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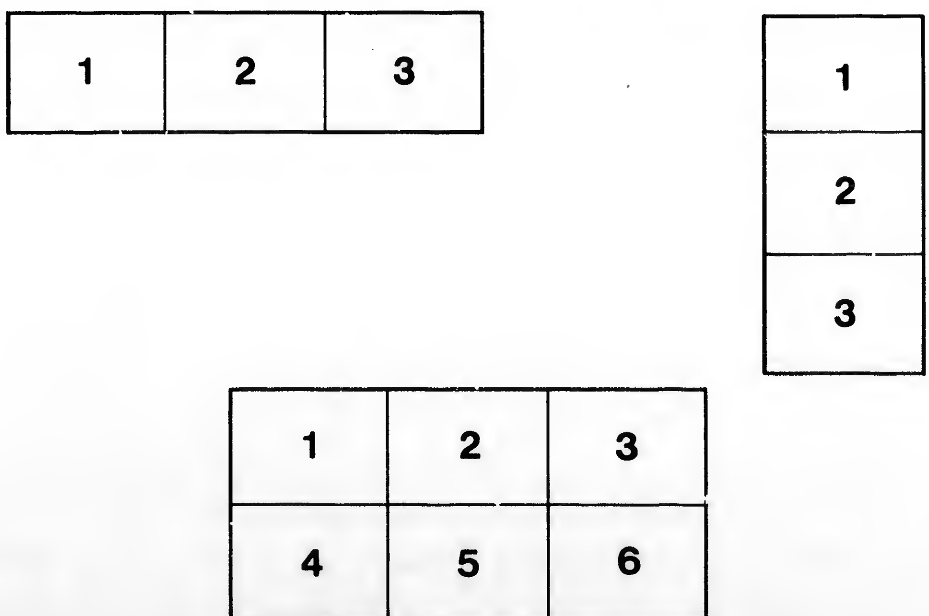

REPORT

—OF—

D. M. GREENE, C.E.,

TO THE

WATER WORKS COMMITTEE,

OF THE

CORPORATION OF THE CITY OF OTTAWA.

OTTAWA:

1871.

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REPORT.

W. Mosgrove, Esq.,

Chairman of Water Works Committee,

City of Ottawa, Ontario,

Sir,—

The various plans proposed for supplying your city with water having been submitted to me for a decision as to which in my opinion is the "best method," have been carefully considered, and I now have the honor to submit the following:

REPORT.

Immediately upon my arrival in your city, on the 3rd ultimo, in response to the invitation contained in your letter of the 22nd June, I was furnished with copies of the Reports of Messrs. Keefer and Perry, and access was furnished to the map accompanying the former, showing at a glance the different routes proposed—excepting the Little Chaudiere—together with the system of distribution recommended by Mr. Keefer.

In company with City Engineer Perry, I made a tour of the city, for the purpose of acquainting and familiarizing myself with its topography; and afterward, in company with several members of the City Council, I visited and examined the several routes from the source of supply—the Ottawa—to the proposed sites for the location of the Pumping Machinery, and for the commencement of the Distributing System.

These examinations were repeated, and continued from day to day, as occasion seemed to require; and I also gladly availed myself of such information and such suggestions, from whatever sources, as I was able to obtain.

The Members of the City Council, and the citizens, so far as I met them, uniformly manifested a desire to do all in their power, to put me in full possession of all the information thus far accumulated, which could, in any wise, be of assistance to me in the proper discharge of the delicate and responsible duty imposed upon me.

Gentlemen have, at my request, freely presented what, in their opinions, constituted the advantages and disadvantages of the several plans; but I am happy to be able to say, in no instance has any gentleman sought to unduly or improperly urge the merits of any particular locality or system.

While there was a great diversity of opinion among those whom it was my pleasure to meet, and each had his favorite idea, all seemed to be animated with the common desire and determination that your city shall be provided with a Water Works System, and that right speedily.

The necessity of an abundant supply of pure water for your city is, I believe, admitted by all. The advantages which would certainly attend its introduction,—such as the increased comfort and convenience of the people; the promotion of cleanliness and health among the poorer classes; the protection from fire, and the consequent reduction in insurance rates; the added attractions of the city for persons of wealth, leisure and culture, in the shape of fountains and well-sprinkled streets—all these have been dwelt upon at length in the reports already referred to, and in the general conclusions of which I fully concur.

In considering the question of water supply, the questions that naturally present themselves to the intelligent citizen,—and to the Engineer as well,—are:

1st. What ought the works to cost?

2nd. What amount of revenue may be reasonably expected from such works?

3rd. Are there any special pecuniary advantages to be derived from the possession of such works? In a word—*will they pay?*

For the purpose of answering these questions, in a general way, we naturally turn to the experience of other cities.

The following table shows—

1. The total cost to January, 1868, of over *twenty* of the principal City Water Works of the United States.

2. The cost for each individual of the population supplied 50 gallons daily—the population being assumed to be such that 50 gallons per capita per diem would just equal the supply furnished.

3. The cost per annum of supplying each individual 50 gallons per day.

4. The annual receipts for each individual so supplied.

The table has been compiled from official reports, and the information which it furnishes may, therefore, be relied upon; except, perhaps, in the case of the Philadelphia Works, some of the elements of cost and supply for the several branches of which have been estimated.

STATISTICS OF WATER SUPPLY.

