because they are not usually observed. The gases of dissolving matter frequently impart a sparkling life to well water, and a small mixture of earthly salts adds a flavor, and with a temperature lowered by ice, induces many to express a preference for such mixtures over more pure, but to them less palatable water.

This popular fallacy often forms one of the strongest objections to any scheme of public water supply. Investigations have been made all over the country, which show that some of the most serious diseases arise from the use of well water in cities.

In times of cholera, the progress and fatality of this disease has been traced, in a vast number of cases directly to the use of impure water from certain wells, and their analyses, compared with that of other water
in the same cities, show that this frightful disease is promoted and rendered more fatal by the use of impure well water.

Analyses of cistern water in other places have shown them also to be very impure, and, when not well ventilated, they frequently become exceedingly offensive. The cause of this offensiveness is well known. It is nature’s method of purification. The vegetable and animal matter which water has absorbed is dissolved, and all of its lighter portion thrown off in gases, which are so evident to our senses. Hence I am warranted in the assertion that stored cistern water is certainly unwholesome, and generally loathsome and unfit for use.

Water from wells is rarely found soft enough for washing, and resort is therefore had to cisterns of rain water. It has been ascertained that in the use of soap, the difference between well water and tolerably pure brook water is equal to a dollar per annum for each inhabitant, and a saving equally great will be made in the wear and tear of clothes.

It will follow from this discussion that all of the water which is obtained from wells is that which the excavation intercepts as it flows subterraneously through the soil. The quantity which any well will furnish depends merely upon the area of land which flows into it, and the porosity of the soil to receive and store it.

The waters of rapid brooks and rivers become highly charged with air, but their currents abrade the banks and bottom, and take up in suspension the alluvial matter which renders them turbid; and, in that condition, unfit for domestic use. When such water is discharged into a lake or artificial reservoir, and allowed to stand quiet, it precipitates all the heavy portions of such suspended matter, and becomes clear and limpid.

These rapid streams also gather and carry forward with them a considerable amount of vegetable matter, which is of the same or less specific gravity of the water. When these streams discharge into a lake, a warm atmosphere dissolves the latter into gases, which arise and are driven off by the winds, and a process of self purification goes on, which greatly improves the water thus stored. It is often asserted that the impurities of water may be corrected by filtering. In most of the filters in use, the operation is merely to separate such matter as is held in mechanical suspension—or when the molecules are larger than those of water; but they will not remove anything which is chemically united with it.

Turbid waters may be rendered clear by filtering, but the best one is quiescence, such as in a natural lake, or the engineer’s imagination thereof—a reservoir. The reservoir or lake also performs another important service in purification which artificial filters cannot do. When the water is kept quiet, all foreign matter, which is heavier than it, is precipitated to the bottom, and, if the water is deep enough, it is no longer subject to decomposition; and all that is lighter floats, and in warm weather is dissolved into gases, which the wind drives away, leaving the water in its most pure condition.”

It will be observed that the plan now submitted is based on general reasons similar to those quoted above.

But whilst, as stated in the first part of this report, it is not intended
to resort to the use of water from the present canal, it will be evident from what follows that should it at any time become necessary to do so, it can be supplied from the most favorable point for that purpose.

About midway between Thorold and Allanburgh, there is a weir in the west bank of the canal, which serves to regulate the water in the long reach between these places, as well as to aid in discharging its contents when the canal is emptied for repairs.

This structure is known as "Higgin's Flume," and there is now water almost constantly flowing from it into the Beaver Dam's Creek, one of the branches of which passes under the canal close to the "Flume" in question. The weir is also used in the spring to fill up the long level below Lock No. 2 by way of the Creek, without passing the water through the intermediate locks and weirs of the present canal.

It therefore appears that in operating the existing line of navigation, a considerable amount of water flows from it down the valley of the Beaver Dam's Creek, which, in case of need, might prove an important auxiliary to the plan proposed; whereas, when the water of Lake Erie is introduced, no reasonable objection could be urged on the score of impurity, against filling the reservoir with it if so desired.

During the past month, the water flowing over the crown timber of the mill dam at Decew's Falls, when the mill was in operation, averaged about 1,400 cubic feet per minute. This was measured at times when there had been no rain for several days previously.

To illustrate how easily a considerable quantity of water could be spared from the enlarged canal at the point above referred to, it may be stated that the maximum flow contemplated through its prism of 1,638 square feet area, during one minute, would suffice for the wants of the present population of St. Catharines for a day.

