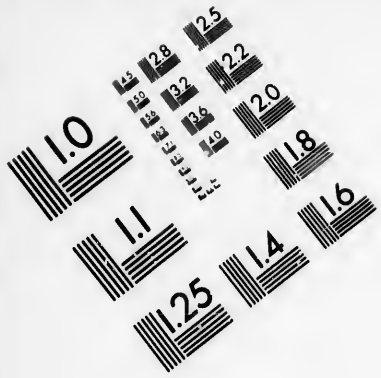

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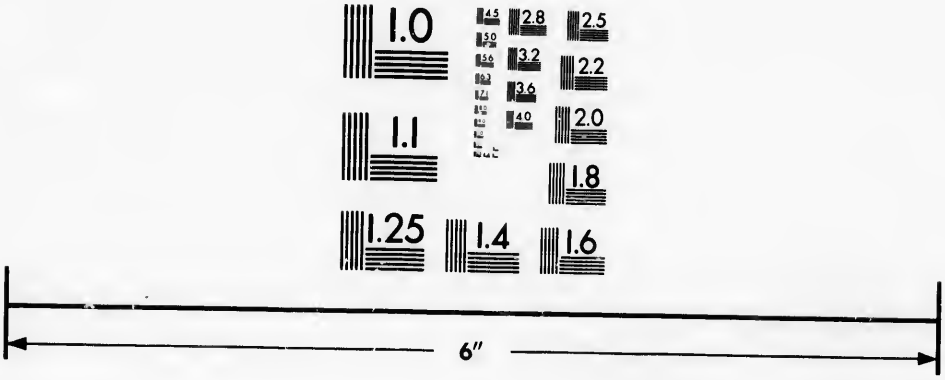

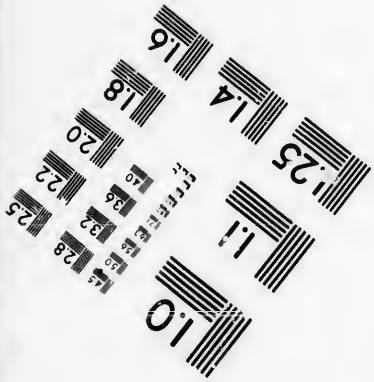

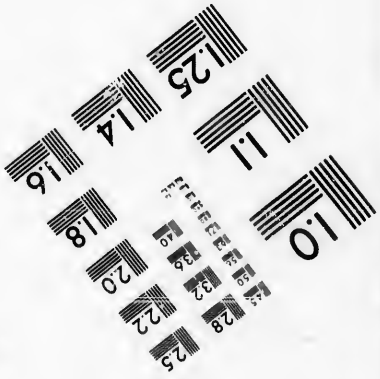

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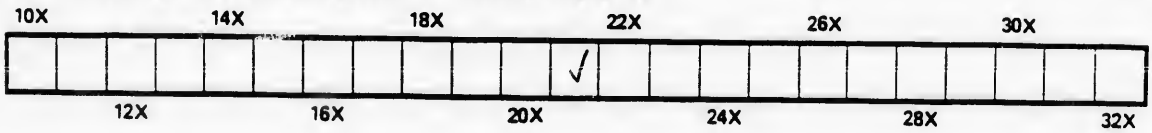

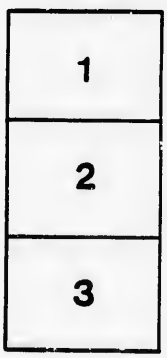

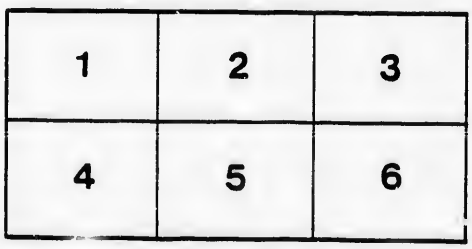

REPORT

OF

W. J. McALPINE, Esq., C.E.

ON THE

WATER WORKS

OF

THE CITY OF MONTREAL.

MONTREAL:

STARKE & CO., PRINTERS, ST. FRANCOIS XAVIER ST.

1869.

MONTRÉAL. WATER WORKS

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ALBANY, *October 21st*, 1869.

J. W. McGAUVRAN, Esq.,

Chairman Water Committee,

Corporation of Montreal:

SIR,

I regret that my protracted illness has delayed my Report on the Water Supply of your City.

The resolution of the City Council, inviting Mr. Chesbrough and myself to examine the Water Works of Montreal, in its technical language, would have confined us to the plans which have been presented by Messrs. Cooke & Plunkett, without change or modification. But the subsequent resolutions of the Water Committee, and the verbal expression of their wishes, by the Members, have opened the whole subject to the present examination. Nevertheless, these resolutions give such prominence to the plans of Messrs. Cooke & Plunkett, as to render it quite proper that particular attention should be given to them

I deeply regret that Mr. Chesbrough's engagements prevented him from making the personal examinations contemplated in the Resolution, and I hoped to have been able to consult with him before his departure for Europe, on at least the general subjects involved; but in a recent letter he says it will be impossible for him to devote any time to the question.

The subject of an increased Water Supply has been reported upon by Mr. Keefer, who constructed the original works, and by Messrs. Shanly & Francis, and has been discussed in Reports of your Committees,* and in the newspapers, so as to develope nearly all of the questions which are involved.