Name of Works.	Total Cost of Works to December, 1867.		Cost per Capita, each person 50 gallons per day.		Cost of supplying one person 50 gallons per day for one year.		Receipts from each person for one year.	
	$	c.	$	c.	$	c.	$	c.
Fair Mount	2,395,282	01	5	45		88	1	10
Schuylkill	1,197,422	39	10	88	1	53	1	08
Delaware	770,480	20	9	81		90	1	33
24th Ward Works	265,546	27	7	15	1	33	1	21
Germantown	150,000	00	13	34	2	29	1	10
Total	4,778,730	87	7	07	1	02	1	13
Croton	14,000,000	00	11	80		91		99
Brooklyn	7,000,000	00	28	37	2	58	2	14
Chicago	2,373,919	80	13	67	1	51	1	73
Cincinnati	875,000	00	5	56	1	36	2	04
Jersey City	1,373,000	00	16	01	1	87	1	75
Hartford	471,872	00	11	84	1	47	1	56
Cambridge	532,273	72	21	10	2	19	2	61
Detroit	1,000,000	00	12	67	1	33	1	32
Burlington	56,306	81	10	25	1	31		53
Buffalo	705,000	00	6	41		64		83
Cleveland	690,232	70	18	09	1	63	1	35
Louisville*	1,211,630	60	32	76	3	73	2	04
Louisville†	1,500,000	00	9	45	1	33	2	04
Albany, 1859	921,892	00	18	44	1	64	1	57
Troy, "	216,000	00	7	35		92		80
Boston, "	5,500,000	00	18	33	1	37	1	05
Mobile, "	300,000	00	60	00	6	23	6	50
New Orleans, 1859	1,400,000	00	11	67	1	02	1	16
Pittsburg, "	900,000	00	7	50	1	09		84
Richmond, "	654,000	00	16	35	1	59		79
Averages			$15	05	$1	72	$1	56

* Present consumption.

† Full capacity with completed works.

It, therefore, appears that the average cost of works in the United States has been $15.05 for each individual supplied 50 gallons per day; and that the average annual cost of so supplying each individual is $1.72.

In the annual cost of supplying water are included interest on cost of works, cost of superintendence and repairs, and the cost of pumping,—wherever the supplies are obtained by that means.

The average receipts per capita, per annum, are $1.56; showing a slight deficiency in revenue. This results from the fact that a few of the works are constructed of a capacity largely in excess of the present consumption.

The principal obvious pecuniary advantages resulting from an abundant supply of water, are,—the enhanced value of property, immunity from extensive and destructive conflagrations, and a very large reduction in Insurance rates; the latter amounting to a sum largely in excess of the annual cost of supplying water.

The effect upon Insurance, however, having been already very thoroughly discussed in the Reports made to your Council, need not be further discussed here.

The proposed capacity of the Works for your City being ample for a population of 50,000 people, a reasonable expenditure for their construction—based upon the above average—would be $750,000; or, if the estimate be made upon the basis of present population, and at the same rate per capita, the reasonable cost of Works of capacity to meet present wants, simply, would be $375,000. The former estimate, however, is the proper one, inasmuch as most of the Works included in the Table were taxed to nearly, or quite, their full capacity at the time when the Reports referred to were made.

The annual Revenues, supposed to be only equal to the annual cost of maintaining the supply, would be $86,000 for a population of 50,000, or $43,000 for a population of 25,000.

I have introduced the foregoing facts, and the estimates based upon them, in this place, for the purpose of enabling you, in advance, to form some idea of the expense which may be reasonably incurred by your City in the construction of Water Works; and of also giving you an idea of the amount of annual Revenue which may be expected from the Works, if constructed.

A provision, at the outset, for the large supply, will be the more economical in the end; for the reason that all the features of the larger supply are common to the smaller, while the cost of each element of the former will be much less, relatively, than in the latter.

The cost of the right of way, for example, and of the water privilege, will be practically the same in either case; while the canal for conveying the water to the pumping station, can be constructed of ample capacity, at first, more cheaply than it can be enlarged or duplicated at some future time.

Again, owing to the sparse population of the greater part of your City, it is probable that much of the future increase in population will be within the present City Limits, so that the extent of the distribution required for the larger supply, will not materially exceed that for the former; except that larger pipes will be required. The cost of laying the larger pipes will not, however, under the circumstances, be very much in excess of that of laying the smaller. These remarks relate simply to the question of first cost; other, and entirely obvious considerations, render it essential that provision be made at the outset, for furnishing the larger supply.

In this connection, it may not be out of place to introduce some statistical information in regard to the capacity of, and cost of constructing, the City Water Works of New Bedford, Mass. These Works, recently completed, were constructed under the direction of the Hon. Wm. J. McAlpine, as consulting Engineer.

The population of the City, in 1870, was 21,320; or a little less than the present population of the City of Ottawa.

The capacity of the Pumping Engine is 2,000,000 gallons in 10 hours, or 4,800,000 gallons in 24 hours.

This capacity of Engine was provided to obviate the necessity of pumping at night, and to provide for any necessary stoppage for repairs.

The Distributing System, at the close of 1870, embraced 17½ miles of pipe, which has since been increased to 20 miles. About 10 per cent of the pipe is laid in rock.

The Works comprise, a Storing Reservoir; a Brick Conduit about 5½ miles long; a Receiving Reservoir, near the Pumping Station; a Pump House, with the requisite Steam Machinery; a Rising Main, 1960 feet long; a Distributing Reservoir, and the necessary Distributing Pipes.