It is also probable that by the process of self-purification above described, the water of the present canal would be rendered much less objectionable than if taken directly from the channel, especially near a lock, but at all events it is an evident advantage to possess so valuable an alternative for the future.

When the water of Lake Erie is introduced, that passing through the enlarged canal during winter, under cover of the ice, would be quite free from pollution, and in the best possible condition to receive into the pond, should it be preferred to the softer waters of the creek; and as the canal is drawn down for repairs generally after the spring freshets have passed off, the water collected from the spring rains and melted snow, could be run out of the reservoir, and Lake Erie water substituted for it.

In short a pond of great capacity can be established at the place proposed, so that no reasonable doubt can be entertained of obtaining a plentiful supply of pure water from the rainfall, whilst as before stated, there always remains the alternative of increasing or wholly changing the volume by the introduction of the water of the canal.

But it may be said that it will be impossible to prevent the waters of the present canal from mingling with those of the catchment basin. This, can, under any circumstances, be to a great extent affected by means of the dividing dam already referred to; and besides I am credibly informed that it is not absolutely necessary to use "Higgins' flume" except at times of heavy freshets, which occur
very seldom during the season of navigation. Moreover the capacity to
pass water at Allanburgh, as compared with points below Thorold, might
now be nearly equalized by opening the sluices, which are at present
closed, in the weirs from Lock 25 downwards—and on the completion of
the new canal, the reach between Allanburgh and Thorold can be easily
regulated, and that above the entrance lock at Port Dalhousie filled,
without its being necessary to do so by way of the Beaver Dam's
Creek.

Although the government have, I am informed, the right to flow the
water down this channel, it is presumed that the wishes of the inhabi-
tants of so important a town as St. Catharines would be considered in a
matter of this kind, and the supply from the flume either shut off or let
run as may be found desirable; at least during such times as this would
not interfere with the efficient operation of the canal.

As regards the value of the land overflowed by setting the water
back to form the pond, it should not exceed from $50 to $60 per acre, as
it is used only for farm purposes, and has, I am informed, been offered
for much less price without finding a purchaser.

It would be well, however, if the committee adopt the plan now pro-
posed, that the area inscribed by the flow line marked out on the ground,
together with a margin all around of say half a chain wide, should be
provisionally agreed upon as soon as possible, contingent upon the pas-
sage of the by-law by the popular vote.

GRAVITATION MAIN.

An ample supply of pure water having, it is believed, been thus se-
cured, the next question to be considered is the size of main which
should be adopted to carry it to the town.

A leading objection usually made to gravitation systems is that the
supply being arranged for a fixed head, when the draft on the mains, by
increased consumption and waste, approximates to their capacity to de-
deliver water, no higher head to meet this can be substituted, and thus the
mains at first fail to give the requisite pressure for fire purposes, and
eventually prove too small to afford even the required quantity for do-

testic use at remote points in the distribution. It is urged that in order
to secure a proper provision for the future, it is, therefore, generally ne-
cessary to lay down much larger mains than are required for present use,
at a considerable outlay, whereas in pumping systems, additional power
can be applied when required, at a small cost.

There are, doubtless, some cases in which these statements would be
well worthy of consideration; as, for example, where a gravitation sup-
ply could only be obtained by bringing water from a long distance,
and with low pressure; when, in the same locality, power could be
readily obtained to force water through a short main with abundant
fire pressure.

As, however, it has been shown that the canal cannot afford the
supply without depending upon a reservoir of great capacity, which, in
order to have the requisite altitude must be placed near the edge of the
escarpment, the only alternative would seem to be steam pumping from
Lake Ontario.
It could scarcely, however, be seriously argued even by the warmest advocate of pumping systems, that it would be better to lift and force water from Port Dalhousie through a main of about four miles long, rather than let the supply descend by gravitation through a pipe of similar length from the level of the upper plateau.

It is certain that the erection of the works necessary to pump water from Lake Ontario would be much more expensive in first cost than those connected with the gravitation supply now proposed, while it is probable that the capital represented by the annual expenditure for elevating say from one to two millions of gallons per day, with the auxiliary power necessary for fire pressure, even if the work were performed with the cheapest machinery known, would exceed the total outlay required to carry out the plan now proposed.