From these various sources of information, and my own observation and reflection, I deduce the following points :—

1. That for the mere *consumption* of Water in the City, for the present or any probable future demands, your present Works are amply adequate.

2. That for Water *power* during the summer months, to elevate the Water into the Reservoir up to ten millions of gallons per day, your present Works are also sufficient. But that they are only able to furnish the power to elevate five or six millions of gallons during the winter months, and, for a short time, (varying from one to eight weeks in each year,) they are nearly or quite useless; and during this period, the steam engine now in use has the power of elevating but about four millions of gallons per day.

3. That while the St. Lawrence river can furnish, to works similar to those now in use, water power sufficient *at all seasons*, to elevate any required quantity of water into the Reservoir, yet that, with your present works, and the fluctuations of the level of the river, and its consequent effects in severe cold weather, they are unable at such times to furnish the requisite power for even the present demands of the City.

A stranger readily perceives the strong feeling of favor which your Citizens and Engineers entertain, for the utilization of the immense water-power which surrounds your City. It is one of the most distinguishing characteristics of its location. With ocean vessels co-

* I have received great benefit in the examination of the plans, from a pamphlet written by Alderman Rodden, on the comparison of the plans of Messrs. Keefer, Shanly and others.

ming into your port, with shorter voyages from the great European markets; standing, as you do, an hundred miles nearer the chain of great Lakes, which penetrate the most fertile grain producing region of the world, from which inland vessels of large burthen can float and transfer their cargoes of the cereals directly to ocean-bound ships, or to mills, where such grains may be condensed in bulk and weight by cheap water-power. Such advantages of water-power ought not to be ignored by your municipality in its own works.

Nowhere else, on the American continent, do these advantages of transport and water-power unite as they do at Montreal; and hence it furnishes an additional reason why you should avail yourselves of this power to its utmost extent in your municipal works, and thus encourage its development for those other important purposes.

The several plans which have been presented, are as follows:—

First.—That of Mr. Keefer, which contemplates an extension of the present works by a Canal of about two miles in length up the river, where the level of the water is about three feet higher than it is at the entrance of the present aqueduct, and also a subsequent enlargement of this aqueduct.

Second.—That of Mr. Shanly, which proposes the construction of a portion of the extension by the River Canal, as proposed by Mr. Keefer, as far as the still water, below Fraser's Hill, and the enlargement of the present aqueduct, parallel to its present route, and contiguous thereto.

Third.—The construction of a new Canal of large size, and three feet deeper than the present aqueduct, from the River near Fraser's Hill, to the Pump works, intersecting the present aqueduct at 4,800 feet below its entrance, and thence parallel and contiguous to it to the Pumping works.

Fourth.—The plan of Messrs. Cooke and Plunkett, which is a covered conduit, of smaller size and with more descent, placed at a lower level, and following the line proposed for the third plan.

Fifth.—The abandonment of the present works, and the construction of new ones, jointly with the St. Louis Hydraulic Company, at Isle-aux-Herons.

Sixth.—The use of the present works up to their capacity, and supplying the deficiency of power by steam engines.

These several projects have been so thoroughly discussed in the Reports of Messrs. Keefer and Shanly, that I shall often be compelled to use their arguments in the expression of my own opinions, and can therefore be more concise.

I entirely agree with Mr. Shanly, in the inexpediency of connecting your Water Supply with the operations of any private Hydraulic Company, if it can be avoided.

When the Canals of New York were first built, the surplus water was sold or granted; and these connections in every case proved so injurious to the interests of the State, that they now have all been repurchased.

The tables furnished in Mr. Lesage's Reports, of the elevation of the water in the St. Lawrence at the Lachine Rapids, show that the back water sometimes nearly obliterates the fall, at the place selected by the St. Louis Hydraulic Company for their dam.

It is claimed that the new works will have the effect of lessening this back water, but I am not sufficiently acquainted with the river and the movements of the ice in that locality to form an opinion upon this claimed effect.

The power required to elevate the water into the Reservoir through pipes of more than twice the length of the present ones, would have to be much increased beyond that necessary at the present works.

The cost of construction, and the hazard and expense of maintaining these long mains, will also be increased.

If this plan should be adopted, your present works would be rendered useless, except for a supply of the water to be delivered to the City, when that at *Isle-aux-Herons* is unfit for use. It is quite probable that the cost by this plan, would eventually prove as great as by one of the others.

Under the circumstances of the case, I do not recommend the adoption of this plan.

The examination of some of the plans, requires a comparison between that of enlarging the present aqueduct, and of building a new one. I have had the opportunity of some long conversations with the Contractor who constructed the aqueduct, and the information derived from him confirms that which I had previously obtained from your Superintendent, who was also engaged upon the original construction.

Mr. McDonald describes very graphically the difficulties which he encountered, in placing a culvert at a depth of nine feet below the bottom of the present aqueduct, located about two-thirds of a mile below the entrance.

In the excavation for the aqueduct above this place, the water encountered was chiefly that from the adjacent land, and but little came in from the river. In the excavation for the culvert, however, the water flowed in very copiously, "bursting up from the bottom in a large volume, and with great force, and we all believed that it came from the river, through strata of coarse sand and gravel."

It is not certain that this large quantity of water came from the river, as supposed by the Contractor, but it is evident that in carrying an excavation to a depth of eight or ten feet deeper than the bottom of the present aqueduct, a large quantity of water will be encountered, under circumstances that will render this portion of the work very expensive.