The Cost of these Works, to December 1870, was as follows:

Conduit	$170,541	42
Dam	18,845	24
Distributing Reservoir	59,591	58
Distribution, including services	164,097	50
Engine House	32,156	69
Engine	37,456	33
Running Engine	3,799	95
Engineering	23,511	88
Storing Reservoir	45,556	72
Receiving Reservoir	26,448	81
Inspectors	5,570	39
Engine House Lot	16,055	70
Salaries	9,225	00
Incidentals	7,843	18
Carried forward	$620,700	39

Brought forward	$620,700 39
Pump-Well and Culvert	16,561 41
Homestead of A. White	4,000 00
Peckham Road	512 00
	$641,773 80
Preliminary outlay	2,605 34
Discount on Bonds sold	5,000 00
Whole amount expended	$649,379 14

$15,05 per capita, for double the present population, would amount to....................$641,732 00

This example, selected as a basis of comparison, only for the reason that the Works are of recent construction, and are intended for the supply of a City of about the same size as the City of Ottawa, is, it will be observed, is a fair representative, as to cost, of the average of Works in the United States.

If we deduct 25 per cent, as the average difference in cost of labor and materials, between the United States and Canada, the reasonable cost of City Water Works, in Canada, with capacity sufficient to supply 50,000 people, will be $562,500.

Your Works may be considered cheap, just in proportion as their cost shall fall below the above sum.

GENERAL CONSIDERATIONS.

In any efficient Water Works System the following conditions must be satisfied:—

First,—There must be an available *source* of supply.

Second,—There must be an abundant and permanent supply of pure and wholesome water.

When these are provided it is the province of the Engineer to point out the best and most efficient mode of collecting and distributing the supply, and this involves the design and construction of suitable, *substantial and permanent works.*

The first two conditions are satisfied by the magnificent river which runs at your feet, with water and power enough to supply a hundred cities like yours.

The character of the Ottawa River is peculiar, made up as it is of a regularly alternating series of lakes and rapids—the former serving most effectually to insure the deposit of all earthy matters brought down in mechanical suspension by the tributaries, and the latter providing for the thorough purification from any organic matter at present existing, or which may in the future find its way into the river above the city.

We can readily understand why a chemical analysis should show, as that of Dr. Hunt has shown, that the purity of the Ottawa water, even at its junction with the St. Lawrence, is scarcely equalled by that of any city supply on the continent.

Nature having thus provided settling ponds and other means of purification on a large scale, and there being also very frequent changes of water from the rapid circulation, there will be no occasion for the expensive and often indispensable auxiliaries of settling and filtering reservoirs; and hence the water may be taken at once ffom the river and transferred, by such means as may be provided, to the points of consnmption in the city.

THE WORKS.

The topographical features of the city are such as to preclude the possibility of availing yourselves of the many and important advantages of a Distributing Reservoir; among which may be mentioned the facility which it affords for storing up and keeping constantly on hand a large supply of water, which may be drawn from in case of accident to the Pumping Machinery, requiring a temporary suspension of its operations for repairs; and also for storing the surplus water at such times as the consumption may fall below the uniform normal capacity of the pumps, and keeping up the supply whenever the consumption exceeds that capacity—in other words, serving as a sort of balance-wheel for the system.

In the absence of a site sufficiently elevated and of sufficient extent for such a reservoir, the benefits naturally flowing from it must be forborne, and recourse must be had to the "High Pressure System," of which the so-called "Holly System" is the American representative.

This system has its advaniages as well as its disadvantages. Prominent among the former may be mentioned its comparative cheapnes, especially where water power is abundant and cheap, and its availability as an efficient substitute for the fire engine, whereby a large saving in the usual expense of maintaining a Fire Department may be effected; while among the latter may be mentioned the greater cost of operation in consequence of the exceedingly variable character of the speed and power to be developed by the machinery, the greater stress upon the pipes and house plumbing during the maintenance of fire pressure, requiring greater thickness, weight and cost in the former and greater care in executing the latter; the greater liability to accident at the precise time when an accident might prove most disastrous in its consequences; and the absolute necessity of duplicating the machinery, not only for the purpose of guarding, as far as practicable, against those consequences, but to insure at all times the requisite supply of water.

You have, however, no alternative, and it is therefore absolutely necessary that not only the pumping machinery but the entire works shall be of abundant capacity, and of the most permanent and substantial character.

QUANTITY OF WATER.

The mode usually adopted by Engineers in the United States, for determining the daily capacity of works designed to supply young and growing cities with water, is to estimate at the rate of 60 U. S. gallons per capita per diem, for double the existing population. The experience of the past few years has clearly demonstrated the necessity of providing thus liberally, not only for the present but for the future wants of cities.

The necessity for extension and enlargement, in a large majority of cases, presents itself much earlier than was originally anticipated; as the Water Works histories of the cities of New York, Boston, Brooklyn, Philadelphia, Albany, Troy, Utica, Syracuse, Buffalo, Cleveland, Chicago and Watertown have clearly shown.

As showing the rate of increase in the consumption of water, the following figures are presented. They are taken from the Official Reports of the cities of Brooklyn, N. Y., and Louisville, Ky., for the years 1870 and 1869, respectively; and show the absolute average daily consumption for each year, from 1861 to 1870, inclusive:—

	Brooklyn. Gallons.	Louisville. Gallons.
1861		640,627
1862	5,021,250	1,012,811
1863	6,490,750	948,646
1864	7,932,850	1,241,170
1865	9,233,350	1,706,835
1866	10,905,450	1,849,123
1867	12,348,100	1,878,547
1868	15,710,700	2,055,325
1869	17,630,400	2,475,910
1870	18,682,219	

The increase in population from 1860 to 1870, as shown by the census returns of the two cities, was as follows:—

Brooklyn	50 per cent.
Louisville	48 "

In both cases the consumption was about quadrupled in ten years. Much of the increase was undoubtedly due to the extension of the pipes to localities previously settled but unsupplied with water; nevertheless the increased demand due to increase of population is sufficiently obvious, as the length of distribution pipe was only *doubled* in each city in the interval between 1860 and 1870.