The calculations prepared by Mr. Lesage as to the size of the main, are based upon what is known as Eytelwein’s formula, and are given in his report (p. 7) as follows: 12 in. pipe; length, 18,096 feet; head, 180 feet; delivery, 231 cubic feet per minute. 14 in. pipe; length, 18,096 feet; head, 180 feet; delivery, 289 cubic feet per minute.

The first of these calculations is nearly correct; but there is a considerable error in the second, the delivery for which should be 345.2 cubic feet per minute, instead of 289, as stated.

All the formulae in use give only approximations to the actual discharge; but adopting the above for purposes of comparison, and applying it to a 14 inch main on the line now proposed, the delivery at the junction with the distribution pipes at the corner of St. Paul and James Sts., would be as follows: 14 inch pipe; length, 21,852 feet; head, 165 feet; delivery, 300.8 cubic feet per minute; equal to 2,707,200 gallons per diem; and for a 16 inch main of the same length and under similar head, the delivery would be 420 cubic feet per minute, equal to 3,780,000 gallons per diem.

If the supply to be pumped for domestic purposes reached, say 1½ millions of gallons per day, the diameter of pipe requisite to convey this, and keep the frictional head within practicable limits, would be also about 16 inches. From 120 to 150 feet per minute is considered a fair velocity of current in the force mains for regular work. If a mean of say 135 feet is taken and multiplied by the area in square feet of a 16 inch pipe, the matter will stand thus—

\[1.396 \times 135 \times 1440 \times 6.25 = 1,696,140 \text{ gals. lifted per day of 24 hours.}\]

That is, the pumps would require to run constantly day and night to lift uniformly at a judicious velocity less than half the quantity of water that would be delivered through a pipe of the same bore by gravitation.

In the estimate submitted in the latter part of this report the cost of a 14 inch main, is compared with that of one of 16 inches diameter.

Although the difference in cost is insignificant when compared with the largely increased delivery, I may say that I should have hesitated to recommend the larger pipe, were it not that I am convinced that the growth of St. Catharines will in all probability be proportionately much more rapid in the future than in the past. Lying as it does be-
tween two great navigable channels, upon which most valuable and extensive manufacturing power will doubtless be developed, and large docks established for the building and repairs of the fleet which will be engaged in the Western Lake trade; its prospects appear to be such as to warrant a considerable outlay to secure an abundant supply of good water; whereas the natural facilities for obtaining it are so marked, that if they are utilized as now proposed, it is believed a comparatively moderate sum will secure the accomplishment of this most important object.

It will be observed on reference to the accompanying profile that the pipe line presents no peculiar features beyond the necessity of crossing under the Great Western Railway, and the present Welland Canal. The south end of the line is somewhat rough, and the trench from the reservoir to the edge of the escarpment deeper than usual; but there are about 18,000 feet which could scarcely be improved; so that the whole may be taken as moderately fair throughout. It is possible, however, that a closer examination would lead to several minor alterations, which would end in obtaining a better line than that represented.

The pipe track is located where but little damage (if any) will be done to private property, and out of the reach of villages or of any temptation, through promises of revenue, to tap it until the water is thrown into the centre of the town which it is intended to supply.

The Great Western track can be supported on timbers whilst the necessary excavation is being made and the pipe laid under it. This can be readily done without any danger to the traffic. At the point of crossing, the main might be placed in a wooden box which could be filled up solidly with cement so as to render the whole quite secure.

Where the main crosses under the canal above Lock No. 3, as shown, it is considered advisable that arrangements should be made to have this part of it as accessible as other points, so that should any leak or accident occur, the necessary repairs may be readily effected at any time.

For this purpose it is proposed to construct a culvert under the canal where marked. This will be formed of strong masonry wells to be built on each side of the canal during the summer months and in the positions indicated.

Openings to be left in these wells for the reception of the ends of a wooden culvert, 4 feet inside diameter, and formed of four-inch plank properly keyed and well put together. The whole to be strongly hooped with iron. This might be formed in suitable lengths, and be ready to place in position when the water is drawn off the canal, at which time the trench necessary to receive it might be dug, the pipes laid and jointed, and the whole culvert set, well covered in, and puddled all round; its top being placed about two feet below canal bottom, or at such other depth as the Government might require.

The main could also be laid at the same time from the north culvert well, up the St. Paul street, advantage being taken of the the water being out of the races to perform the work without interfering with the operations of the mills or manufactories.
DISTRIBUTION.