Mr. McDonald said: "I would be willing to undertake the excavation of a Canal four to five feet deeper

than the present aqueduct, but no price that would probably be offered would induce me to excavate one to a depth of eight or ten feet greater."

The information which I obtained at Montreal, confirms to some extent the description of the difficulties which would be met with in excavating much below the bottom of the present aqueduct.

An enlargement of the aqueduct, would involve the necessity of providing for the passage of sufficient water for consumption in the City, at least, and of temporary steam power to elevate it to the Reservoir while the enlargement was in progress. The cost of these provisions, would be almost equivalent to the value of the excavation which has been made for the original work, which, with the other inconveniences of working while maintaining the supply, would overcome the advantages of this plan, and render it preferable to construct a new Canal.

Mr. Keefer's plan contemplates the erection of a wooden pier in the river, parallel with the shore, from the head of the present aqueduct nearly two miles up the river, and rendering it water-tight by a facing of earth. This plan would increase the depth of water in the present aqueduct about three feet.

The cost of a work like this, built in water from twelve to thirty feet deep, would evidently be very great. Mr. Keefer has made an estimate per running foot, amounting to $25; but I am not sufficiently acquainted with the value of such work in that locality to pass an opinion upon the adequacy of this estimate.

The wooden crib would be exposed to injury, and, I fear, destruction from the large masses of floating ice which would be driven against it. It is true that a similar pier has been in existence for several years at the head of the Lachine Canal, but this pier is in comparatively still water; and yet I saw one place where it had

recently been destroyed by the ice, and I understand that similar injuries are produced almost every season.

The area of the present aqueduct, with ten feet depth of water, is three hundred and twenty-five feet square; and with an increased elevation of three feet, it would be about four hundred and seventy square feet.

The ice is said generally to form to a thickness of about three feet, which would reduce the capacity of the present aqueduct nearly to that which it now has in the summer; and this has been found to be insufficient to meet the prospective demands for water in the City.

It is therefore evident that an enlarged water way is, or soon will be, required to take the place of the present aqueduct.

Under the circumstances of the case, I am of the opinion, that the construction of an enlarged new Canal will be preferable to the plan recommended by Mr. Keefer, on account of its greater certainty, efficiency and economy.

Messrs. Cooke and Plunkett claim for their plan over that of the others, "perfect certainty of supply, irrespective of winter difficulties, by drawing the water from a depth of fully ten feet below the surface at the entrance of the Canal near Fraser's Hill; and also thereby securing a greater purity of water."

They also claim an advantage in their small subterranean conduit, with a fall of six times that of the present aqueduct, over a large open Canal with a very small fall; and that their location permits of the construction of their conduit, without interference with the present works, and with greater economy; and also affords facilities for future enlargement.

It will simplify the examination of this project to

eliminate from it the advantages claimed, which are, or can be obtained by the other plans.

The advantage of a covered conduit, so far as it maintains the purity of the water, will be obtained in the open Canals during the winter, and at other seasons defilement may be prevented by outside drains and strict supervision.

The Syphon principle at the entrance of the aqueduct, which, it is claimed, will secure greater purity of water, escape from the frasil, and a certain supply of water at all times, can, if desired, be applied in precisely the same manner as proposed by Messrs. Cooke and Plunkett, on all of the open Canal plans.

In like manner, by giving the open Canals the same descent, as proposed by Messrs. Cooke and Plunkett, their sectional areas may be correspondingly reduced and the expense lessened, and when these areas (below the ice covering) are made equal to that proposed by Messrs. Cooke and Plunkett the quantity of water, which such open Canals will deliver, will be equal in the winter, and much greater for most of the year, when water is in greater demand.

In the open Canals the area can be obtained by a greater width than would be admissible, or at least advisable, in the arched conduit, and this greatly lessens the amount of the most costly part of the excavation in the bottom.

A further enlargement of the open Canals will be easy, but, of the conduit, would practically be equal to the cost of an entire new conduit.

The route proposed for this conduit, and the place of its entrance into the River, are the same as proposed by Mr. Lesage for the enlarged Canal. Mr. Shanly's modification of Mr. Keefer's plan gives an entrance at substantially the same place, and therefore both of these plans have the same merit claimed for the conduit plan, namely, of not interfering with the present works.

The details of the plan of Messrs. Cooke and Plunkett are not furnished in their communication; they have, however, given me verbal explanations as far as they have digested their plan. I am of the opinion that several material modifications would be found necessary to practically carry out this scheme, and, in the consideration of it, I have assumed that such modifications would be made as would be necessary to meet the objections to the original plan.

The enlarged Aqueduct, or Canal, proposed by Mr. Lesage, has a bottom width of sixty feet, side slopes of three to one, and the bottom excavated to a level three feet lower than that of the present Aqueduct, namely, at twenty-five feet above the datum level, giving eleven feet depth of water at its low winter stage in the St. Lawrence, and thirteen feet depth for the general summer level, and with a fall on the bottom of the Canal, of three inches per mile.

The Conduit proposed by Messrs. Cooke & Plunkett, has an upper semi-circular arch of ten feet radius, side walls of six feet height, battering inside one foot, and a segmental arch at the bottom of eighteen feet chord and one foot versed sine, (which I have assumed would be changed to three feet, and the arch lowered so as to give the same sectional area of conduit.) The descent of the conduit as given to me by Mr. Cooke was six feet in five miles, but, I have assumed it at the rate of fifteen inches per mile.

