PRELIMINARY REPORT

ON

THE WATER SUPPLY

FOR THE

CITY OF MANCHESTER,

MADE TO THE

DIRECTORS OF THE CITY AQUEDUCT COMPANY,

NOVEMBER 23, 1869.

BY

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CIVIL ENGINEER.

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REPORT OF ENGINEER.

To the Directors of the City Aqueduct Company:

GENTLEMEN: —

In view of the fact that the citizens of Manchester are to be called upon at the approaching municipal election to vote on the question whether it is expedient for the city to contract with your company for the purpose of introducing water from the Massabesic into the city, it seems desirable that all the information on the subject which is now at hand should be communicated to the public.

You are aware that the surveys instituted under the vote of your board passed October 28, and under the resolution of the City Council of October 5, are still incomplete, and consequently but little can be said of their results.

But I have, at intervals of other engagements, studied the subject considerably, made some preliminary surveys, and collected many items of information bearing upon the general subject of water supply, which may be of interest to the people of the city. I therefore beg leave to submit the following

REPORT.

An abundant supply of pure and wholesome water is everywhere one of the first requisites for health, cleanliness and comfort. It is especially so in large towns and cities. But in these places the supply from the ordinary sources, the wells and springs, is certain to fail in one or all of these qualities. It usually becomes, in process of time, neither abundant, pure, nor wholesome. In all such places the earth is constantly becoming contaminated by the secretions and excretions of animal life, the ashes from fuel, the rubbish from demolished buildings, and from new buildings erected, the waste products of domestic life, and of chemical and mechanical manufactures.

When the town is new, the earth under it, acting as a filter, arrests most of these contaminations at or near the surface. But in a few years they penetrate to greater depths and affect the wells. We may especially expect this to be the case when, as in Manchester, the filter-bed is not very deep, and is traversed in many parts by veins of coarse, dry gravel through which water may find its way with great facility.

The soil on which the compact part of the city is built, being generally of a loose and sandy nature, formerly absorbed the rain with avidity, and being underlaid at no great depth by an impermeable bed of compact clayey quicksand, it was once easy to get water for domestic uses in abundance and of fair quality, by sinking wells to the depth of ten or fifteen feet. The surface sand was a great natural filter-bed which served to store up and purify the water that it absorbed, and to give it out slowly to the wells and springs. But these wells and springs have generally deteriorated both in the quantity and quality of the water which they afford. Every year wells are failing and requiring to be made deeper. Others become unsatisfactory and are abandoned for new ones, or for rain-water cisterns.

Let us look at some of the principal causes of this deterioration. The decrease in quantity is occasioned in part by the increase of the area covered by roofs, streets and side-walks, all of which, in proportion as they approach perfection, prevent the rain-water from soaking into the earth, and turn it away on the surface, or into the sewers. The sewers also drain away a great deal of the underground water. The cement sewers, in particular, have many openings at their joints into which water readily percolates; and being laid, in many places, upon, or partially below, the surface of the impervious stratum on which the water is found, they operate precisely like the tile-drains laid by farmers for draining land. Both of these causes must continue to increase in extent as the city becomes more compactly built and increases its area.

The causes of deterioration in quality are equally obvious. The filter-bed, having no great depth, is gradually becoming choked up. It does not pass so much water as formerly, nor purify it as well. A larger proportion of the water in the wells finds its way there without filtration, that is, through fissures and crevices, such as are to be found where quantities of small stones or brickbats are covered up, or where buried wood decays, or old disused drains are left in the ground. Or, if in some cases the process of filtration still goes on, so does likewise that of lixiviation, and thus the water exchanges one set of impurities for another. Water may be at the same time clear and bright, and yet very impure. Sea-water is a well known example.

Many localities in the city have been filled in, and this has not always been done with choice materials. Witness the mass of filthy rubbish which has accumulated in the ravine south of Granite street, and which is now being covered up by the grading operations in progress there. The water of that locality was formerly good so that the place was used for picnic parties and out-door celebrations. But I suppose no person expects that it will ever be good again.

The circles of contamination around stable cellars, sink drains, privy vaults, pig-sties and leaky gas-pipes are constantly widening and becoming intensified. When we consider that the impurities from these and many other sources are now intruding themselves into a diminished quantity of water, it is not strange that many wells are gradually but surely becoming unfit for use.

It is evident that the action of these causes must likewise increase with the age and growth of the city. We are simply trying the experiment which every populous town in the world has to go through with, and which, in every civilized community, has ended and must ever end in the introduction of water from abroad. This experiment is now so far advanced, that by the common consent of our people we seek for a new and better supply.

The first question that arises is that of

THE QUANTITY REQUIRED.

This can only be estimated roughly from the experience of other places where such a supply is enjoyed. The population of Manchester, according to the census of 1860, was 20,109, the increase for the previous ten years being 44 1-3 per cent. on the population of 1850. Assuming the same rate of increase for the next two decades, the population of 1870 will be 29,000, and that of 1880, 42,000. There are many well informed persons who believe the next census will show that this ratio is more than maintained. But if it is only maintained, and if we are to provide works which may be expected to prove sufficient for ten years from their completion, we must calculate on a population of 42,000. The number of gallons* consumed per day for each individual is found to vary considerably in different cities, as well as in different months of the year in the same city. In our climate the consumption is generally greatest in midsummer and midwinter, and least in the spring and autumn. Of course the works should be so constructed

*The gallon used in this report is the American Standard Gallon of 231 cubic inches. When reduced to cubic measure it is treated as 2-15 of a foot, or 230.4 inches, an approximation sufficiently near for our purpose.

and the source so chosen that any such irregularity in the demand may be met without inconvenience.

In the city of Cambridge the water works came into the possession of the city by purchase in April, 1865. The population was then 29,114, and the average daily consumption, from May 1 to Dec. 1, was 974,032 gallons, or about 33 1-3 gallons to each person. The works were found inadequate to the proper supply of the city, and have since been much enlarged and improved. Last year, with a population estimated at 36,000, the average number of gallons pumped daily was 1,732,755, being more than 48 gallons for each individual; and the present consumption is stated to be about two million gallons per day.

In Hartford, for the year ending March 1, 1865, the daily average quantity actually pumped was about 1,560,000 gallons. The population being 34,135, the average to each person was 45 3-4 gallons.

Here again the supply was insufficient. The commissioners report that "it has not been possible to furnish supplies to new demands as fully as desired, or to grant so free a use of the water for many purposes of minor importance as has been applied for." Since that time the supply has been much increased by the introduction of water from a stream in West Hartford, and the average daily consumption for 1866 was reported at "fifty gallons for each inhabitant, calling the population of the city 40,000." Since that year the consumption is not reported.

In Charlestown the water was introduced November, 1864. The enterprise had met with strong opposition, and one of the principal objections urged against it was that everybody was supplied by wells, and but few would incur the expense attending its introduction into dwellings, and the rates for its use.

What was the result? The commissioners, in their next succeeding report, say: "It is gratifying to know that in this the third month of its introduction, the water is already supplied to 990 families, 52 stores and shops, 17 manufacturing establishments, 43 stables, 10 saloons, 4 engine-houses, 1 church, 1 armory, and the McLean Asylum at Somerville. There are further applications for water from 418 families, 25 shops and stores, 8 manufactories, 18 stables and 2 saloons."

Since that time the consumption has steadily increased, and in the year 1868 the works supplied, in Charlestown, Chelsea and Somerville, 4,693 dwelling-houses, 6,861 families, 311 stores and shops, 47 manufactories, 249 stables, 10 tug-boats, 11 fire-engine and hose houses, 51 public schools, 18 saloons, 40 offices, 13 churches, 4 armories, 4 hotels, 3 railroads, 1 brewery, 2 tanneries, 2 gas-houses, and various other miscellaneous establishments. The amount of water pumped was 30 1-2 per cent. greater than in the preceding year, and the average number of gallons drawn per day for each inhabitant varied in different months from 36 in March to 49 in December, and for each *consumer* from 56 in March to 77 in December.

In Boston, when the Cochituate works were projected, it was estimated that 28 1-2 gallons per day to each inhabitant, would be sufficient. This was based on the experience of London and Philadelphia. The Cochituate works were opened in October, 1848. The consumption at once outran the estimate. In 1850 it was 42 3-4 gallons, and in 1861 it had risen to above 100 gallons for each individual. Since that time some measures have been taken to prevent waste, and the daily average quantity consumed since 1865 ranges between 60 and 70 gallons.

Mr. J. H. Shedd, civil engineer, in a recent report upon a supply for the city of Providence, gives a detailed estimate, based on the experience of Boston, and taking into account the greater proportional number of steam boilers and manufacturing establishments in Providence. He concludes that that city will require a supply of 93 gallons per day for each person, if used with strict economy, or 120 gallons if used as water is ordinarily used in Boston. And he adds a remark which may with equal force be made to this community: "I suppose the citizens will prefer to sustain larger works, rather than submit to the constant oversight of police and inspectors upon their premises, to see that the water is not wasted."

Boston and Providence, being maritime cities, compactly built, will obviously require a greater quantity of water in proportion to population than Manchester. We have no shipping and steamboats to be supplied, and a considerable part of our population, living in the suburban villages and on farms, will never require to be supplied from any public works.