Estimating then upon the proposed basis,—remembering that the Imperial gallon which constitutes your standard is about 20 per cent. larger than the U. S. standard—and taking the present population of the City of Ottawa at 25,000 souls, provision must be made for supplying 50,000 people with 50 Imperial gallons per diem each; or an aggregate of 2,500,000 gallons per diem.

POWER REQUIRED.

In estimating the power which will be required, provision must be made, not alone for raising the daily supply *at a uniform rate,* but to meet an extraordinary demand for the extinguishment of fires, which may occur at the precise hour of maximum consumption for other purposes.

While the demand must of necessity vary between wide limits, even at the outset, it is desirable, in order to insure the greatest efficiency in the pumping machinery, that those limits be narrowed to the greatest possible extent. In accomplishing this, the size and location of the pumping main will exert a powerful influence as will presently appear.

For the ordinary requirements of the works, water will have to be raised about 200 feet above low water in the Bay above the Chaudiere.

To raise 2,500,000 gallons of 10 pounds, 200 feet, at a uniform rate, in 24 hours, there will be required an expenditure of 105.2 horses-power, effective; to which should be added, for friction in the pipes, say 10 horses power; making a total of 115 horses, effective; or, taking the efficiency of the motor at 70 per cent, the gross power required will be about 164 horses.

In order that frictional head in the pipes may be kept within practicable limits, the average velocity of the ascending current, in the mains, should not much exceed 2 feet per second; and it is this consideration which, together with the quantity of water to be pumped, should determine the size of the Pumping Main.

Two million five hundred thousand gallons represent 400,000 cubic feet: the average quantity per second will, therefore, be 4.63 cubic feet. If the velocity be fixed at 2 feet per second, the requisite sectional area of the main will be 2.31 square feet, and its diameter about 21 inches. A pipe 18 inches in diameter—the largest yet recommended—would require a velocity of current equal to 2.62 feet per second. This, in view of the fact that the distance will be short from the probable location of the pumping station to the points where branch mains will lead off from the principal main, reducing the quantity flowing in it, and consequently reducing the velocity of the current; and in view also of the fact that the above velocity is that due to the ultimate supply now contemplated, is large enough.

We have to consider further, however, that the ordinary consumption of water will be by no means uniform. During the night, for instance, the consumption will naturally fall very much below the average rate; while, on the contrary, on certain days, and at certain hours of the day, the consumption will very largely exceed the average rate.

I shall assume that the maximum rate of consumption for ordinary purposes will be *double* the average rate; in other words, that there will be times when, with the present population, the rate of consumption for ordinary purposes will reach 2,500,000 gallons per day. To this must be added the maximum *probable* requirement for fire purposes—for an extensive conflagration is liable to occur at the instant when the maximum consumption for domestic purposes is taking place.

To fully provide for such a contingency, let it be assumed that a fire may occur in the Parliamentary or Departmental Buildings requiring *five one-inch streams* to be thrown to a height of 90 feet above the ground in front of the buildings. In order to reach a height of 90 feet, the pressure head at the point of discharge must be about 135 feet, so that the corresponding aggregate discharge would be $\left(\frac{5 \times 0.8 \times .7854 \times 8.02 \sqrt{135}}{144}=\right)$ 2.013,—*say* 2 cubic feet per second; or at the rate of 1,080,000 Imperial gallons in 24 hours.

It appears, then, that the maximum present requirement may reach $(4.63+2)$ 6.63 cubic feet per second; or at the *rate* of 3,580,000 gallons per day. When the population of the City shall have reached 50,000 souls, the maximum probable rate of supply, determined as above, will reach $(2 \times 4.63+2=)$ 11.26 c.f.s.; or at the rate of 6,080,000 gallons per day. Of course it is not expected that the necessity will ever exist, at least while the population is less than 50,000, for pumping 6,080,000 gallons in any one day; but it is not unreasonable to suppose that such a *rate* of consumption may be reached. Should the demand equal this rate, if for no longer than 30 minutes, the power, and water, must be at hand to supply it.

We are now prepared to estimate the ultimate power required, and for which provision must of course be made. As a preliminary step in this determination, the two routes proposed for the Pumping Main must be considered, with the view of reaching a decision as to which should be adopted.

If the main be laid along Maria and Theodore Streets, with an 8 inch branch, extending to the Government Buildings, as proposed by MR. PERRY, and we take the quantities of water following through 6,350 feet of 18 inch main and through 1700 feet of 8 inch pipe at 7 c.f.s. and 3 c.f.s. respectively, as the maximum probable requirements for domestic and fire purposes combined, we shall find that the frictional heads in the two pipes will be as follows:—

In the 18 in. main	30 ft.
In the 8 in. pipe	70 "
Total frictional head,	100
Add height of ground in front of Parliament Buildings, say	118 "
And pressure head at delivery	135 "
Total	353 "

Again, if the 18 inch main be laid in Wellington street, and a short 8 inch branch be run up to the Parliament Buildings, the heads representing the frictional resistances would stand as follows:

In 18 in. main	30 ft.
In 8 in. pipe	17 "
Total frictional head	47 "
Add, as before,	118 "
And,	135 "
Total	300 "

Thus, it appears, that in this view the Wellington street route for the Pumping Main, at least as far as the Government Buildings, is decidedly preferable.