In the annexed table I have used Eytelwein's Formula $V = \sqrt{h.} \times 2f.$, which is not strictly correct, but, sufficiently so, for the purpose of making the general comparisons.

In computing the velocity of the water in the Canals when covered with Ice, (which I have assumed at a maximum of three feet thickness,) I have added this three feet to the descent, as suggested in Mr. Keefer's report.

TABLE.

		COVERED CONDUIT.	ENLARGED AQUEDUCT.	RATIO.
Areas.	At Winter low water 36 + Sq. ft.	281	1,023	1 to 3.64
	At Summer low water 38 + " "	281	1,287	" 4.58
	At 36 + with Ice 3 feet thick " "	281	672	" 2.39
	At 38 + " " " " "	281	900	" 3.20
Discharges per Minute	At 36 + Cu. ft.	51,620	111,375	" 2.16
	At 38 + " "	56,565	150,772	" 2.67
	At 36 + with 3 feet of Ice " "	51,620	84,672	" 1.64
	At 38 + " " " " "	56,565	122,760	" 2.17
Theoretic Horse Power	At 36 + H.P.	782	2,950	" 3.77
	At 38 + "	977	4,569	" 4.66
	At 36 + Ice 3 feet "	782	1,764	" 2.25
	At 38 + " " "	977	3,021	" 3.10

The sectional area of the enlarged Canal, will be from three and a half, to four and a half times as great as that of the covered conduit, when not frozen, and two and a third, to three and a quarter times as great when covered with ice three feet thick.

The practical comparison of the two plans, however, is shown by the theoretic power of each, as given in the Table, which is from three and three-quarters, to four and two-thirds times as great when not frozen, and from two and a quarter to three times as great when the enlarged Canal is covered with Ice.

The current in the enlarged Canal will be so much less than in the covered conduit, that, the quantity of frasil drawn into the former will be much less, and in this connection it may be suggested, that the frasil, when disengaged from the bottom of the River, at first floats below the surface, and is more liable to be drawn into the Syphon formed conduit, than it would be in a wide Canal of less depth.

The covered conduit would require an excavation carried to a depth of at least eight feet deeper, than that for the enlarged Canal, and for the reasons herein before stated, the cost of this increased depth of excavation would be very great. When to this is added, the cost of the Masonry, a large portion of which must also be laid

subject to the influx of water at this increased depth, and the extra width of the excavation for the side walls, together with the nearly total loss of the existing Pumping Works, I am decidedly of the opinion, that, the cost of this covered conduit, will be fully equal to that of the proposed enlarged Canal, and will not furnish the same power.

It is therefore evident, that, the plans of Messrs. Cooke & Plunkett, not only have no advantages over that of the enlarged Canal, but are decidedly inferior to it. There are also so many practical difficulties and objections to this plan, that, I am constrained to recommend that it should not be adopted.

From the foregoing discussion it would follow, that, the plan of an enlarged Canal on a new route, is the proper one to adopt. Its dimensions and particulars of construction, will be the next subject for examination.

The present population of Montreal is probably about one hundred and fifty thousand. The number of water takers is from one hundred and ten, to one hundred and twenty thousand, having doubled within the last ten years. Whenever a liberal supply of water is furnished, the consumption is equal to about fifty gallons for each person.

It has been found in the large Cities in the United States, that, the consumption for all purposes is equal to seventy-five gallons per head. If the population of Montreal, should again double in the next ten years, it is quite certain that there would be a demand for more than fifteen millions of gallons per day.

Mr. Shanly estimates the capacity of the present Aqueduct, with the water at the entrance thirty-eight feet above the datum, as equal to four hundred and twenty actual horse power, capable of delivering ten millions of gallons daily into the Reservoir. Mr. Keefer considers the capacity somewhat greater. By Mr. Shanly's estimate, it would require an Aqueduct of a capacity

of about thirteen hundred theoretic horse power, to furnish fifteen millions.

By the above Table, a Canal of the size proposed by Mr. Lesage, would furnish a power, capable of delivering twenty millions into the Reservoir when the water level at the entrance was at thirty-six feet above the datum, and the Canal was covered with ice three feet thick; and fifteen millions if the ice should even form four feet thick, with an entrance level of thirty-five feet above the datum. The last case is not a probable one and can only be regarded as a remote contingency.

Machinery of the character of that which will be necessarily used for these works, (the gates, wheels, pumps, valves and mains,) are peculiarly liable to derangement and breakage, especially during the severe cold weather of a Northern climate, and therefore an excess of power should be provided.

Mr. Sippell informed me, that, in the worst times the Lachine Canal had an area of five hundred square feet under the ice, with a velocity of fifty feet per minute, which indicates a fall of but two inches per mile, and a theoretic horse power, under fourteen feet head, of six hundred and sixty-three, and he stated, that, at such times the ice formed to a depth of three feet, while at the same time the ice on the Water Works Aqueduct, was in some places six feet thick, and he is of the opinion, that, in a wide Canal like that of Lachine, three feet is the extreme thickness which the ice will form under the usual circumstances. He also states, and Mr. Lesage and others agree in the opinion, that, the extreme thickness of the ice will be less in a Canal as wide as the Lachine, as it has been found to form in the present Aqueduct.