In regard to the other cities named, it may be urged that the greater number of wealthy citizens who can afford to use water freely in their houses, stables and gardens, as well as the greater number of steam boilers, make their experience unreliable for us; but it may fairly be presumed that ten years will make a great difference with us in these respects, and it should not be overlooked that an abundant supply of good water will of itself be one of the chief agencies in the growth of the city.

It is true that most of our large manufacturing and mechanical establishments have an independent and unfailing supply of their own, and this fact should be taken into the account in making up our estimate; but in view of the facts presented, it seems hardly possible to estimate the daily consumption at less than 50 gallons for each inhabitant. At this rate we shall want, for 42,000 persons, 2,100,000 gallons daily; and the source should be so selected and the works so constructed, as to admit of a large subsequent increase.

It is doubtless true that a large proportion of the water furnished to the cities to which we have referred is wasted. The city engineer of Boston thinks that is the case with one quarter part of the water drawn from the Brookline reservoir. Complaints of reckless and culpable waste abound in annual reports of water boards and superintendents throughout the country. Vigilant officers and stringent regulations may do something to check this evil, but the use of meters is the only sufficient remedy; but their great cost has hitherto prevented their general introduction. It has generally been found better to increase the supply than to furnish meters. A cheap, durable and reliable meter is yet to be invented. Until it is invented we must be content with the same experience that falls to the lot of all other water-works.

WELLS AND SPRINGS.

The idea has sometimes been expressed by persons who have not fully considered the subject, that a supply of water can be procured by digging for it, in the high ground east of the city. Let us see whether this quantity of water can be obtained from wells and springs.

In this region of primitive and metamorphic geological character, it is beyond question that all the subterranean water is derived from rain falling on the surface. No district of any considerable extent derives its underground water from another considerable district. But a much smaller proportion of rain-water penetrates the earth to the depth of an ordinary well than is commonly supposed. Some observations made on a small scale, near Ferrybridge, in Yorkshire, England, and continued through five years, beginning with 1842, indicate that less than one-fifth of the rain-fall penetrates to the depth of three feet in magnesian limestone soil.* To those who have had the

* Rudimentary Treatise on Drainage, by G. D. Dempsey, C. E.

care of house-plants, and have noticed the considerable quantity of water that may be poured upon a potful of moderately dry earth, without causing any percolation into the drain-cup at the bottom, this statement may not seem unreasonable, especially when it is considered that in this climate the earth is usually sealed up by frost for about one-third of the year, during which time absorption is reduced to very small proportions.

The amount of absorption varies, of course, with the nature of the soil. Sand takes water more readily than clay. If we assume that in our soil one-third of the water penetrates to the depth of three feet, we must suppose that even a smaller proportion goes to a greater depth, and that no system of wells or drains, however elaborate, can intercept all the water that penetrates to them, but that some quantity will inevitably go deeper into the earth and be lost.

But, disregarding these considerations, we will assume, for our present purpose, that one-third of the rain-fall may be intercepted under ground and secured in the form of well-water. By reference to the table of rain-fall,* it will be seen that the average for this vicinity may be supposed to be about 43 or 44 inches, or 3.6 feet per annum. One-third of this is 1.2 feet. The daily quantity to be obtained from an acre will be $\frac{1.2 \times 43560 \times 7.5}{365} = 1074$ gallons. At this rate it will require 1955 acres to give us the quantity we seek. If we suppose that we should need six wells to an acre, their total number would be 11,730, and estimating each one, with its connection with the main pipe, to cost fifty dollars, the whole cost of our source of supply would be $586,500.

If it be objected to this view, that some wells do actually furnish more than this quantity of water, we reply that

* Appendix A.

these are the exceptions to the rule. There is a far larger number that do not afford 100 gallons per day, and this notwithstanding the fact that wells are usually located in what is thought to be the most favorable spot in the vicinity for a good supply. And besides, there are seldom, if ever, five other wells on the same acre, each yielding 1000 gallons per day. Nor does it prove the fallacy of these calculations to say that the present supply of the city is drawn from probably about one-eighth of this number of wells; for,

1st. The present supply is confessedly insufficient.

2d. We seek a supply for a larger population.

3d. Water will be used more lavishly when it flows freely from a tap, than when, as now, it has to be pumped from a well by manual labor.

4th. A considerable part of the water for household use, and nearly all of that for extinguishing fires, is now drawn from brooks, rain-water cisterns, and the Amoskeag Manufacturing Company's works.

5th. The necessary and unwasteful consumption will be increased in a greater ratio than the population, because a plentiful supply will develop those branches of business which use much water and which can exist only where plenty of good water is obtainable.

I think that not more than one-eighth or one-tenth of the quantity we should need for a public supply is at present drawn from our wells. They would fail at once under a draft of 2,100,000 gallons daily.

Similar considerations will show the futility of seeking for a supply by boring artesian wells. The water so obtained is commonly derived, like that of other wells, from the rain-fall. Perhaps in some instances such wells may be fed from distant streams, or lakes, or even from the ocean. But the conditions necessary to the success of such wells are that they should penetrate a bed or stratum of highly pervious stone or earth, lying between two impermeable strata, and extending away to some higher section of country, where it comes to the surface over extensive tracts, and so is free to absorb a large quantity of surface water. This water, obeying the law of gravitation, descends along the pervious and slightly inclined stratum, in some cases probably for hundreds of miles, arriving at length at the well. In other cases it finds natural outlets, forming immense springs. Humboldt found a river, thirty feet broad, rolling along the floor and issuing from the portal of a magnificent cavern in the valley of Caripe, in South America. The fountain of Vaucluse, in the south of France, issues from subterranean rocks, and pours forth a volume of 13,000 cubic feet per minute, and this is sometimes increased to 40,000 cubic feet. Sometimes these springs are beneath the waters of the sea. It is said that on the south coast of Cuba, some distance from the shore, the fresh-water springs burst upwards with such violence that boats cannot safely approach the spot. Such a spring was discovered, projecting its waters to the surface, in the Indian Ocean, one hundred miles from land, by the crew of a becalmed vessel.

It is in the secondary and tertiary formations that such great quantities of water are sometimes found, and where borings may occasionally be moderately successful. There the basins are immense and the springs few, but powerful. In granitic regions the under-ground water-table, like the surface of the earth, is divided into numerous small valleys, giving rise to great numbers of springs; but, being numerous, they are correspondingly small. In New Hampshire, a spring that will, in a dry time, fill a hole three inches in diameter, cut in a thin plate, and under a twelve-inch head, is rare; I know of but two or three. And yet, it will require fourteen such to furnish the water we must have. It is evidently impracticable to get a supply from such sources.

Messrs. Rawlinson and Smith, in a report on the supply of Birmingham, make the following statements:—

"1. No large town can be permanently supplied from wells sunk into the strata upon which it stands. The experiment has been tried in many places. London and Paris, notwithstanding they stand in the most favorable situations for artesian wells, do not obtain more than a limited supply by these means.

"2. The water for the supply of a large town should be visible, and should be of such extent as to preclude the possibility of failure. That wells can be exhausted, however powerful the springs apparently are when first opened, is proved by all mining operations."

QUALITY.

It being manifestly impracticable to procure from wells or springs any such quantity of water as we require, we must have recourse to some large body of surface water; that is, to some stream or pond. And here we have to meet the common impression that such waters, though usually very soft, are not fit for drinking and culinary purposes; in a word, that they are *dirty*.

It is patent to our senses that all such bodies of water receive some impurities, and, failing to consider the insignificant amount of these as compared with the copious and constant streams into which they intrude themselves, most persons imagine the streams and lakes too impure for domestic use. But the same quantity of filth which would poison a well or cistern, would be absolutely inappreciable in such a body of water as the Merrimack or the Massabesic; and, moreover, there is an admirable provision in nature, by which all water, and more especially running water, is continually and speedily ridding itself of its organic impurity. It is only during the process of decomposition that such substances are noxious and offensive. In waters exposed to the air, and containing but a small proportion of such matters, this process goes on with great rapidity. The volatile products pass off into the air to become the food of plants, while such substances as nitrogen, sulphur and phosporus are quickly oxydized, forming acids that enter into new compounds generally inoffensive and harmless. Nature, no less than man, abhors effete and decaying matter; or rather, we should say that decay is nature's process of destruction and removal, reducing such matters to their elements, which are immediately recombined in a thousand forms of beauty and utility.

The purest natural water is that which descends in the open country from the clouds, in the form of rain. Falling on the earth, it becomes more or less contaminated by the substances with which it comes in contact, particularly by decaying organic matter. A part of this water is drained off into the streams, another portion is evaporated, and a third portion sinks into the earth to reäppear in wells and springs. In its descent it loses by filtration most of the organic impurities which were taken up on the surface, and in their stead loads itself with such soluble minerals as it finds in its course.

In our granite region, and away from the immediate vicinity of large towns, these soluble earthy matters are not very abundant; and, consequently, the waters of the springs and properly arranged wells are usually of a good degree of softness and purity, and they will probably forever remain the cheapest, the most wholesome and the most popular supply of our rural population.

But chemical science teaches us that even the best well-water of our large towns is not as pure as that of the streams of New England.