Again, by the Wellington street route, the pressure to be sustained by the main would be less than that by the Maria street route, by the pressure due to the difference of level of the two streets plus the pressure due to the difference in frictional heads, amounting in the aggregate to about 40 pounds per square inch, and permitting a saving in weight and cost of pipe which would alone compensate for the extra cost of laying the main in rock.

By locating the main in Wellington street, therefore, we have a clean saving of the difference in power required to pump against heads of 353 feet and 300 feet respectively.

It may be said that, as there is an abundance of water power, this last consideration should have little weight in deciding as between the two proposed routes for the Pumping Main; but it should be remembered that the greater the power used, the greater the expense of constructing the conduit to convey the water to the machinery, and the greater the expense of the machinery itself.

It would be clearly unwise in developing a Water Works Scheme to neglect or ignore those considerations which are essential to the economical and efficient accomplishment of the deired object, simply because we have an abundant water power at our command.

The power to be provided must then be capable of raising 6,080,000 gallons, 300 feet high, in 24 hours, and hence must be equivalent to $\left(\frac{6,080,000 \times 10 \times 300}{33,000 \times 1,440}=\right)$ 553 horses effective, or to $\left(\frac{553}{0.7}=\right)$ 790 horses gross.

This power, it is to be understood, will only be required in a remote but possible contingency, and when the population of the City shall have reached 50,000 souls. For the present, however, and for a term of years, one-half this power will doubtless be ample; so that while the canal or conduit should be constructed of the full capacity indicated; and while provision should be made for ultimately setting wheels to furnish the above power, the present and immediate future wants of the city will be satisfied by erecting machinery sufficient to develope a power of 400 horses, gross, or 280 horses effective.

For this purpose there will be required two wheels of approved construction, 5 feet in diameter, and making about 80 revolutions per minute, under a head of 20 feet, that being the uniformly available head at most of the proposed sites for the Pumping Machinery.

In case a site should be selected where the available head is only seven feet, *nine* wheels of the same size will be required for present supply, while for the maximum power estimated *eighteen* wheels will be required.

THE PUMPS.

These, as recommended by Mr. Keefer, and for the reasons stated by him, should be of the plunger type, single acting, and in gangs of three to each wheel. In my opinion, however, these pumps should be set with their axis vertical,—to prevent friction, wear and consequent leakage; should be connected with cranks, dispersed at angular intervals of 120° about the shaft to insure uniform action, and should be so arranged that either of the gangs, or all of them, may be operated at the same time by any of the wheels, as may be desirable or necessary.

I recommend that the diameters of the pump cylinders be made 18 inches, that their stroke be 3 feet, and that the maximum speed of plunger be fixed at 120 feet per minute—corresponding to 20 revolutions per minute. Slight modifications may be required in these speeds and dimensions whenever the details come to be finally arranged.

One gang of pumps will thus suffice to meet the maximum present requirements of the city, leaving the second gang as a reserve, and making provision for repairs when necessary.

A spacious air chamber should also be provided,—with means for constantly replenishing its supply of air, for the purpose of relieving the pumps and pipes from the injurious shocks which would be experienced in its absence.

The third and fourth gangs of pumps may be supplied with the wheels to drive them as the increasing demands of the city may require.

The cost of pumps, pumping machinery, and pump house, for present purposes, I estimate as follows:—

2 gangs Pumps	$ 6,000 00
2 Turbine Water Wheels	3,000 00
Pump House	20,000 00
Total	$29,000 00

QUANTITY OF WATER FOR POWER.

With a clear head of 20 feet the quantity of water required to furnish a gross power of 800 horses will be $\left(\frac{800 \times 33,000}{62.5 \times 20 \times 60} = \right)$ 352 cubic feet per second.

With a head of 7 feet, the quantity required would be $\left(\frac{20 \times 352}{7} = \right)$ 1006 cubic feet per second, or about one twenty-seventh of the entire flow of the river at low water.

THE CONDUIT.

Having determined the maximum power required, and the quantity of water necessary to supply that power, under the heads stated, we prepared to estimate the size of the conduit which will convey this water.

For the purpose of reducing, as far as practicable the size and cost of the conduit, I adopt a mean velocity of current of 4 feet per second. With this velocity, the sectional area of the conduit which will convey 352 c.f.s. of water, must be $(\frac{352}{4}=)88$ square feet; or, starting at 10 feet below low water in the Bay, and providing for a depth of 10 feet in the conduit, its width must be 8.8 feet. For safety, and to insure convenience in making the excavation, I fix the width of the conduit at 12 feet, and the inclination of its bed at $\frac{1}{2640}$—corresponding to a fall of 2 feet per mile; which will be sufficient to induce a mean velocity of 2 feet per second in a conduit of the size stated.

With the depth of 6 feet, and a mean velocity of 4 feet per second, the requisite width of a flume or conduit capable of conveying 1006 c.f.s. would be about 42 feet.

It will be observed that by thus providing for an increased velocity of current, in the conduit, we are able to reduce its size one-half, and its cost in nearly the same proportion.

DISTRIBUTION.

In regard to the details of the distribution, I need say but little, as they seem to have been very thoroughly considered in the Reports of Messrs. Keefer and Perry. Great care should be observed in the disposition of the 2 in. and 3 in. pipes; and it is, indeed, questionable, whether any pipes of so small calibre should be admitted in the system. They should only be employed,—if employed at all,—in short lengths, and in the lower districts of the City, where head may, in some degree compensate for small size.

According to the best authorities, the thickness of the 18 in. Pumping Main, in the vicinity of the Pumping Station, should be $1\frac{1}{4}$ inch thick. This thickness may, however, be reduced to $1\frac{1}{8}$ in., at an elevation of 33 feet; and to 1 in., at an elevation of 66 feet. At points more remote from the pumps, the pressure due to the frictional head being reduced, in consequence of the smaller quantity and velocity of water, a thickness of 1 inch will suffice, even though the elevation be less than 66 feet above the pumps.