Although my impressions would have been in favor of a Canal of somewhat smaller dimensions than those assumed by Mr. Lesage, yet under all the circumstances stated and especially after giving due weight to the better knowledge possessed by Messrs. Lesage & Sippell,

of the climate and its practical effects upon Canals so similar to the one proposed, I am of the opinion, that, the dimensions assumed by Mr. Lesage are proper.

Mr. Shanly recommends that the entrance of the new Canal to the river, shall be made near that of the present aqueduct, and then be extended to near Fraser's hill, by a crib work in the river, upon the plan recommended by Mr. Keefer; while Mr. Lesage is of the opinion that a new inland Canal had better be made, from near Fraser's hill to an intersection with the line of the present Aqueduct, at 3,400 feet below its entrance.

The question of cost should mainly control this part of the location. If the inland Canal can be made nearly as cheap as the other, I would prefer it, under the belief before expressed, that the long wooden crib in the river is very liable to injury from the heavy drift ice. On the other hand, a basin of comparatively still water, such as the crib work would produce, would undoubtedly lessen the amount of floating frasil entering the Aqueduct.

The place selected by Mr. Lesage, for the entrance of the Canal, is decidedly better than that of the present aqueduct, as there is a considerable eddy or bay of still water. The existence and extent of this bay was demonstrated by the course of a half a dozen floats, which were placed in the river channel, half a mile above Fraser's hill, at different distances from the shore, all of which passed outside of this eddy or bay, and indicated that the course of the water and floating ice, &c., would be outside, and leave this bay still water.

It is generally believed that the frasil does not form under the ice or any other covering over the water, and hence, that as this bay will freeze over early in the winter, no frasil will form at that place, and the course of the current in the river will carry that which is detached from the bottom above this entrance, mostly outside of this bay.

The formation of this kind of ice does not seem to be generally understood, and I therefore make two

extracts in regard to it. The first is taken from a Report of Mr. Keefer on the Water Works of Ottawa, and the second from the Report of the Detroit Water Works.

Extracts from Thos. C. Keefer's Report on the Water Works for Ottawa,—page 13 *et seq.*

"The Lachine Rapids is open throughout all the year, and, though below the freezing point, is only prevented from congealing by its motion. Under this open water a granulation or formation of ice takes place on the bottom of the River, which is the effect of rapid radiation, the cold rapid surface-current acting on the bottom like a cold wind on the human body. The process is analogous to hoar-frost by night radiation from a warm soil into a cold atmosphere, and in both cases is arrested by any covering. Thus this formation of anchor ice (frazil) never takes place when the surface is frozen over, nor under the arches of bridges, etc., in open water. During the continuance of extreme cold, this growth of icy moss, at the bottom of the River, goes rapidly on, increasing in intensity just in proportion to the degree and duration of the cold, until, at a season when all land streams are reduced by frost to a minimum discharge, and when the River volume is known to be less than at any other period, and to be daily diminishing, a sudden rise of the surface, more rapid than could be produced by any freshet, takes place."

* * * "These severe cold terms are usually followed by a rapid rise of the thermometer, and when the air gets to about 40° the anchor ice leaves the bottom and bursts up to the surface. * * *

"This detached ice, called "*frasil*" by the *habitants*, being nearly of the same specific gravity as water, *floats chiefly below the surface*, and is easily drawn by any current under the fixed surface ice."

Extracts from the Report of the Water Commissioners of the City of Detroit for 1867, pages 11 et seq.

"Occasionally during cold weather, interruptions to the pumping have occurred *as heretofore* by the formation or accumulation of Ice (frasil) on the strainer, over the end of the inlet pipe. Experiments suggested by scientific minds have been tried, which although they failed to overcome the difficulty, resulted in disclosing a singular fact in regard to this most singular phenomenon, which is fully explained in the Report of the Committee hereto appended."

Extracts from the Report of the Committee.

"After describing at length the shape and position of the inlet

pipe, which is of boiler iron, 30 inches in diameter, 220 feet long, and submerged in water 34 feet deep at its extremity and the piles driven to secure it against the anchors of vessels and adding, that, "when the Engine is pumping, the pipe must deliver 120 barrels per minute," they add, "under certain circumstances, during extreme cold weather, it is with difficulty that a supply of water can be obtained, in consequence of the Ice (frasil) on the strainer frequently requiring the speed of the Engine to be reduced, and at times to stop it for several hours together, no water passing into the pump well. The circumstances under which the difficulty occurs are, when the weather is cold and Ice is forming in the Lake above, and on the shores of the River, and the River is free from Ice over the strainer. But when the River is covered with Ice over the strainer, the difficulty does not occur at any degree of cold. The greatest difficulty occurs when the thermometer ranges from 7 to 18 degrees (Farenheit) above zero, but when the mercury rises above 20 degrees the difficulty soon ceases. The greatest number of detentions occur at night, and when the sun is obscured by clouds; but, when the sun is unclouded no difficulty is ever experienced. This peculiar stoppage of the water has been encountered for many years." * * * *

It has now reached a point when "this remarkable phenomenon must be solved, and the difficulty overcome. Your Committee have adopted every accessible means of investigation to obtain suggestions and information on this subject. * * * Men of science have been seen and corresponded with, and scientific associations have been requested to investigate the subject, but as yet no complete remedy has been discovered. * * * The theory of anchor ice (frasil,) was so strongly presented, that in the summer of 1866, we caused a diver to cut an opening on the lower side * * *

"When the River was entirely covered with ice no trouble was experienced. We then suspended a beam of logs until the ice formed inside of it, but failed to accomplish the object. The theory that the covering of the entire surface of the River by ice prevented radiation, and by that means the ice (frazil) did not form on the strainer (of the inlet pipe) was strongly urged, and if so, any covering over the strainer would answer the same purposes. To test it we last summer employed divers to build a platform above the strainer, which proved of no avail, for the stoppages (of the water) the succeeding winter occurred at (even) a higher temperature than before."