I have not thought it necessary to go into the details of distribution, which are doubtless thoroughly understood by Mr. Lesage. I may, however, state that the quantity of pipe, number of hydrants, valves and special castings estimated for by him could not, in my opinion, be supplied and laid for less than about $50,000.

It is proposed to lay a distribution main of 12 inches diameter along St. Paul street, as shewn. From this, 6-inch pipes will be laid along the streets running north and cross-pipes supplied where required. The lower level of the mills and manufactories along the line of the canal and its banks can be furnished with pipe of smaller diameter.

St. Catharines is very favorably situated for uniform distribution; the most thickly populated portions of the town being on a plane gently sloping to the north, so that the supply can be easily regulated to all parts without any of the trouble which is experienced where there are districts of very unequal elevation.

The soil of St. Catharines is generally gravelly, which is an advantage for the drainage of the hydrants.

These should be of the kind called Mathews' patent, the chief merit of which is that they are provided with a frost jacket, so-called, which effectually prevents the hydrant from freezing, provided the water is shut off at the valve in the bottom of the hydrant, and that the water remaining in the hydrant after the valve is closed can run out and waste.

The pipes should all be coated with coal tar varnish, to prevent rusting and the formation of tubercles on their inside. All of them should be tested by water pressure to about 300 pounds to the square inch, at the foundries.

It will probably be found best to adopt the pipe laid in lengths of 12 feet; but this question can be subsequently decided.

It will also be a matter for discussion as to whether the pipe should be laid by day's work under inspectors to be appointed by the Water Commissioners, or be let as a part of the same contract as that for digging the trenches to receive them.

If the work is let by contract, the contractors should be made to guarantee the pipe free from leaks for a certain length of time after it has been laid, to ensure this important part of the work being faithfully executed.

ESTIMATE.

The scheme of taking water from the canal at Thorold having, it is believed, been proved undesirable, even if practicable, it would at first seem unnecessary to say anything about its estimated cost.

But on examining Mr. Lesage's report, it was found that attention should be drawn to certain matters contained in it, so that a fair idea might be formed of the cost of his proposal, as designed, when compared with the plan now submitted.

Without referring to the prices given by him, which are quite too low for work in this locality, it was evident that, even supposing they represented the proper values, a serious error had been made in calcu-
lating the cost of the 12-inch main, as shown on page 13 of the report in question.

On page 12 the schedule of prices on which the estimate was based is given. This shows that the price for 12-inch pipe from the "reservoir to the mountain," is $2.12½ per foot laid; and that for pipe from the "mountain to the city," $2.25 per foot.

Of this, the distance from the "reservoir to the mountain," as shown on the profile, being 3,800 feet, and the total length of main 18,096 feet, the calculation would be as follows:

3,800 lineal feet light in inch pipe, at $2.12½, ........................................... $8,075  
14,296 lineal feet of light 12 inch pipe, at $2.25, ........................................... 32,166  
Total, .............................................................................................................. $40,241

Instead of $28,322, as shown on page 13 of the report referred to.

Various items are apparently omitted from the estimate, as, for example, the cost of the culvert for passing the main under the Welland Railway in 13 feet embankment, valve house at reservoir, brick sewer to drain reservoir, etc., etc. Land and land damages have also not been taken into account for the reasons given by Mr. Lesage; but, without going further into this matter, a fair estimate of the scheme as proposed would, when revised, probably stand as follows, the prices being based on those now paid for similar work in Toronto, a reduction being made for the present extremely low rate of iron.

Conduit from Canal to reservoir, bulk-head, etc., ........................................... $88,500 00  
Reservoir and valve-house, ............................................................................. 25,000 00  
14-inch gravitation main, 18,096 ft., at $2.90, ........................................... 52,468 40  
Town distribution, ........................................................................................... 50,000 00  
Land and Land damages, ................................................................................ 15,000 00  
Culverts, brick sewer, &c., ............................................................................. 7,500 00  
Add 10 per cent., for sup. and contingencies, .................................................. $158,468 00  
Total, .............................................................................................................. $175,314 00  
Say $175,000.

In preparing the following estimate of the plan now proposed, I have adopted the form, dimensions and weight of pipe at present being laid in the Rochester Water Works.

The 16 inch pipe used there are subjected to a proof pressure of three hundred pounds to the square inch, which is equivalent to a head of water of over 690 feet; and are carefully coated inside and out with coal pitch and oil, the pipes being heated for the purpose, and the process performed before rust sets in. The weight of 16 inch pipes to lay 12 feet averages closely 1,360 pounds. The form of hub is excellent, as has been proved by the results so far, the whole having been subjected to severe strains by the pumps of the Holly system.