Taking the estimate of Mr. Perry as to the *weight* of pipe required, as probably a close approximation to the truth, and estimating the cost of the pipes, together with lead for joints, delivered at the trench, at 2 cents per pound (the cost in Glasgow is from 1 to 1⅛ cents), the cost of the pipes will be—

	$112,387 96
Add for Stop Cocks	10,000 00
" Hydrants	18,000 00
" Laying pipe	60,000 00
" House Service	60,000 00
Total	$260,387 96

Say, $260,000; which I consider a liberal estimate—probably somewhat in excess of what the actual cost will prove to be.

In 1859, the actual cost of about 26 miles of distribution, for the City of Louisville, Ky., was $273,320 62.

At that time the cost of labour and materials, in the United States, did not materially differ from the present prices which obtain in Canada.

In New Bedford, Mass, the cost of 17½ miles of distribution—a large part of which was of cement lined pipe, which with us is about 20 per cent. cheaper than iron—was $164,097 50. Here, however, the portion of the house service ssumed by the city, embraced only that portion of the pipe lying within the street lines.

The average cost of distribution per mile, in each of the above cases, was—

Louisville	$10,512 33
New Bedford	9,377 00
Ottawa (estimated)	9,629 62
Mean	$ 9,839 65

These figures may be taken as an indication of the adequacy of our estimate.

CANAL ROUTES AND SITES FOR THE PUMPING MACHINERY.

The selection of a Canal or Conduit route, and a site for the Pumping Station, will be controlled by the following considerations, viz.:—

1st. The water power must be permanent and entirely reliable.

2nd. The Pumping Station should be isolated, as far as practicable, from surrounding buildings, especially from manufacturing establishments, where, from the character of the materials employed, fires are liable to occur.

3rd. The point from which water is to be taken for the power, and for the city supply, should be in deep and comparatively still water, so as to avoid, as far as practicable, the tendency to draw anchor-ice from the rapid current in the main channel; and it should also be located above the more objectionable sources of contamination, and where not only the water itself but the entire canal route may be wholly and absolutely within the control of the city.

4th. The location of the Conduit should be such that its construction will not interfere with street transit, or with any of the legitimate or proper uses of streets, such as the laying of gas and water pipes and the construction of drains and sewers.

5th. The location must be such as will admit of the construction of *substantial, permanent works*, to the end that an abundant and *uninterrupted* supply of water, both for power and for the city supply, may be assured.

The sites proposed, and from among which a selection is to be made, are—

1. Victoria Island.
2. Amelia Island.
3. Oregon Street.
4. Queen Street.
5. The Gully.
6. Little Chaudiere.

The Victoria and Amelia Island schemes may be considered together. These and any other plans which contemplate drawing their supply from the Government Slide Channel have like advantages and are open to the same objections. Among the former may be mentioned, as most prominent, the cheapness of construction; while among the latter it is to be observed that the sites are confined, that the adoption of either of them—with the exception perhaps of that on Amelia Island—would involve the occupation of valuable space now used by the mill owners, and which can only be acquired at large expense for damage to present owners and occupants, whose facilities for conducting their extensive business is already limited; and that it is by no means certain that the Government will permit the City to erect its machinery upon and draw its water from the Slide Channel. This work is of great importance to the lumbering and timber interest of the Dominion; and as it yields a considerable revenue, the Government could not—consistently with its own interests and the interests of citizens engaged in the timber trade—permit any use of it which could, by any possibility, interfere in any wise with the full and efficient performance of its legitimate functions.

The work is built largely of perishable material, requiring frequent repairs and occasional renewal; and for this reason alone it is, in my opinion, unfitted to serve as an important element in a Water Works System, especially where, as in the case of the City of Ottawa, it will be of the utmost importance that the works be not interrupted in their operations even for a single hour.

Again, there would be great risk of obstruction from anchor-ice—a risk too great, in my opinion, to be accepted, in view of the serious consequences which might follow a stoppage of the machinery from this or any other cause.

Finally, at this point the water will have been exposed to all the causes of pollution which now exist, or which may hereafter be brought into action above, among which may be mentioned the deposit of night-soil and other filth along the railway grounds, which, I am informed, has been practiced during the winter for many years, and which the city authorities have thus far been unable to prevent.

In regard to the Oregon and Queen streets and the Gully routes, the estimates of Mr. PERRY show that the difference in cost—after deducting from the estimated cost of the Gully route the cost of drains, which are not properly a water works charge—is not sufficient of itself to warrant a decision in favor of either. The preference, as between these three routes, must be based upon other considerations.

The right of way for all of these routes would have to be obtained wholly, or in part, from the same parties; and it might be for the interest of the city pecuniarily to consult their preferences, especially if these preferences incline in the direction of any one route which possesses marked advantages over either of the others.

The Oregon street route is without special advantages. It is open however to serious objections. The head of the conduit would be in too close proximity to the head of the Slide Channel, and would thus interfere with the movement of timber cribs. For this reason, and for the reason that it would necessarily cross the Government Reservation at the head of the Slide Channel, the Government would undoubtedly decline to grant its permission to the City to construct the Conduit and draw its water from that point. Moreover, there would be danger of obstruction from anchor-ice; and the objection as to possible and even probable pollution of the water would apply here with equal force as to the schemes for taking water from the Slide Channel.