"On the 20th of December, 1866, Mr. Harrington (the Diver) went down to the strainer. The thermometer was 26 degrees, and

he discovered that the strainer and the piles around it were one mass of ice particles collected in a mound 10 feet high and 15 feet diameter, and *that large quantities of minute crystals of ice were rapidly passing* and adding to the mass already collected. Specimens of the ice were brought up in a bag. They were in sheets and particles thin as paper, translucent, with sharp pointed edges." * * *

"We thought we were about to solve the problem and provide a remedy for the difficulty, especially as a similar experiment had been successful at the Buffalo Water Works.

* * * The weather became colder; the thermometer indicated several degrees below freezing * * * At 11½ a.m. went down, and this important fact was ascertained,—that with the temperature of the atmosphere at 29°, the water at the surface at 33°, at the bottom of the river it was 35°, and much less ice (frasil) was found round the pipe * * * Three hours later, the diver again descended, (thermometer at 33°) and found that the ice had entirely disappeared," * * * "Your Committee, by the aid of the diver, have ascertained the fact, that at certain temperatures, these ice particles (frasil) are ever present in the river, and are continually passing down with its current, and whatsoever obstructions they meet with, they collect upon."

These extracts, and the opinions of persons experienced in the formation of frasil in Canadian waters, substantially confirm the views which have been above expressed, in favor of the location of the entrance of the new enlarged Canal, at near Fraser's hill, and against the Syphon method of forming this entrance.

The experience obtained by your works, enables you to determine the relative merits of Breast Wheels and Turbines. For your works, and especially after they have been enlarged as proposed, I am of the opinion that Breast Wheels will be the most suitable.

These now built, including the Turbine, may be regarded as having capacity sufficient to supply at all seasons, ten millions of gallons daily: with an enlarged Canal, and when the demand shall exceed this power, additional wheels and pumps can be added as they are required. Whenever such demand approaches the whole

power of the new Canal, it will become advisable to lay down additional force mains.

It has been suggested, that it was desirable to provide a supply of water to certain portions of the City, which are too elevated to be accommodated from the present works. When the new Canal has been completed, this can be accomplished by arranging a wheel, pumps,—extension of one of the force mains, (or an independent one,) and reservoir, at such higher elevation, but as the demand for this upper service will probably be comparatively small, the force main from this pump should have a water gate and branch pipe leading to the lower reservoir.

It will be understood, that the distribution pipes of the upper service must not be connected with those of the lower, except at particular places, where water gates can be placed to control the connection. This arrangement of two services at different elevations, has been in use in Albany for twenty years, and works well practically. In the event of a large conflagration, by opening the water gates between the two services, all of the water then in the pipes of the lower service will be instantly placed under the head due from the upper reservoir, and the hydrants and hose alone, at Albany, have extinguished fires without the aid of the fire engines.

I examined a location for a large reservoir, selected by Mr. Lesage, on the Priests' Farm, proposed to be built at the same elevation as the McTavish reservoir, and designed to contain 136 millions of gallons.

The site is a favorable one and the Reservoir may be made in two divisions, each at different times, so as to spread the expenditure over a longer period.

I regard a large storeage Reservoir, at an elevation high enough to supply the City, and placed as near the centre of consumption as possible, as a most important element in a well arranged system of water works.

The importance of such a Reservoir is greatly increased when the system of supply is dependent upon

machinery and mechanical power, and this importance is again increased in your case, when your power is obtained by the use of waters flowing through a comparatively long Canal, debouching from a large River which annually sends down great masses of Ice, which at some period may block up the entrance.

You have experienced the results of the cold weather upon your present works, and though a similar result in an enlarged Canal is only remotely probable, yet it cannot be said to be impossible, and taken in connection with the hazard of the failure of either of the forebays, machinery, or force mains, greatly strengthens the argument in favor of a large storing Reservoir.

With such a Reservoir you will be able to annually examine and repair your Canal and the mechanical works, and thus lessen the danger of their breakage at times when it would be difficult to repair them.

Almost every large American City, including your own, has at long intervals been visited with extensive conflagrations. On such occasions the demand for water is often more than such machinery as you will have, can supply, and this demand is frequently continued for a length of time, which would exhaust your present Reservoirs.

Under the excitement produced by such rapid and enormous destruction of property, it would be almost certain that your machinery would be forced up to its utmost capacity and thus greatly increase the hazard of its breakage, and that too, at the precise time when it would be most disastrous.

On the other hand, with a large Reservoir to draw from, the head of water in the pipes would be maintained at its maximum height, and they would deliver more water, and with greater force, than would be safe from the mechanical power.

Apprehensions have sometimes been expressed, that water stored for a long time in Reservoirs might become contaminated and unfit for culinary use.