Pipe is now about £2 sterling per ton less than the price paid for those used in the Toronto Water Works, and I am informed that American pipe, to lay 12 feet, can be put down at the St. Catharines wharf on the canal for about $50 per gross ton of 2,240 pounds, duty paid.

The cost estimated for handling, trenching, laying, etc., is based on
information obtained from parties now doing this class of work, and
may be accepted as fully representing its value.

The prices, given for the reservoir, dams, sluices, regulating weir,
valve house, etc., are liberal, and have been fixed with a due knowledge
of the cost of similar work in this vicinity.

In short it is believed that the whole of the works necessary to
bring the water to St. Catharines and lay down the extent of pipage
provided by Mr. Lesage can be done in a substantial and satisfactory
manner for the sum set down.

The estimate will be as follows:

Reservoir, dams, valve-house, wrought iron pipe between upper and lower
portions of pond, regulating weirs, etc., ............................................. $32,500
21,852 feet of 16" pipe laid complete in trench having 5 filling over pipe
the whole at $3.25 per lineal foot, ..................................................... 71,029
Distribution as above, ................................................................. 7,500
Land and land damages, ............................................................. 7,500
Culverts, etc., .............................................................................. 50,000

Add 10 per cent. for supt. and contingencies, .................................. 16,852

Say $185,000.

That is to say, the plan now proposed will only cost $10,000 more
than that submitted by Mr. Lesage, but will have a main of 16 inches
diameter instead of one of 14 inches.

As before stated, the delivery of a 16 inch main will be about one
million gallons greater than that of the smaller pipe.

Should the town more than double its population in the next 15
years (which is probable) and its manufactories increase as largely as I
am convinced they will, the daily consumption and waste for say 25,000
inhabitants will be over 1½ millions of gallons, but with a 16 inch main
there would be even then a large surplus for effective fire pressure
throughout the whole area of distribution.

A saving of about $10,000 might be effected by adopting the
1½ inch main, but I would not advise this to be done where the difference
in cost as compared with the relative efficiency is so small, and the in-
terest thereon quite inconsiderable.

Besides, the works will, even with the larger main, be very cheap
when compared with the outlay on those designed for other places in
Canada.

For example: Toronto, with a population of say 65,000, is to spend
$2,000,000 for water works, or over $30 per head. The Hamilton works
cost, I believe, $750,000, or about $41 per head of the inhabitants when
they (the works) were constructed. The Montreal works, when com-
pleted will, it is stated, cost about 7½ millions of dollars; and taking the
present population of the city and suburbs at 150,000.—this would
show about $50 per head—whereas the works now contemplated for
St. Catharines will cost only $18.50 per head for a population of 10,000,
and can be made to supply a town four times the size by an extension
of the distribution as the necessity for this arises.

It will also be borne in mind that both Toronto, Hamilton and Mon-
treal have to bear the large annual expense of pumping the water
required at each of these cities; whilst St. Catharines, if supplied by
gravitation, would have but little to pay for the repairs and maintenance
of the works, when they were properly completed.

REVENUE.

In the United States, the water rate is usually calculated at about
$1.70 per capita per annum on the whole population; but taking the
sum named by Mr. Lesage, that is, $1.20 per head for say 12,000 people,
which will probably be the number when the works are finished; the
probable revenue would be say $14,000 per annum, on the completion of
the distribution.

**ANNUAL EXPENSES.**

<table>
<thead>
<tr>
<th>Description</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>The annual interest on first cost at 6 per cent. is</td>
<td>$11,100</td>
</tr>
<tr>
<td>Cost of maintenance say</td>
<td>3,000</td>
</tr>
</tbody>
</table>

$14,100

It thus appears that the works can, when fairly started, be made
self-sustaining, and when it is necessary to increase the distribution,
the revenue for new customers ought easily to pay for this and produce
a surplus; as of course the cost of the reservoir and main constitutes
the chief items of outlay; the laying of smaller pipe being comparati-
vely inexpensive. The surplus might go to form a sinking fund to
meet the debentures when they fall due. Those issued for the Rochester
Water Works are made payable in 1902, or 30 years after the commence-
ment of operations.