Finally, the great depth of rock cutting, and the fact that the route lies for a portion of its length through a public street—the travel over which must be wholly interrupted during the progress of the work—and for the remaining portion across valuable private property, already occupied, or required for important improvements contemplated by the proprietors, are objections the importance of which should not be overlooked.

What has been said with regard to the Oregon street route—except so far as relates to interference with the Slide Channel—applies with equal force to the Queen street route. In making the rock excavation on either of these routes, there would be serious danger of causing serious damage to persons and property, for which the city would of course be liable. Ordinary prudence suggests the avoidance of such danger wherever it is possible.

The Gully route has many advantages over the others. By it the water will be taken from the river above Rochester's Mill, and above all the more objectionable sources of pollution; and hence will be purer and better adapted to the wants of the City, than that obtained by either of the other routes.

This route lies in a natural depression, extending from the Bay to the proposed location of the Pumping Station at Pooley's Bridge, and over land now for the most part vacant, and where the construction of the Conduit would be attended with none of those inconveniences or dangers which would necessarily be experienced on either of the other routes.

The Government has already granted its permission to the City to draw its water from this point, both for power and for the City supply; and will undoubtedly transfer to the City its reserve of one chain wide above high water, which will enable the City to effectually control the river front above the head of the Conduit, and to adopt measures to prevent the deposit there of filth of all kinds.

Should the future growth of the City extend in that direction, the sewerage may be brought down and deposited below the Pumping Station. By this means the future purity of the water may be assured.

The only objection to this route is the length of Conduit required, which, however, is largely compensated for by a smaller depth of cutting than will be required on either the Oregon or Queen street routes.

To make the Gully route available for the purposes contemplated, a Conduit about 3,600 feet in length will have to be constructed, extending from a point in the Bay about 600 feet distant from the present water line—where a depth of 10 feet may be maintained at low water—to Pooley's Bridge, at which point a natural depression provides for the free escape of the tail water from the wheels. This Conduit will be principally in solid rock, and should, as before stated, be 10 feet deep, 12 feet wide, and should have an inclination or grade of two feet per mile.

From a point near the Pumping Station to a point say 2,500 feet westerly therefrom, the Conduit should be arched, for the purpose of keeping out surface drainage, and so that the ground may be restored and improved, and thus made available for other purposes.

The necessity for bridging the structure will also be avoided.

From the upper terminus of the arch, pier-walls should be extended out into the Bay, to a depth of 10 feet at low water. Between these walls—which should extend about 5 feet above high water mark—a bulk-head, with suitable head-gates, would be required for the purpose of regulating and controlling the flow during high water.

My estimate of the cost of the works, in case this route should be adopted, is as follows:—

Excavation for Conduit	$ 20,000 00
Arch	15,000 00
Masonry at head of Conduit	15,000 00
Coffer Dam	18,000 00
Right of way	30.000 00
Pump House and Machinery	29,000 00
Distribution, including House Service	260,000 00
	$387,000 00
Add for contingencies	38,700 00
Total	$425,700 00

This estimate is for first class works, of abundant capacity for supplying the present and future wants of the city; and which, from their permanent and substantial character would be in a high degree creditable to the intelligence and enterprise of a city of so much importance as that of the Capital of the Dominion.

Estimates of the cost of the Oregon and Queen street routes are not introduced for the reason, already stated, that the *relative* costs are sufficiently indicated by Mr. PERRY's estimates; and for the further reason that the preference, where the difference in cost is so slight, must be based upon considerations to which a money value cannot be assigned.

THE LITTLE CHAUDIERE.

This site, and the route leading from it have been carefully examined. The desirable features of this scheme are, the purity of the water, and the possible cheapness of the site for the pumping machinery, and the right of way for the pumping main.

The available head claimed is seven feet; which must of necessity be considerably reduced during the prevalence of high water.

Again, after carefully weighing all the evidence which I have been able to obtain, I have been forced to the conclusion that the operation of the requisite machinery at the site of Sparks' old mill would be subject to frequent interruption during the Winter season from anchor-ice. The only way, in my opinion, in which this danger could be averted, and a reliable power assured, would be to extend a wing-dam up to, and across, the foot of the Remoux Rapids, of such a height as to effectually flood them out; and even this might not prove effective. Such a dam would be about 1¼ mile long, and would close up the channel which I understand to be now used for running timber cribs; and for that reason, probably would not be permitted by the Government.

Finally, about 8,000 feet of extra main would be required; much of which would have to be laid in rock.

I estimate the cost of the Works, constructed upon this plan, to be as follows:

New Wing Dam, 1¼ mile..............	$70,000 00
Pump House and Machinery..........	42,000 00
Water Privilege and Right of Way	25,000 00
8,000 feet 18 inch Main, at $5..........	40,000 00
Distribution, including H. services.....	260,000 00
	437,000 00
Add for contingencies........	43,700 00
Total	$480,700 00

It thus appears that the Little Chaudiere—when considered with reference to cost alone—is the least desirable of all the plans.

In view of this fact, and of the great risk of obstruction from anchor-ice; of the necessary interference with the running of timber; of the amount of machinery required; and of the troublesome effects of unavoidable variations in the low head at this point, I am forced to the conclusion that the best interests of the city will not be subserved by the adoption of the Little Chaudiere, as a source of power and supply.

Of the other routes, that through the Gully seems to me to possess the greatest advantages; its location, natural adaptation, and undoubted capacity for furnishing an abundant and always reliable power, indicate unmistakeably its superior fitness for the purposes of a water power and supply for the City of Ottawa.

Again, the cost of developing this route is entirely reasonable.

For these reasons, after careful examination, and mature deliberation, I feel constrained to recommend the adoption of the Gully route.