The following tables exhibit the results of all analyses of waters in New England which have come to my notice. When I have found the results reported for the imperial gallon, they have, for the purposes of these tables, been reduced to the wine gallon :—

I.—WELLS.

LOCALITY.	Grains of impurity in wine gallon.	Hardness.	Analyst.
Boston, Longacre	56.80	....	
Beacon Hill	50.00	....	
Tremont street	26.60	....	
Charlestown	26.40	....	
Hartford, State House Yard	41.47	....	B. W. Bull, 1847.
State House Yard	43.60	10.55°	Prof. Silliman, 1861.
43 Maine street	32.16	13.44°*	B. W. Bull, 1847.
Am. Asylum Grounds	19.33	8.39°*	" " "
Lane's Coffee House	37.10	....	" " "
New England House	69.05	19.22°*	" " "
New Haven, average of five	20.32	....	
Providence, average of twenty-four	33.66	10.92°	Prof. Appleton, 1868.
best of do	11.12	4.90°	" "
worst of do	81.17	22.26°	" "
Lowell, average of fifteen	39.33	8.71	L. S. Burbank, 1869.
best of do	2.11	1.40°	" "
worst of do	77.94	22.50°	" "

* Hardness ascertained by Prof. Silliman in 1861.

II.—STREAMS AND PONDS.

SOURCE.	Supplied to or proposed for.	Grains of solid matter in wine gallon.	Hardness.	Analyst.
Cochituate................	Boston........	3.37	....	Prof. Silliman, 1845.
Cochituate................	"	5.00	....	Prof. Jackson, 1845.
Spot Pond, 26 ft. below the surface...............	"	6.19	....	Prof. Silliman, 1845.
Fresh Pond................	Cambridge....	6.32	....	Prof. Horsford, 1853.
Mystic Pond...............	Charlestown ..	3.22	....	Prof. Silliman, 1862.
Mystic Pond...............	....	4.08	....	Dr. Hayes, 1859.
Connecticut River.........	Hartford......	2.57	1.64°	Prof. Silliman, 1861.
Trout Brook...	"	3.27	1.19	" " "
Sluice Pond...............	Lynn..........	1.44	....	Prof. Jackson.
Acushnet River, 4 samples.	New Bedford..	3.19	0.84	Prof. Chace, 1863.
Mill River................	New Haven...	4.00	....	
Pine River................	" " ...	5.60	....	
Pawtuxet River, 6 samples (av.).............	Providence ...	2.15	0.57	Prof. Appleton, 1868.
Pawtuxet River, at Pawtuxet dam............	" ...	3.11	....	Prof. Chace.
Woonasquatucket	" ...	2.23	0.72	Prof. Appleton, 1866.
Ten-Mile River............	" ...	2.74	0.88	" " "
Blackstone River	" ...	2.53	0.70	" " 1867.
Canal at Lonsdale.........	" ...	2.42	0.70	" " "
Scott's Pond..............	" ...	2.28	0.70	" " "
Charles River, at S. Natick.	....	1.67	....	
Charles River, at Watertown................	....	2.55	....	
Lynde Brook, ...	Worcester	1.73	....	Prof. Jackson, 1860.
Merrimack River..........	Lowell........	2.08	0.50	Prof. Appleton, 1869.
Beaver Brook A...........	"	4.40	0.50	" " "
Beaver Brook B...........	"	2.36	0.50	" " "
Stony Brook..............	"	2.47	....	Mr. L. S. Burbank, 1869.
Concord River............	"	3.21	....	" " "
MASSABESIC LAKE........	MANCHESTER	2.82	0.84	Dr. S. D. Hayes, 1869.
Maple Falls..............	"	2.78		" " "

The following table may be of interest, as giving the means of comparison between the waters of the preceding tables and those used in some of the large cities of this country and England:—

III.

SOURCE.	Supplied to.	Grains of solid matter in a wine gallon.	Hardness.	Analyst.
Croton...............	New York........	10.60	....	Prof. Silliman, 1845.
Fairmount...........	Philadelphia......	5.50	....	
Lake Michigan.......	Chicago...........	8.01	....	
Gunpowder..........	Baltimore.........	4.41	....	
New River...........	London, England.	16.26	14.9°	Dr. Graham.
Thames........... ..	" "	18.11	14.	
River Ouse..........	York, "	7.50	....	Messrs. Spence and White and W. V. Harcourt.
Average of 14 wells..	" "	53.95	....	
Artesian well	" "	80.06	....	

The most casual inspection of the foregoing tables will show the error of the popular belief that the water of streams and ponds is not good enough for domestic use. The most impure water of Table II, that of Fresh pond, in Cambridge, has less than one-sixth of the impurity of the average of the Lowell wells. It is noticeable that the water of the best of the fifteen wells at Lowell, examined by Mr. Burbank, is far better than any of the others in the table. It is nearly, but not quite, equal to that of Merrimack river. Mr. Burbank says this well is located in the yard of the High School house, and only a few feet from the canal of the Merrimack Mills. The water is, in fact, canal water filtered through a few feet of earth.

The waters of artesian wells, on account of having traveled great distances under ground, and lying long in contact with mineral substances, are liable to be hard and impure. This is illustrated in Table III, in the case of the city of York, England. In that ancient city, we are told, the rubbish of centuries has accumulated in some places to the depth of three or four yards, and has had its effect on the wells, which are usually from 12 to 40 feet in depth. Fourteen of these wells give an average of 53.95 grains of solid residue to the gallon. But even this is only about two-thirds of the quantity found in the water from the borings, 350 to 380 feet in depth. One of these yielded water giving a residue of 80.06 grains to the gallon.* Such water must be totally unfit for domestic use.

The quality of "hardness" is occasioned chiefly by the salts of lime and magnesia. "The lime and magnesia of such waters, upon the introduction of any ordinary soap, decompose the latter, taking by substitution the place of the soda or potash which was its base, and thus forming, in fact, with the fatty acids, a lime or magnesia soap, which, being insoluble, is precipitated, and appears as a white, curdy matter. Thus the cleansing property of ordinary suds is not obtained. The precipitated lime soap is greasy and tenacious; and it not only fails to cleanse, but, entering the interstices of cloths, or in bathing obstinately closing the pores of the surface, it communicates also a hard and rough feeling. Hence it is that hard waters are rightly considered unfit for use in washing, as they really are for bathing or drinking, unless means be taken to render them soft; and hence also it is that the attempt to make any water wash with soap, or the use of the soap test, readily determines in this respect the quality of the water, and its fitness for any of the purposes named. This soap test consists in observing the quantity of a prepared solution of

* Dempsey on Drainage.

soap which must be added to a given measure of water in order to produce a permanent lather."*

The scale used in the tables is that of Dr. Clark of England. Each degree of this scale represents one grain of carbonate of lime or its equivalent in each imperial gallon (10 pounds) of water, and this quantity of water has the power to destroy ten grains of soap for each degree of hardness. Thus four imperial gallons of water like that from the well in the State-House yard at Hartford, decomposes 422 grains, or almost one ounce of soap. And yet it will be observed that this is not uncommonly hard for well water. It is better, in this respect, than the average of the twenty-four wells in Providence which were analyzed by Prof. Appleton.

This loss of soap, the vexation and discomfort occasioned by the insoluble curdy matter which is produced, the increased labor of the laundress, and the resulting injury to the fabrics washed, are serious objections to the household use of hard water. But such water is equally objectionable in its application to many important manufacturing purposes, and for use in steam boilers. Incrustation or "scale" is a well known cause of loss of fuel, wear of boilers, and danger of explosion. In some of the arts and manufactures a good quality of water is so indispensable as to control the location of the establishments against many disadvantages in other respects.

The hygienic and sanitary considerations involved in the use of impure water are themes for the physician rather than the engineer. But, in view of the great importance of the subject, I may perhaps be pardoned for introducing here a few extracts from well known medical writers.

Dr. W. B. Carpenter, in his *Human Physiology*, says: "The purity of the water habitually ingested is a point of extreme importance. A very minute impregnation with

* American Cyclopædia, Art. Water.

lead, for example, is quite sufficient to develop all the symptoms of chronic lead-poisoning, if the use of such waters be sufficiently prolonged. In the case of the ex-royal family of France, many of whom suffered in this manner at Claremont, the amount of lead was only about one grain per gallon; and in a case subsequently published, in which also the symptoms of lead-poisoning were unequivocally developed, the amount was no more than one-ninth of a grain. So, again, an excess of the saline ingredients, which appear to be innocuous in small quantities, may produce a marked disorder of the digestive organs and (through them) of the system generally. Moreover, as in the case of food, the presence of a very small amount of putrescent matter is quite sufficient to produce the most pernicious results, when the matter is habitually introduced into the system; and these results, on the one hand, manifest themselves in the production of certain disorders which appear distinctly traceable to the direct action of the poison so introduced; whilst, on the other, they become apparent in the extraordinary augmentation of the liability to attacks of such zymotic diseases as may at the time be prevalent."