Such contamination has taken place at long intervals in the water contained in the Reservoirs at Boston, New York, Albany and some Western Cities. After patient investigation it has been ascertained, in all of these cases, that the defilement of the w ter arose from the sudden generation of animalculæ vegetation, the germs of which were either in the water or carried to it by the winds. To produce this generation it is necessary that the water shall have been quiescent and at a high temperature for a long time.

This ephemeral life, following a law of nature, has an existence as short as its generation is rapid, and the defilement of the water takes place only during its decomposition, which continues but a few days, a brisk wind for a few hours being sufficient to carry off the gases of decomposition, and leave the water pure and wholesome.

As your works are arranged, if either the water from the River or from the Reservoir, should ever become contaminated from any cause, it is almost impossible that both would be simultaneously affected, and hence you can resort to the one which is most pure, until the other has also become so.

Except in the cases cited, the storage of water in suitable Reservoirs tends to purify it. Being quiescent, all foreign matter which is heavier than water settles to the bottom, and that which is lighter floats upon the surface. Professor Silliman says, that animal and vegetable decomposition does not take place in water below a depth of twelve feet, and hence such matter which falls to the bottom produces no effect, except by the slow dissolving process. The foreign matter which floats upon the surface, is quickly dissolved in gases and carried off by the winds.

This process is illustrated in the great Lakes above the St. Lawrence, which are supplied from turbulent streams bringing down to them muddy water, and the filth from large populations, all of which however is

either precipitated to the bottom or evaporated from the surface of these quiescent Lakes, and produces the beautiful, clear and pure water of the St. Lawrence.

The new works which have been above recommended will require several years for their construction, and in the meantime the necessities of the city require a temporary increased supply.

On the 24th of August last I addressed to you a letter, part of which I transcribe herein, with a renewed recommendation of the necessity of an additional steam pumping engine.

Extract from a communication made to the Water Committee August 24th, 1869.

"It thus become obvious to me that if you should adopt any of the plans which have been offered for furnishing power by water, that their execution will require several years, and, meanwhile, you will be subject to the inconveniences and expense which you have already experienced before resort was had to steam-power."

"As a *merely temporary measure*, therefore, I am of the opinion that it is necessary that you should at once provide additional steam-power, at least equal to that now furnished. * * * In making this recommendation, I do not wish to be understood as approving of steam-power instead of water-power for your permanent works."

On further consideration of the subject, I believe that a non-condensing steam engine will answer the purposes now desired. The expense of such an engine will not be one-third of that of a condensing engine of the same power.

It is true that the cost of performing the same work will be considerably greater by a non-condensing engine, but it will not probably be required to be used for more than one, or at most, two months in any year during the construction of the new works, after which it will only be required on rare occasions.

Therefore the interest on the difference of cost between it and a condensing engine, will, probably, be sufficient to pay for the increased amount of fuel which the non-condensing engine will consume.

If, however, you should decide to construct an additional condensing engine, I would recommend to your consideration the plan of one which I have just put in operation for the New Bedford Water Works.

After many years of study upon this subject and the operations of three engines of large size, which I have built upon this plan, I am convinced that it is superior to any of the pumping machines in use, at least in this country, having reference to the cost of construction and operating simplicity, the small liability to get out of repair, and ease of repairing or replacing any defective part, but especially in its conformity to well-established principles of mechanism.

This machine is not an invention, but corresponds almost exactly to those constructed for the same purpose, more than 80 years ago, by James Watt.

The leading principles which should govern in such a machine are:—

1.—That steam and water cannot be moved at the same velocity without a considerable loss of power. The former is very light and elastic, and the latter seventeen hundred times heavier and inelastic. Hence, all direct acting pumps are wrong in principle.

2.—That water cannot be abruptly changed in its direction or form of volume without great waste of power, and hence, double-acting pumps, which must have two absolute reversals of the water, are much inferior to single-acting pumps, where these reversals are avoided.

That the induction and delivery pipes of the pumps should be in straight lines, or where necessary, in curved lines of large radius, and with no changes, or at least with very gradual ones, in the passage of the water to, through and from the pumps.

That valves, which produce the least distortion of the form of the volume of the water, and without unnecessary changes in its direction should be used.

3.—That in reciprocating engines and pumps, the

power developed by the steam should be wholly exhausted (if possible) at the end of each stroke, and that. (unlike almost all the other applications of steam power,) the perfection of motion of the stroke of a water pump piston, is a slow commencement, increasing speed to the middle of the stroke, and a gradual reduction, until at the end of the stroke, the power (including the momentum) is barely able to carry the engine over its centres.

In a Cornish pumping machine the steam engine and its pump work independently, and are, in fact, two distinct machines.

The load on the pump is carefully adjusted to overcome the resistances of the water and exhibits the natural and nearly perfect movement, which ought to be given to water passing through a pump.

The ordinary application of steam working expansively in the cylinder, produces precisely the degree of speed in every part of the stroke of the water piston that is desired.

The Watt pumping machine, accomplishes all of these objects better than any other in use.

It is a vertical beam engine; the steam cylinder is placed under the end of the beam, and the water cylinders at such distances toward the main centre as will give the exact relative speed to the steam and water pistons.

Two single acting pumps are placed, one on each side of the beam centre, with the delivery pipes carried off from the pumps, on gentle curves, to the force main.