In fixing upon the size of the conduit, I have been governed solely by the requirements of the City. It is obvious, however, that the route recommended offers unusual facilities for the development of a much larger power; which, on account of the inducements which it would offer to manufacturers to establish works of various kinds at that point, might be made a means of contributing largely to the future growth and prosperity of the city. It becomes then a question of some moment, whether it would not be better in the end, to construct a conduit of larger capacity, and to compensate the proprietors of the route, for the right of way, wholly or in part, by furnishing them the surplus power; to be used at all times subject, of course, to the requirements of the city.

I am not quite prepared, however, to recommend this course, as I deem it of the highest importance that the Works which supply the city, should be isolated to the greatest practicable extent, and wholly under the control of the city.

FIRE ALARM TELEGRAPH.

I fully concur with Mr. Keefer, in the opinion that a Fire Alarm Telegraph should be connected with the Water Works. As a medium of communication, between distant parts of the city—especially in case of fire—such an auxilliary will prove invaluable. Intelligence of a fire would be transmitted to the Pumping Station as quickly as to the Fire Department; power and speed could be increased and the fire pressure realized in a few seconds; and in a majority of cases, with a well disciplined Fire Brigade, streams would be playing upon the fire within a period of five minutes after sounding the alarm.

The losses sustained by citizens of Ottawa, during my short stay in the city, would pay for the Fire Alarm Telegraph twice over.

Putting the cost of this important auxilliary at $10,000, as estimated by Mr. Keefer, the estimate will stand thus:

Water Works proper................	$425,700 00
Fire Alarm Telegraph..............	10,000 00
Total...............	$435,000 00

ANNUAL EXPENSES.

The annual Interest upon the above sum, at 6 per cent. will be	$26,250 00
Add for Sinking Fund, to cancel Debentures at end of 30 years	8,000 00
Add for Superintendence, Repairs, and Operating Expenses	6,000 00
Total Annual Expenses	$40,250 00

ANNUAL REVENUE.

Taking the present population to be supplied with water, at 25,000, and assuming the water rates to be so adjusted as to be equivalent to the average rate of cost in the United States—$1 72 per capita per annum—the annual revenue will amount to the sum of $43,000 00; or $2,750 in excess of the annual cost of the Works.

The average rate per house, per annum, will be about $7 60; while the average cost, per thousand gallons furnished will be only about 9½ cents.

It thus appears that the works may be made self-sustaining from the outset; that they may be constructed and maintained without increasing in the slightest degree, the present rate of taxation; and that with the inevitable future increase of population, the water rates may be gradually reduced; or, the works may be made a fruitful source of revenue to the city.

FUTURE GROWTH OF THE CITY.

The probable increase in the population of the city is a matter of much interest in the present connection; for upon it will depend the possible future reduction of the water rates; or, in the event of their being maintained at the proposed standard, will show the extent to which the works may become a source of net revenue to the city.

An approximate estimate may be made as follows:—

The census returns of 1870 show that, of 65 cities in the United States, which in 1860 had populations exceeding 10,000, the increase in 10 years was 69.7 per cent. The average annual rate, therefore, for a period of 10 years, was about 7 per cent. In 1851, the population of Ottawa is put at 7,760; in 1856, at 12,155; showing an increase, in 5 years, of 4,395; equal to about 57 per cent., or an average *annual* increase of 12.4 per cent.

Taking the present population at 25,000, the increase has been 12,855, in a period of 15 years, which is an average annual increase for this period of 7.1 per cent. There appears to be no reason why the rate of increase in the City of Ottawa should be less in the future than it has been in the past, or less than the average of cities in the United States, for the last decade.

Should the rate continue, we may expect the population to be doubled in 15 years, and quadrupled in 30 years, so that the population will be—

In 15 years	50,000
In 30 "	100,000

And the annual revenue from the Water Works—

In 15 years	$ 86,000 00
In 30 "	172,000 00

In view of these results, the fact that the construction of the works will prove to be a remunerative investment for the city, appears to be satisfactorily established, and the success of the enterprise would seem to be assured.

THE GENERAL DIRECTION OF THE CONSTRUCTION AND MANAGEMENT OF THE WORKS.

Having been requested to state my views as to whom should be charged with the general direction of the construction of the works, and with their management after completion, I have to say that, in my opinion, the entire management of the construction and maintenance of the works should be vested in a Board of Water Commissioners.

This Board should be composed of five gentlemen, who should be elected by the popular vote of the city. In case of any vacancy in the Board, caused by the death, resignation, or removal from the city of any member, such vacancy should be filled by a vote of the City Council.

The Commissioners should hold their offices until removed by a two-third vote of the Council; and should serve without compensation, except for such incidental expenses as may be incurred in the discharge of their duties.

They should be authorized to employ such services, of whatever kind, as in their judgment may be necsary to insure the full and efficient execution of the trust reposed in them; in a word, they should be put in possession of the means provided, and should be required, within a reasonable time, to provide the City with an efficient Water Works System.

After the completion of the Works, the Commissioners should exercise a general supervision over them; should establish and regulate water rates; should direct repairs, and extensions, when necessary; and should make all needful rules and regulations in regard to the use of water; and to insure the efficient operation and the proper preservation of the machinery and works generally.

The proposed Board, selected as it should be without reference to personal, local or sectional interests, but with reference to *fitness* only, invested with ample power and acting in the interest of the whole City, will be able to furnish that which is so much desired—and which more than anything else is now essential to the future growth, prosperity, healthfulness and safety of the City of Ottawa—an abundant supply of pure and wholesome water.

Respectfully submitted,

D. M. GREENE,

Civil Engineer.

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