Dr. Carpenter speaks of an instructive case which occurred within his own knowledge. "In a certain terrace in the most aristocratic suburb of a large provincial town, consisting of houses of a superior class, and very favorably situated as regards the access of pure air, an epidemic of gastric fever broke out, much to the astonishment and dismay of the residents, no such malady having ever been known to prevail in the neighborhood. It was soon observed, however, that the attacks of the fever were limited (in the first instance at least) to those individuals who were accustomed to use the water of a neighboring well; those who were supplied from a deep spring at a distance being entirely free. For some little time before this outbreak, a disagreeable taste had been observed in the well-water; and this was subsequently traced to the bursting of a sewer, which had discharged part of its contents into the well. This cause being removed, the terrace has since exhibited no tendency whatever to a recurrence of the effect."

Dr. Ira Warren, in his *Household Physician*, says: "Pure water is as essential to health as pure air. When either of these fluids is rendered impure by mixture with foreign matters, disease will be a frequent result." And again, "For all remedial as well as hygienic purposes, water should be as pure and soft as can be obtained."

Numerous facts observed by medical men in all parts of the world lead to the belief that the unsightly bronchocele or goitre is occasioned by the use of water impregnated with lime and magnesia. "In the gaol at Durham, Johnson states that when the water contained 77 grains per gallon (chiefly of lime and magnesia salts), all the prisoners had swellings of the neck; these disappeared when a purer water containing 18 grains to the gallon was obtained."—*Parkes' Hygiene.*

"The valley of Baribice [in India] is elevated 4000 feet above the sea. Its eastern extremity is composed of clay-slate, and in five villages, containing 152 inhabitants, there is not one goitre. The other extremity of the valley is partly composed of limestone; and of 192 inhabitants, distributed in six villages, 70 are affected with goitre; but Ducygong, one of these villages, supplied with water from the clay-slate, has not a single case of the disease, while Agar, only half a mile distant and containing 50 inhabitants, has no less than 40 cases; and of that number 20 are cretins. They use the water which issues from an old copper-mine in limestone, and which contains carbonate of lime and of soda, but no sulphate."—*McClelland, quoted in Watson's Practice of Physic.*

"Some striking facts have been collected by Dr. Snow, which warrant the presumption that a most fearful outbreak of cholera in Soho was attributable to the water of a certain pump, contaminated from a neighboring sewer." *Ibid.*

Quotations like these might be multiplied indefinitely, but I have room for only one more.

"This much seems to be certain, that as precise investigations proceed, and, indeed, in proportion to the care of the inquiry and the accuracy of the chemical examination, a continually increasing class of cases [of disease] is found to be connected with the use of impure water, and it seems only reasonable to infer that a still more rigid inquiry will further prove the frequency and importance of this mode of origin of some diseases."—*Parkes' Hygiene*, 1866.

Hard water appears to be not less hurtful to animals than to man.

"There is nothing in which the different effects of hard and soft water is so evident as in the stomach and digestive organs of the horse. Hard water, drawn fresh from the well, will assuredly make the coat of a horse unaccustomed to it stare, and it will not unfrequently gripe and otherwise injure him. Instinct or experience has made even the horse himself conscious of this, for he will never drink hard water if he has access to soft, and he will leave the most transparent and pure* water for a river, although the stream may be turbid, and even for the muddiest pool." *Youatt.*

It is said that in England soft water is often carried for miles to the race-course, lest the horses should suffer from the use of hard water furnished on the grounds.

I have not considered it as within the scope of my instructions to procure a chemical examination of any of the well waters of this city. But there can be no doubt that many of them contain an amount of impurity which totally

* *Pure* seems to be used here in the sense of bright, or clear.

unfits them for drinking and domestic use. We need no chemist to tell us that they are hard and unpalatable. It is probable that they are no better than those of other New England towns, as given in Table I. It is a significant fact that many horses will refuse well water at their stables, and, on being driven immediately afterwards to the troughs on Elm st., will drink deeply. The well-worn foot paths to the spring on Hanover Square before that water was diverted to other uses, and the frequent collections of persons with pails and pitchers, awaiting their turn around the little aqueduct in front of the City Hall, are sufficiently eloquent on this topic.

Any stream or pond that we should be likely to select as a source would, almost certainly, be of better qnality than our present well-water.

This brings us to the consideration of the

SOURCES OF SUPPLY.

It is of the utmost importance that the source should be so abundant as to furnish the requisite quantity even in the seasons of greatest drought, for these are the times when consumption will be largest; and the experience of other cities has proved that where aqueduct water can be obtained, it soon comes to be almost the sole reliance for that indispensable liquid. Wells and cisterns are neglected and get out of repair. Hence the discomforts, losses and risks occasioned by a temporary interruption, after the inhabitants have been led to depend upon a regular supply, are so great that they must be avoided at any expense.

Moreover, in order that the supply may be prompt and unfailing, we must have a body of water on some higher ground, and not too remote, from which to draw. This hight should not be less, nor much greater, than that of the Amoskeag Manufacturing Company's reservoir which is about 104 feet above Elm street at the City Hall.

In our case, as in that of most other cities, we have no natural collection of water possessing all the requisite characteristics as to hight, proximity, quantity and quality. We must therefore make a selection from the sources at our command, and give it artificially the characters which are wanting.

In regard to quality we can improve the water, to a limited extent, if necessary, by removing sources of contamination, and by subsidence and filtration.

We can only affect the quantity by combining two or more sources, or by saving the excess of one season to meet the lack of another.

But the conditions of hight and proximity are more fully under our control. The waters of a distant source, having sufficient height, may be brought near, or those of a nearer, but too low source, may be raised; or, if found to be more advantageous, some combination of these two processes may be adopted.

There are an indefinite number of distant sources of sufficient hight for our purpose. The head waters of the Piscataquog river in New Boston or Weare might be taken. So might those of the Suncook in Pittsfield, and those of several more distant tributaries of the Merrimack. The length of the Croton Aqueduct at New York is forty miles, and one of the many aqueducts of ancient Rome was more than fifty miles in length. Such distances would reach the Sunapee and Winnipesaukee.

The ancient engineers, being unacquainted with the manner of employing the powers of falling water and of steam, had no means of raising water in sufficient quantities for a city supply. They were consequently obliged to seek a source sufficiently elevated for their purpose, however distant it might be. But we are happily relieved from this necessity. Modern pumping machinery has limited the distance to which it is either necessary or desirable to extend an aqueduct. Of course the running expenses may be expected to be less where a gravitation plan is adopted, but it is quite possible to buy this advantage at too dear a rate.

If, in a given case, the supply by gravitation and by pumping be equally valuable and reliable, the limit of distance will be found at the point where the excess of the first cost of the works on the gravitation plan, over those on the pumping plan, is so great that the interest on such excess will be equal to the difference in the cost of running and maintaining the two kinds of works. For instance, let us suppose that this difference is 2,500 dollars per annum in favor of the gravitation plan, and that interest should be reckoned at seven per cent. This annual outlay would represent a capital of about 36,000 dollars, and economy would dictate that the gravitation plan be adopted, even though the first cost should be so much greater than that of the pumping plan.

We will now further suppose that the land and water damages, the distributing reservoir, and the distribution are to cost the same in either case, and that the pumping station and the rising main will cost 140,000 dollars. We should then have a limit of 176,000 dollars as the cost of our conduit. Such a structure, built of arched bricks and cement, with all its appurtenances of culverts, overways, man-holes, ventilators, waste weirs &c. could not cost less than three dollars per foot, or about 16,000 dollars per mile. We should, therefore, under the circumstances supposed, have eleven miles as the utmost economical limit of such a work. If, as is more likely, it should cost four dollars per foot, we should be limited to 8 1-3 miles.

If, as is almost certain in our case, no route level enough and high enough for such a conduit could be found, we should be obliged to use a pipe of sufficient strength to bear the pressure occasioned by the head of water upon it.

Such a pipe might be of smaller caliber, but it would cost more than a conduit ; and we should thus be circumscribed within still narrower limits.

It is not claimed that the foregoing suppositions are in strict accordance with the facts in our case. Several of them relate to matters which can only be precisely ascertained by such thorough surveys as have never yet been made. But in making them I have had in view the project of pumping from the Massabesic by water power, as that scheme has thus far been developed by preliminary surveys, and it is believed that they are approximations sufficiently near the truth to show that the sources just named, and all others equally remote, may be dismissed from further consideration.

We will now consider in detail, and in the light of such facts as are at present known, the various sources within ten miles of the city which have ever attracted any considerable degree of attention.

MERRIMACK RIVER.

This is the nearest, the largest, and therefore, perhaps, the most obvious source within our reach. Recent examinations at Lowell have shown that the water there, when not roily, is of suitable quality for a public supply. It is, without doubt, also suitable at Manchester. At Amoskeag Falls there is abundant water power for pumping, and the charter of the company gives the same power to take a privilege there as at any other place. These are strong points in favor of this source. But as compared with the Massabesic, there are, in my judgment, countervailing disadvantages.

One of these disadvantages is the fact that for several weeks in every year the water is very turbid. The material in suspension at such times is partly composed of a fine sharp sand which settles quite readily from the water when at rest, and partly of an exceedingly fine clay, enough of which remains suspended to give the water a whitish appearance after two or three weeks of perfect repose. This would render necessary a set of expensive filtering apparatus.