It may be said that there is a class in the community who will not
take water, and that therefore the estimated revenue is too high. This
is perhaps the case in St. Catharines, but it is nevertheless a fact that
elsewhere those persons who most strenuously opposed the establish-
ment of water works, were afterwards found to be loudest in their demands
for a supply.

The Water Commissioners of Rochester, in their last annual report,
remark in reference to probable revenue: "We discover the most
"general calls for connection with the mains come from the streets where
"are the homes of those of moderate or even humble means, rather
"than those inhabited by the wealthy." They also state that "a demand
"for manufacturing uses has been developed which has largely exceeded
"our most sanguine expectations, but it is universally waiting for the
"soft and pure water of Hemlock Lake." This lake, as before stated,
will give the gravitation supply, which is to be brought from it to the
city by a conduct 28 miles in length.

The Commissioners look forward to making the works self-sustain-
ing, notwithstanding they are to cost, when completed, three millions of
dollars.

INSURANCE.

They also say very justly that, although the insurance companies
lowered their rates to the amount of 20 per cent., the people should not
be satisfied with this abatement. The protection afforded by the pumping
works has, however, resulted in a reduction of risks of at least 20 per
cent., so that, taking the total reduction in rates and the amount of risks,
it is at least 40 per cent.
I have no statistics of insurance at hand to enable me to form an idea of the saving in this respect which would be effected in St. Catharines by the construction of the proposed works; but if it be in the ratio of the population to that of Rochester, it ought to amount to one-eighth of $120,000—or a sum at least equal to the payment of 6 per cent. on the first cost of the scheme now submitted.

GENERAL REMARKS.

With reference to the quality of the water to be supplied, I may say, in conclusion, that, in the absence of chemical analysis, and reasoning simply from known facts, it is certain that the soft water obtained from the rainfall (which is undoubtedly the best)—that to be taken from Lake Erie via the enlarged Welland Canal—or the water of the present canal in its worst condition—or either of them must be admitted to be infinitely better than the distilled sewage which a large number of the inhabitants of St. Catharines are now obliged to use.

All the arguments in favor of water works which are urged in other towns apply with peculiar force to the case under consideration. St. Catharines has become a fashionable place of summer resort, where large numbers of people come during that season to enjoy the salubrious air of the place, and take the mineral baths, for which it is now so widely celebrated. But great inconvenience is experienced on account of there being no supply of pure water. The streets, instead of being filled with dust clouds, as they now frequently are, should be well sprinkled, which could readily be done from hydrants at a small expense. The gardens and lawns could be kept moist and green, and the whole appearance of the place rendered as fresh and beautiful as that of some of the neighboring towns in the State of New York. This, together with the natural advantages of the situation, would doubtless induce many persons of wealth and leisure to adopt it as a place of residence, and thus increase both the importance and prosperity of the town.

But above all these considerations—beyond even the benefits of comparative safety from disastrous conflagrations—the question of the public health vastly predominates.

In the more crowded districts, inhabited by the poorer classes, water must be brought to the spot in order to induce them to use it freely; and yet it is precisely in such localities that epidemics generally arise, which often spread from them as a centre and embrace the whole community. No sanitary regulations however well conceived, can be carried out efficiently unless the means to do so are supplied—and the experience of the past season of great drought must have clearly shown the necessity of having plenty of wholesome water, if the prevalence of low fevers is to be guarded against in the future. If the natural facilities for throwing the supply into the heart of the town did not exist—and an outlay beyond the means of the community were required to procure it, there might be an excuse for the condition of affairs which prevailed during the hot months of last year—but with empty tanks, fetid wells, and dusty thoroughfares, when there is, within a reasonable distance a fountain, fed from certain and practically inexhaustible sources, which may be conducted at a moderate expense, to the house of every inhabitant of the town, I cannot imagine upon what grounds an
intelligent citizen can look on with apathy. The matter, however, rests
in the hands of the people, and I trust that the whole question has been
explained in such a manner as to clearly shew both the urgent necessity
for the establishment of the works, and the means which, in my humble
opinion, are decidedly the best to adopt, so as to secure to the town of
St. Catharines an abundant supply of good water.

I cannot close this report without acknowledging the services of Mr.
Edward Gardiner, P. L. S., who has made the necessary surveys and
measurements with much energy and care, even whilst suffering from
the effects of a painful accident.

I have the honor to be, Sir,

Your obedient servant,

THOMAS MONRO,

Civil Engineer.