The valves are similar to those ordinarily used in the air pump. The fly wheel is made as light as possible, being only used to carry the engine very slowly over its centres, and the cut off is so adjusted, that almost the whole power developed by the steam is exhausted at the completion of each stroke.

There is therefore no concussion, or wrenching of the various parts of the machine at the end of the stroke, where the direction of its reciprocating parts are changed,

and the machinery, except the rubbing surfaces, must therefore endure almost indefinitely.

The water, starting from the pump well, passes to, through and from the pumps to the force main, without change of direction, in straight lines, or gentle curves, with small changes of form of volume or direction, and therefore its resistance from these causes, is reduced to a minimum.

It is safe, therefore, to claim for this machine as effective a duty as can be obtained by any other pumping machine.

This machine is simple in construction, and the steam engine part corresponds with that in use in most of the large engines built for other purposes. Its cost is therefore reduced to a minimum. It can be built, or repaired at any good machine shop, and can be run with perfect safety by a moderately good mechanic, in fact by any one who can run an ordinary river steam boat.

There are no patents upon any portion of the machine.

My time has not allowed me to re-write and condense this report, and I, therefore, present a condensed summary of the results which have been arrived at in the preceding discussions.

SYNOPSIS.

The following projects have been considered.

1.—The use of steam power, wholly, or as an adjunct to the works.

2.—The abandonment of the present works, and the construction of new ones in connection with the St. Louis Hydraulic Company.

3.—The enlargement of the present aqueduct.

4.—The Keefer plan. An extension of the present works by a Canal two miles long up the River, and a subsequent enlargement of the present aqueduct.

5.—The Shanly plan. An extension up the River

to Fraser's Hill and an enlarged independent Canal parallel to the present one.

6.—The Cooke & Plunkett plan. A covered conduit of small size placed at a low level, with a great fall on the Lesage route.

7.—The Lesage plan. An enlarged independent Canal from Fraser's Hill to the present pumping works.

The conclusions arrived at are :

1.—That the use of steam power, except as an adjunct and for temporary purposes, would be as costly as water power, and inexpedient.

2.—That it would be inadvisable to abandon the present works and construct new ones in connection with the St. Louis Hydraulic Company, on account of the expense, the uncertainty of the power at all times, and the many objections to connecting public and private works of this character.

3.—That the difficulty and annoyance of maintaining the supply by the present aqueduct while it was being enlarged ; the additional cost of such enlargement while maintaining a supply to the City, and that of temporary steam power to elevate it, render it preferable to construct a new independent Canal.

4.—That the hazard of maintaining a wooden crib of two miles length along the shore of the River, annually subject to the destructive action of the large masses of ice moving in a rapid current, added to the cost of the work and that of an enlargement of the aqueduct at an early future day, renders this plan inferior to that of an independent Canal, on account of the comparative certainty, efficiency and economy of the latter.

5.—The fifth project will be considered in connec-connection with the seventh.

6.—That the Cooke & Plunkett plan has none of the advantages claimed for it, which may not be as well obtained by the seventh plan, and has many practical objections and difficulties, and is inferior to the latter in efficiency, capacity and economy.

That the plan of Mr. Shanly or Mr. Lesage, and particularly the latter, is the one recommended, and that the location (with a slight modification at the entrance), and the dimensions proposed by Mr. Lesage are proper.

Breast-wheels are recommended whenever additional power is required; also an independent upper service and Reservoir to supply the higher portions of the City.

A large storage Reservoir is earnestly urged, as necessary to provide against a possible obstruction of the Canal or the failure of the complicated machinery, and to enable examinations and repairs to be made in these works, and as securing, during extensive conflagrations, a more abundant and certain supply of water, under greater head, and also in securing against any future defilement of the water which is to be served to the City.

The immediate construction of another steam pumping engine is urged, to provide against disasters similar to those recently experienced, and for occasional temporary use, during the construction of the proposed new works.

A non-condensing engine is recommended for this purpose, but if the Committee shall decide in favor of a condensing engine, one of the James Watt pattern is recommended, as less expensive in construction and in operating, less liable to breakage, and more correct in principle, than any other pumping engine in use.

In conducting this examination I have had occasion to make estimates of the cost of the various plans, and calculations in regard thereto, which were sufficiently accurate for the purpose required, and for the comparisons made in the argument; but, as the data furnished me was not complete, it would not be advisable to insert these estimates in this communication.

I have, to a considerable extent, relied upon the

estimates made by Messrs. Keefer, Shanly and Lesage, modifying them where my opinions, in regard to the plans or cost of the work, differed from those gentlemen.

In regard to the prism of the new Canal, I have followed the opinions of Messrs. Lesage & Sipple in making the estimates of its cost and capacity. The experience of these gentlemen on the effect of the rigorous climate upon Canals, so similar to the one proposed, entitle their opinions to great weight. Before new works are commenced, it may be advisable to have this question of the form of the prism again carefully examined.

Before I could advise, in regard to the details of the protections and form of the entrance to the new canal, it would be necessary to obtain more information than I now have, of the action of the ice and frasil which pass down the river at that place.

Whenever you shall have determined upon the general plans of the new works, I will be happy to furnish your Engineer with some further suggestions, in regard to the details and execution of the work, which have occurred to me during the present examination.

Respectfully submitted.

WM. J. McALPINE,

Civil Engineer.