A filter bed is usually constructed by making, in the first place, a water-tight basin of suitable size. On the bottom of this basin a system of drain-pipes is laid, and then between and upon these pipes the materials of the filter are placed. These consist of successive layers of small stones, coarse gravel, finer gravel, coarse sand and fine sand, the whole forming a body some five feet in thickness. Each layer has to be carefully made of uniform material and of uniform thickness. The water is let on at the top, and passing through the filter, is drawn off at the bottom.

The turbid water of the river would soon deposit on the surface of the sand a substance similar to those thin but impervious layers of clay which are so abundant in the beds of quicksand underlying the city. This of course would obstruct the passage of the water, and require frequent removal. We should need three such beds of about a quarter of an acre each. It is manifest that their construction and maintenance would involve a heavy expense which could be avoided by taking the Massabesic water.

Another objection is that it would require more power to pump the water from this source than from the Massabesic. In one case the lift would be about 167 feet, while in the other, for an equal altitude, it would be but 95 1-2. To elevate the quantity we require from the Merrimack, through one mile of 24-inch pipe, in the usual working hours of the mills, will require 180 horse-powers. To raise the same quantity to the same level from the Massabesic, in the same time, will require only 111 horse-powers.

A third objection to this scheme is, that although, as before stated, there is abundant water power for pumping, it is power located in the midst of a populous and growing town, and is therefore more valuable than equal power four miles away and off the lines of the railroad. The time is at hand when all the power of the Merrimack will be fully employed, and will be as valuable as equivalent steam power, and this prospect would even now have an influence in determining the value of a mill privilege taken by the Aqueduct Company. The advantage of using such water power rather than steam power would of course be small.

A fourth difficulty with this plan arises from the fact that the water for the motive power would have to be drawn from one of the canals of the Amoskeag Manufacturing Company, and therefore perfect control of the power could not be secured. Consequently we could not be certain of being able to run the wheel except on working hours of working days; and, moreover, if the wheel were run at other times, the water used on one level would be wasted on the other. This last consideration would only be of importance at times of low water, but it would be at such times that the consumption of water would be greatest, and that therefore the exigencies requiring the pumps to run extra hours would be most likely to arise.

There is another consideration which deserves a brief mention. It is for the interest alike of the citizens and of the Amoskeag Manufacturing Company that the water power here shall be put to such uses as shall give employment to large numbers of persons, thereby promoting the growth of the city and enhancing the value of property.

It is true that water works, though giving employment to but few persons, would indirectly contribute to these results in an eminent degree. But as long as we have another resource, it would seem better to leave the power of the Merrimack to be wholly devoted to manufacturing purposes.

These reasons seem to me to be so conclusive against this source, that I have no plan to offer for taking the water of the Merrimack.

PISCATAQUOG RIVER.

The Piscataquog river at Kelley's Falls is a source regarded with favor by some of our citizens. A reconnoissance with this scheme in view was made in 1860 by Messrs. Weston and Richardson. They reported that it would be necessary to raise the water 189 feet through a pipe 3,000 feet in length; the reservoir to be situated on the high ground northerly of Rock Rimmon, and its bottom to be 123 feet above the sidewalk at the City Hall.* It is evident that there is no other place of suitable hight for a reservoir in that direction, and there is not room enough there for such an one as the city would now require.

The hight would somewhat exceed that of the Amoskeag Company's reservoir; but this advantage would be nearly or quite lost on the high ground in the eastern part of the city (where alone increased head is desirable) by reason of the greater length of pipe through which the water would come to that locality.

To raise the required quantity of water to this hight in eleven hours we should need 174 horse-powers, and this would be for seven days per week. It would require about 115 cubic feet of water per second on an eighteen-feet fall to produce this power.

From the best information to be obtained in conversation with persons running mills on this stream I conclude that for several weeks in summer there is less than one-half of this quantity of water in the stream. The river could be much improved by reservoirs on its head waters; but even if it were doubled, it would still be inadequate to our present wants, to say nothing of future necessities. I therefore consider this source unavailable.

* Appendix B.

STEVENS' POND.

This pond lies east of the city farm. It has an altitude of about 105 feet above Elm street at the City Hall, from which point it is distant, in a straight line, about two miles; and its waters could be brought to that building with less than three miles of pipe. Considering the loss of head due to pipes of that length, the altitude is not quite sufficient for our purpose. It would practically be lower than the Amoskeag Company's reservoir.

But the graver objections to this source are those which relate to the quantity and quality of the water. The area of the pond is perhaps 20 acres, and it is in large part surrounded by a peat bog of equal extent, and which is in some places more than thirty feet in depth. The same bog underlies the pond. In summer the shallower parts of the water become filled with pond-lilies and other aquatic plants; and the water at the outlet is small in quantity, and highly discolored by the decaying vegetable matter with which it has lain in contact. Indeed for several weeks of the past summer no water ran out of the pond.

The area of land draining into this pond does not exceed two square miles. To afford the supply which we seek we must have a water-shed of at least three square miles, and have the means of storing all the water that runs from it. If this supply is ultimately to be doubled, we must look for an area of not less than six square miles. These considerations show that this source is unworthy of further attention.

MAPLE FALLS.

This is the site of a saw-mill on the stream running from the Sawyer or Whitehall mill in Hooksett, through Tower Hill pond, to the Massabesic at Auburn.

Hon. J. A. Weston and the late Mr. Wm. Richardson made an exploration for a route by which the water at

Maple Falls could be brought into the city. Their report was published in the *Daily Mirror* of July 9, 1860, and a copy has been kindly furnished to me by Mr. Weston.*

From that report we learn that the hight is ample, the distance moderate, the facilities for storage good, and the route feasible. But there seems to be some doubt as to the quality of the water.

I visited this source on the 27th of March last. This was just at the beginning of the mild weather which melted the winter snows, and the stream was evidently beginning to rise, as usual at that season. Such rude measurement as I was able to make at a place where the stream ran over the edge of a plank indicated a flow of about 3,250,000 gallons in twenty-four hours. The water was considerably discolored by vegetable matter. A sample was taken and sent to Dr. S. D. Hayes, State Assayer for Massachusetts, for chemical examination. His report will be found appended.† It shows that, so far as relates to those impurities which can be weighed and measured, this water was then unobjectionable. I regret that I did not obtain an analysis of water taken in the summer, but it was then in such a state as to require no chemical examination to reveal the fact of its unfitness for our purpose. Sawyer's pond, the principal feeder of this stream, is an artificial pond made by flowing a meadow or swamp. It is used as a reservoir for mills, being filled in spring and drawn dry by midsummer. I am informed that during the past summer it was so dry that no water ran from it for several weeks. This shows that it is not fed to any considerable extent by unfailing springs, but is simply a collection of the water of the spring freshets detained and stored on the meadow bottom. During the early part of summer this water becomes very dark colored and offensive to the sight.

* Appendix B.

† Appendix C.

I have no hesitation in saying it is not such water as would suit our people.

There remains for consideration but one other source, and that is

MASSABESIC.

Potter's "History of Manchester" says this word means, in the Indian language, *the place of much water*. It is evident enough that there is more water in the lake of this name than the city will ever require; but as it is, at high water, only about forty feet higher than Elm street at the City Hall, or fifteen feet above Beech street, it will require to be raised by pumping; and, as bearing on the question of the feasibility of pumping by water power, we will consider what quantity of water we can rely upon obtaining from the lake.

In the absence of any known series of observations on the flow of the stream issuing from the lake, we may be guided in estimating it by its drainage area. This area comprises the principal part of Auburn, large tracts in Candia and Hooksett, and a smaller territory in the north-easterly part of Manchester, containing in all, as estimated from the county maps, about forty square miles. This district is sparsely inhabited, and has no considerable villages or manufacturing establishments to contaminate its waters. The soil is generally hard, and the surface broken. It has but few swamps and sluggish streams. There can be no doubt that it furnishes to the lake water of an excellent quality, and in as large proportion to its total rain-fall as the average of other considerable areas where this proportion has been ascertained.

The following table gives the results of such experiments on the relations between the rain-fall and the drainage as I have found recorded:—

Location and description of water-shed.	Time of the experiment.	Area in acres.	Rain-fall in inches.	Per cent. of rain-fall drained off.	Observer.
Madison brook, Madison Co., N. Y., steep slopes, hard soil, with a large swamp................	2 years............	6000	....	51.	W. J. McAlpine.
Eaton brook, Madison Co., N. Y., slopes steeper and soil harder than preceding..............	2 years............	6800	....	78.	" "
Plains near Albany, soil flat and sandy..........	2 years............	2600	....	67½	" "
Water-shed near Albany, one half flat, sandy; other half sloping clay soil....................	2 years............	8000	....	45½	" "
Patroon's Creek, Albany, flat, sandy soil.........	May 22 to Aug. 1, 1850............	2025	15.50	41	
Lynde brook, in Leicester, Mass., broken and hilly country................	May 8 to Nov. 1, 1862............	1870	24.11	42.4	P. Ball, C. E.
Woodburn District, in north of Ireland, bare mountain pasture......	1 year, ending June 30, 1865..	3405	35.87	60.5	R. Manning, C.E.
The same.................	6 mo., Nov. to May.	3405	14.77	97.2	" "
The same.................	6 mo., May to Nov..	3405	21.10	34.9	" "

These, and similar results, have led engineers to rely on a drainage varying in different cases from forty to sixty-five per cent. of the average annual rain-fall; but the actual experience of some of the principal water-works in the country admonishes us to take a smaller figure.*

* At Albany, where the projectors of the works found the mean annual rain-fall to be 40.92 inches, and relied on a drainage of 16 inches, equal to 39 per cent., a year has occurred (1864) in which the rain-fall was only 27.94 inches, and the supply failed. But we are not informed what was the actual percentage collected in that year. The failure might have been caused either by deficiency in the supply, or by excess in consnmption.

The following table is extracted from a more detailed one, in the last annual report of the Cochituate Water Board:—

YEAR.	Rain-fall in inches.	Available percentage of rain-fall received into lake.	YEAR.	Rain-fall in inches.	Available percentage of rain-fall received into lake.
1852	47.93	43	1860	55.44	35
1853	55.86	35	1861	46.44	56
1854	43.15	53	1862	49.69	45
1855	34.96	No acct. kept.	1863	69.30	39
1856	40.80	No acct. kept.	1864	42.60	40
1857	63.10	74	1865	49.46	43
1858	48.66	40	1866	62.32	25
1859	49.02	78	1867	56.25	35

Average rain-fall, 50.93; average percentage received, 46.

In the original table the quantities given as "Total available amounts of rain-fall received into the lake" appear to be made up by adding the quantities drawn for consumption to the quantities "wasted from the lake," with a correction for the difference in the amount remaining in the lake at the beginning and at the end of each year.* It therefore seems to be the percentage delivered from the lake, rather than that received into it, which is given; and this is precisely what we are seeking with reference to Massabesic. The two quantities differ by the amount of percolation and evaporation. This last is an important matter.

* The quantity "wasted" appears to be principally that which ran over the dam, and was unavoidably lost for lack of storage room. For what purpose this was "available," we are not informed.

It will be seen that although the average delivery for fourteen years is given as forty-six per cent. of the rain-fall, yet in five of those years, or more than one-third of the time, it has fallen below forty per cent., and once to twenty-five per cent., of the actual rain-fall of the year. But, the rain-fall of that year being unusually large, twenty-five per cent. of it is equivalent to thirty-one per cent. of the average. In no other year has the delivery fallen below thirty-three and one-third per cent. of the mean rain-fall on its drainage basin, including the water area.

The Massabesic drainage basin is more hilly and broken, and its soil is harder and more impervious, than is that of the Cochituate; and I think we may safely rely on this last ratio in our calculations. There will usually be more water than this percentage gives; but when a year, or perhaps several consecutive years, of scarcity shall be upon us, it will be of no avail that some years previous there was a superabundance, which overflowed the reservoirs and ran to waste.

I am unable to find that the average depth of rain falling on the Massabesic water-shed has ever been ascertained, or that any data exist for its precise determination, but it may fairly be presumed to be about forty-three inches.* One-third of this quantity is 14.33 inches, or about 1.2 feet. The estimated area of the water-shed being, as before stated, forty square miles, we have, as the daily average quantity for a minimum year, $\frac{40 \times 640 \times 43560 \times 1.2}{365} = 3,666,200$ cubic feet.

But this quantity does not flow equally into the lake, nor

* See Appendix A. I am informed by S. N. Bell Esq., that he made observations on the rain-fall in this city within two miles of the Massabesic basin, for several years. The observations for Manchester, communicated by Prof. Henry, were made by Mr. Bell. His observations for other years contain some omissions and interruptions which make them inadmissible to our table; but they indicate an annual rain-fall varying between 42 and 44 inches.

out from it. In times of freshet much more than this passes; in times of drought much less.* This brings us to the consideration of the storage capacity of the lake.

The area of the lake, as deduced from a plan made from actual survey some years since by Mr. Franklin Crombie, is about 2350 acres. The fluctuations of the lake between high and low water are at least three feet three inches, and it is probable that they considerably exceed this, as my observations were made only when casually at the lake a few times for other purposes during the last eight or ten years. It is not likely that I have seen either the highest or the lowest stage of the water. But by deepening the outlet moderately, the lake may be drawn down five feet below high water. Allowing thirty acres for decrease of area when the lake is thus drawn down, we find the storage to be 2320 X 43560 X 5 =505,496,000 cubic feet.

This would be a supply of three million cubic feet per day for 168 days or five and one-half months, allowing the influx from the streams in the mean time to compensate for the evaporation.

In view of these calculations it seems reasonable to expect to avail ourselves of a constant supply of three million cubic feet per day, provided control of the lake were obtained, and the proper dam and gates were built at the outlet.† Subtracting from this quantity the amount al-

*In the Woodburn district, near Carrickfergus in Ireland, to which reference has already been made, the minimum flow off 1000 acres occurred in August, and amounted to 11 cubic feet per minute; the maximum, in September, to 3180 cubic feet per minute; and the mean monthly flow was at its minimum in July, and was 29 cubic feet per minute.—*Jour. Franklin Inst. Aug.* 1866.

† The quantity of water precipitated on the Cochituate water-shed is about 55 per cent. of that falling on the water-shed of Massabesic, and the storage capacity of the former is probably between 75 and 80 per cent. of that of the latter. In 1866, its driest year, its capacity as a source of supply was stated to be 14,265,280 gallons per day, equal to 1,902,000 cubic feet, allowing the lake to be in the same state, as to fullness, at the end as at the beginning of the year.

lowed for the daily supply, 280,000 cubic feet, we have remaining to be used for motive power 2,720,000 cubic feet.

The fall at present utilized at the saw-mill of Messrs. Foster & Clough, at the outlet of the lake, is about sixteen and one-half feet; but it may readily be increased to at least twenty feet. The above named quantity of water expended in twelve hours on a good wheel, with a fall of twenty feet, will give 107 horse-powers.

Turning now to the consideration of the work to be done, we find the best site for a reservoir on the flat land easterly and northerly of the residence of George Porter, Esq. No calculations for determining the exact hight of the water in the reservoir have yet been made; but the actual lift of the water may be taken, approximately, at 95.5 feet, and the length of the force main will be about 9000 feet. To raise the specified quantity of water through this length of 24-inch pipe will require, including pump friction, 84 horse-powers.

This arrangement will therefore answer our present purpose and give a moderate margin for future enlargement of the supply. When the demand for a greater increase comes, as it will come within a few years, unless an available meter is discovered in the mean time, we may have recourse to one or more of the following expedients:

1. A moderate increase of the supply might be secured by having large reservoirs to be filled by extra pumping in the spring of the year, when water would always be wasting from the lake by overflow, and to be drawn in summer when the consumption would be large and the pumping power comparatively small. In other words, by utilizing a part of the water which could not be stored, and which must be used when passing or not at all.

2. A larger increase of supply might be obtained by using the Heselton mill-privilege for additional pumping-works. This privilege is situated immediately below that

of Foster & Clough, and a fall of about seventeen feet could here be obtained at a reasonable expense. The two privileges might probably be combined into one, in which case about 4,000,000 gallons per day could be pumped into the reservoir. If used separately, the lift at the lower privilege would be greater, and the quantity that could be pumped would be correspondingly less, than at the other privilege. Probably a daily supply of about a million and a half of gallons could be raised by this power if the stream were regulated as we have supposed.

3. By securing the right to raise the lake another foot, an additional quantity of 100,000,000 cubic feet could be stored in the lake to be used as motive power when required. If necessary, other reservoirs could be made on the ponds and streams tributary to Massabesic.

There is no doubt that by these means a supply can be had, at a reasonable expense, sufficient for the wants of the city until its population reaches 50,000 or 60,000.

4. If the time comes when a still larger supply is required, it may be obtained from this source, and to an extent practically unlimited by the employment of steam power. The running expenses of steam power would of course be greater than those of water power, apart from interest on the first cost. But even here the Merrimack plan has little or no advantage, for, as we have just remarked, 111 horse-powers at Massabesic will serve the same purpose as 180 at Amoskeag Falls. And before the population of the city reaches 50,000, the water power of the Merrimack will be all in use, and be as valuable as steam power. It is quite probable that if there were no water power at Massabesic, we should still find it the best source for our purpose.

A quantity of water, taken May 17 from the brook at the outlet of the lake, was submitted to Dr. Hayes for analysis. It will be seen that he reports it better than that now supplied to any of the large cities of the United States.* That portion of the report relating to the degree of hardness and the action upon lead is in answer to specific inquiries by me upon these topics. No similar inquiries were made in regard to the Maple Falls water, but I know of no reason for supposing it any better in these respects.

PROPOSED PLAN.

It will be gathered from the preceding pages that it is contemplated to build the pumping-works near the natural outlet of the lake, using for water power the mill-privilege now owned and occupied by Messrs. Foster & Clough, and that the water is to be forced through a 24-inch rising main about 9,000 feet in length to a reservoir near the house of George Porter, Esq. There is here a tract of about 28 acres of land eminently suitable for the purpose. It is nearly level, and almost surrounded by higher ground. The subsoil is quite impervious to water, and it is of just the proper altitude. A suitable reservoir can here be built and leave ample room for one or two more to be constructed whenever the works require enlargement. A reservoir here would be about 127 feet above Elm street at the City Hall, or some 23 feet higher than the Amoskeag Company's reservoir.

From this point to the City Hall, the distance is not far from two and one-half miles, and no serious obstacle need be encountered. It is proposed to lay a 24-inch main as far as to the corner of Park and Maple streets. I am not able as yet to speak definitely of the system of distribution. Probably a good plan would be to extend a 20-inch pipe from Park street northward through Maple street, connecting with the Amoskeag Company's reservoir, which may be supplied, if desired from this source. This pipe would be

* Appendix D.

the feeder for smaller pipes running down each of the streets which it crosses.

Another pipe of perhaps 14 inches in diameter would follow down Park street to Elm street, and be continued through Depot street to the Amoskeag New Mills, there connecting with the pipes of the Amoskeag Company. If thought best the two sets of works could ordinarily be shut off from each other by gates, and worked independently; and still, in case of accident or emergency, either could be made to reïnforce the other.

A large pipe should also be laid in Elm street, from Auburn to Blodgett streets. The distribution would then be effected by smaller pipes (5- and 6-inch) laid in the streets running east and west. By this arrangement the principal mains would form a complete circuit around the most compact and valuable part of the city, and be in connection with two independent reservoirs, thus receiving water from both directions, making their efficiency nearly or quite double that of the same pipe supplied from one end only.

ESTIMATE OF COST.

As a member of the commission appointed by the City Council, some weeks since, to report on the most feasible plan for supplying the city with water, I made an estimate, which was incorporated into the report of that commission.* That estimate amounted to $542,000. It was made hurriedly, and on very imperfect data. It assumed that 20-inch pipe would be sufficient for the mains. On further investigation I am of the opinion that they should be 24 inches. There was also a manifest error in the number of hydrants.

The data for a full and specific estimate are not yet all obtained. This is true especially of the pumping station

* Appendix E.

and the reservoir. But a large proportion of the expense will be for the items of pipe, the lengths and cost of which is known within reasonable limits. To that extent, at least, a reliable estimate can now be made. I therefore beg leave to submit the following

APPROXIMATE ESTIMATE.

Land and water damages		$50,000
Pumping station, including dam, canal, &c.		50,000
Reservoir		60,000
18,500 feet 24-inch pipe	($11.00)	203,500
5,600 " 20-inch "	(8.00)	44.800
9,800 " 14-inch "	(4.50)	44.100
55,000 " 5- and 6-inch pipe	(1.00)	55,000
100 hydrants, set complete	(90.00)	9,000
80 gates, " "	(100.00)	8,000
35,000 feet of service pipe	(.50)	17,500
Engineering, &c.		15,000
Omissions and contingent expenses, 10 per cent. say,		55,100
		$612,000

This estimate is based on the supposition that all pipe larger than six inches in diameter is to be made of cast iron, while all of that size and smaller is to be made of wrought iron and cement.

INCOME.

Inquiry has frequently been made as to the prospect of the company being able to pay annual dividends of seven per cent. from the earnings of the works; and, if not, how much the city would probably be called upon to pay in case the proposed contract, guaranteeing seven per cent. dividends, is consummated.

The following table shows the experience, in this respect, of other New England cities similar in size and circumstances to our own. It is compiled from their reports for 1868:—

CITY.	Population.	Cost of works.	Gross earnings.	Running expenses and maintenance.	Net income.	Ratio of net income to cost of works.
Cambridge. ..	36,000	$733,608.04	$63,747.42	$16,508.85	$47,238.57	6.4 per ct.
Charlestown ..	42,000	1,038,921.06	84,912.95	24,925.49	59,987.46	5.8 "
Hartford	......	870,462.98	68,813.65	15,015.05	53,798.60	6.2 "
Worcester	......	410,133.10	36,086.94	6,698.62	29,388.22	7.1 "

In each of these cities the works have been either newly built, or much enlarged and improved, since 1864, and are capable of furnishing water for a greatly increased consumption, which is expected in the immediate future. Of course such enlargement of the supply will not involve a corresponding increase in the cost of the works, nor in the running expenses, while the income may be expected to increase in nearly or quite the same ratio as the consumption of water.

The table which follows shows the gross earnings, from year to year, of the works in the same cities :—

YEAR.	Cambridge.	Charlestown.	Hartford.	Worcester.
1860.........	....	....	$30,047.69	....
1861.........	....	....	33,263.56	....
1862.........	....	....	37,010.90	....
1863.........	....	....	40,347.49	....
1864.........	....	....	45,645.95	....
1865.........	$32,367.19	....	54,640.80	$11,905.39
1866.........	40,073.27	....	62,329.08	19,084.67
1867.........	52,733.62	$60,118.83	65,465.91	22,531.35
1868.........	63,747.42	84,912.95	68,813.65	36,086.94

It will be noticed that, without exception, the earnings have steadily and rapidly increased from year to year. As before remarked, the principal outlays for construction being already made, there is every reason to expect that not only will the gross income increase in the future as it has in the past, but that the net income and its ratio to the cost of the works will be augmented in a still greater degree. These two tables exhibit a financial history of which the citizens of those places may justly be proud.

It is confidently believed that water-works in Manchester, when once they are fairly established, will pay equally well. But even if it could be certainly shown that this would not be the case, and that the enterprise would forever remain a charge upon the city treasury, that would be no sufficient reason for deciding against it. Many of the advantages arising from a copious supply of good water inure not alone to the water takers, but are public in their nature, and therefore are legitimate objects of public expense. Such are the increased safety from fires, the greater immunity from disease, the better facilities for business, the lessening of the temptations to strong drink, and the enhanced value of property. For these things the public can well afford to pay, and, if necessary, to pay continually.

Nothing in the future history of the city is more certain than that we shall be compelled, ere many years, to bring water from abroad. During the drought of last summer this was admitted on all hands. The history of other places is instructive in this regard. There are but four cities in the United States, having more than 20,000 inhabitants at the last census, in which water-works are not already in operation, or nearly completed. Manchester is one of these, Milwaukee, Lowell and Providence being the others. In the two last named places, if not in all, works have been determined upon, and their construction commenced. Manchester will not long be behind all other cities in the country.

If the works are not built in the manner now proposed, the city will soon be obliged to assume the entire responsibility of their cost and maintenance. Water-works, like our fire-department, schools, highways, etc., will be seen to be a necessity, and as such must be built and maintained, whether they cost little or much. The question, therefore, amounts to this: *Will the city, by a moderate annual expense which will probably cease in a few years, insure the building of the works by private capital, or will they, in their corporate capacity, assume the entire cost and risk of the enterprise, with the consequent increase of the city debt?* It is folly to expect to obtain the advantages of such works free of cost, and if in our municipal capacity we are to do nothing excepting such things as can pay their way without help from the city treasury, it is to be feared that the establishment of almshouses and cemeteries will be about our only ventures.

Respectfully submitted,

J. B. SAWYER, Civil Engineer.

APPENDIX.

A.

TABLE OF RAIN-FALL.

I have not found any recorded series of observations on rain-fall made in Manchester, or the immediate vicinity, and extending over any considerable number of years. The following are all of any importance to our purpose that have come to my knowledge, as made within the past twenty years, and within a circle of some forty-five miles radius:—

Years.	Lowell, by Merrimack Manufacturing Co.	Lowell, by Locks and Canals Co.	Wiers, by Lake M'f'g Co., J. B. French, Agent.	Lake Village, by Lake M'f'g Co., J. B. French, Agent.	Communicated by Prof. Henry, Sec. Smithsonian Institute. Manchester.	Londonderry.	Concord.	North Barnstead, by C. H. Pitman.
	Inches.	Inches.	Inches.	Inches.	Inches.	Inches.	Inches.	Inches
1849......	51.09	....	....	....	....	....	....	....
1850......	45.68	....	....	....	....	....	....	....
1851......	41.00	....	....	....	....	....	....	....
1852......	42.78	....	....	....	....	....	....	....
1853......	43.92	....	....	....	....	....	....	....
1854......	42.08	....	....	....	44.99	41.45	....	....
1855......	44.89	48.41	....	....	....	43.85	....	....
1856......	42.49	45.97	....	....	....	....	34.13	....
1857......	49.38	52.02	49.08	48.17	46.40	....	....	....
1858......	37.73	35.80	42.55	41.73	....	....	38.33	....
1859......	47.51	48.41	46.68	44.82	....	....	....	....
1860......	46.91	46.67	40.43	36.40	....	....	....	....
1861......	43.32	42.95	41.46	42.56	....	....	....	....
1862......	44.26	44.61	49.27	43.51	....	....	....	....
1863......	52.37	57.81	52.35	48.31	....	....	....	....
1864......	38.11	40.64	38.23	36.49	....	....	....	....
1865......	37.38	38.82	41.79	41.38	....	....	....	36.65
1866......	38.18	41.36	40.07	39.70	....	....	....	35.31
1867......	45.54	45.87	39.75	39.22	....	....	....	32.13
1868......	47.96	....	44.32	41.54	....	....	....	....
Averages.	44.13	45.33	43.83	41.99	45.69	42.65	36.23	34.70

Besides the observations at Manchester, Londonderry and Concord, Prof. Henry has kindly communicated from the Smithsonian Institution observations at various other places in the State. Observations at Laconia and Lake Village are identical with those for the same years communicated by Mr. French. The others, by reason of their remoteness, are unavailable.

B.

REPORT

OF

MESSRS. RICHARDSON AND WESTON, MADE JULY, 1860.

The committee appointed to examine Tower Hill Pond and other places, with a view to supply the city of Manchester with water, hereby present the result of their investigations.

In pursuance of the duty assigned them, your committee first visited Tower Hill pond, and from surveys found its elevation to be 43.51 feet above the Massabesic pond. Allowing Massabesic pond to be 35 feet above the sidewalk at the City Hall, the whole elevation of Tower Hill pond is 78.51 feet above that point. A greater hight than this being important, the inlet of Tower Hill pond was explored for the distance of about three miles, to Sawyer's pond, near Rowe's Corner, in Hooksett. The elevation of this pond was ascertained to be 100.62 feet above the present reservoir of the Amoskeag Manufacturing Company; and, according to data obtained of this Company, their reservoir being 112.77 feet above the sidewalk at the City Hall, the entire hight of Sawyer's Pond is 213.39 feet above Elm street at the point named. It is supplied with water, mainly from Moody's pond, situated about a mile to the eastward, and this is furnished by brooks and springs from the hillsides of Candia and Allenstown. A small amount of water is derived from Hinman's pond at certain seasons of the year.

Considerable time was spent in exploring different valleys along which to bring the water directly from Sawyer's pond to Manchester. But the summits of the valleys are so high, that to find a feasible route we were obliged to follow down the outlet of the pond to Maple Falls mill. This is an old saw-mill about one and a half miles below Sawyer's pond, and about the same distance above Tower Hill pond. From this mill a route has been explored and the levels taken in a tolerably direct course to the old Burnham mill on the Mammoth Road, and thence to the reservoir of the Amoskeag Manufacturing Company. One depression is met with between the Chester old road and the Londonderry Turnpike, where it would be necessary to lay the aqueduct about 60 feet below the grade line, and if a more direct location should be thought advisable, the depression would be increased. Aside from this, no serious obstacle need be encountered.

The hight of the mill-pond at Maple Falls is 191.36 feet above the sidewalk at the City Hall, and the height of the *bottom* of the Burnham mill-pond is 160.54 feet above the same point.

In these examinations the distances have not been measured; but from Maple Falls mill to the Burnham mill the distance is estimated to be about 4 miles; and from the Burnham mill to the residence of B. F. Martin, Esq., on Elm street, about 2 miles.

The attention of your committee was also directed to the *quantity* of water that might be obtained from these sources. They estimate the area of Moody's pond at the present hight of water, at 40 acres; but by repairing the old dam at the outlet on Chester Turnpike, it may be raised so as to cover at least 150 acres. The amount of water thus obtained, allowing the pond to cover only 100 acres at an average depth of 6 feet, would be 26,136,000 cubic feet.

Sawyer's pond is estimated to cover about 100 acres with its present dam, and may be easily raised so as to cover a much larger territory. But taking this pond at 100 acres, of an average depth of ten feet, we have 43,560,000 cubic feet.

A small reservoir may be constructed at Maple Falls, and one also at the Burnham mill, both of which would contain at least 10,454,000 cubic feet of water. By adding the contents of these reservoirs together, we have a total of 80,150,000 cubic feet or 601,125,000 gallons.

Assuming the evaporation to be one-half an inch per day on the surface of the reservoir, and allowing 50 gallons to each inhabitant per day, these reservoirs would supply the city of Manchester, with a population of 50,000, for the space of 105 days, or three and a half months, independent of any water that might flow into the reservoir from rain and other causes.

A measurement of the amount of water discharged from Tower Hill pond was made on the 15th of May last. This was several weeks after any rain had fallen, being the driest time of the present season. The result showed a discharge of two cubic feet per second, or 1,296,000 gallons in 24 hours. This alone would supply a population of about 26,000 with 50 gallons each per day. Any further measurements as to the quantity of water discharged, to be of much value, should be postponed till the water is at its lowest stage.

The amount of water requisite to supply the wants of our citizens cannot be accurately estimated. The quantities consumed in different cities, where careful records have been kept, differ widely. In Boston, during the last three years the daily individual consumption has averaged 73 gallons, while in Philadelphia some years it was but 30.6 ale gallons, and in Hartford, Ct., in the year 1859, it was 34 gallons.

Assuming the present population of Manchester at 20,000, and allowing 50 gallons to each individual per day, 1,000,000 gallons per day would be required to supply the present demand. This amount might be furnished from Sawyer's pond, without being to the expense, at present, of retaining water in Moody's pond, which might be done in future years if needed.

The general plan proposed by your committee would be to make the Burnham mill-pond the distributing reservoir, the water to be conducted from Maple Falls mill in a conduit or pipe.

The Burnham mill-pond, when raised, would flow back from the dam eastward a distance of nearly a mile, and by this means save nearly a mile in the aqueduct; so that the distance from the starting point to the distributing reservoir would be only about three miles, and, as has already been stated, the distance from the Burnham mill-pond to the north part of the city is about two miles; consequently the entire length of aqueduct would not vary much from five miles.

As it is a matter of great importance that the water introduced into the city should be of good quality, we would recommend that measures be taken to analyze the water in these ponds.

The amount of damages for land and water privileges on this route, we think cannot exceed $6,000.

The Piscataquog river has been mentioned as a source from which a supply of water might be obtained. This has been examined and levels taken from Kelley's Falls to the high grounds fronting the northerly portion of Rock Rimmon. A favorable location is here presented for the construction of a reservoir from three to five acres area, according to the expense thought advisable in its construction. The bottom would be solid ledge and elevated 123 feet above the sidewalk at the City Hall.

It would be necessary to raise the water by pumps 189 feet from the river, through a pipe 3,000 feet in length to the reservoir. This is about 14 feet higher than the water is now pumped by the Amoskeag Manufacturing Company, but only about three-fourths of the distance. By the construction of a dam at Kelley's Falls, a head and fall of from 13 to 18 feet, according to the hight of dam, may be obtained.

We have no means at present of determining the amount of water that runs in the river in the driest seasons of the year, but those well acquainted with the stream believe the supply to be sufficient for the wants of the city, and to furnish ample power for carrying all the necessary machinery, and that the quality of the water is good beyond question.

The reservoir would be 5800 feet from Canal street at its intersection with Bridge street or 6540 feet from Elm street. The length of the rising main pipe being 3000 feet, the total length of pipe to Elm street at its intersection with Bridge street would be 9540 feet or 1 4-5 miles nearly.

We are not able to state the extent of damages that would be sustained by the owners of the water powers at Kelley's Falls and the mill below, but we have ascertained that the privileges can be purchased at reasonable prices. Aside from these the damages would be trifling.

One advantage derived in supplying the city from this locality, above all others, is that the two villages of Amoskeag and Piscataquog might receive the advantages of the water with much less expense than from any other location.

In conclusion we would suggest that if the result of these examinations should lead to further surveys on either of the routes for estimating the expense of an aqueduct, that measures be taken to secure bonds for the property necessary to carry out the enterprise, and also that the matter of substituting cement-and-iron pipe for iron pipe for aqueduct purposes be thoroughly investigated. All of which is respectfully submitted.

W. RICHARDSON,
JAMES A. WESTON, } Committee.

C.

REPORT OF S. DANA HAYES, ESQ.,

MASSACHUSETTS STATE ASSAYER AND CHEMIST,

ON A SAMPLE OF WATER FROM MAPLE FALLS.

BOSTON, May 1, 1869.

A sample of water received from J. B. Sawyer, Civil Engineer, Manchester, N. H., has been analyzed with the following results:

This water is slightly tinted yellowish brown; it is transparent, nearly odorless and tasteless, and has the specific gravity of pure rain water.

One U. S. standard gallon contains 2 78-100 grains of solid matter dried at 212° F., and consisting of

Vegetable extractive matter (crenic acid, &c.)	1.58
Mineral matter (sulphate of lime and protoxide of iron)	1.20
In one gallon,	2.78 grs.

Or 100,000 parts of water contain 4 76-100 parts solid matter.

It is *soft*, free from animalculæ or animal oil, and possesses the characters of remarkably pure river or pond water. The slight color, due to the vegetable extract present, is the only objection to it, but this does not injure it for washing or drinking purposes,—it is only visible.

TABLE SHOWING PURITY OF DIFFERENT WATERS.

Results calculated for 100,000 parts of water.

Source of water.	City supplied.	Organic matter.	Mineral matter.	Total solids.
Above water	Manchester,	2.70	2.06	4.76
Cochituate water	Boston,	1.22	4.12	5.34
Croton water	New York	1.12	6.72	7.84
Fairmount water	Philadephia,	2.06	3.95	6.01
Lake Michigan water	Chicago,	1.81	9.63	11.44

The large proportion of vegetable matter in this Maple Falls water may arise from the season of the year at which the sample was taken.

S. DANA HAYES,
State Assayer, Massachusetts.

D.

REPORT OF S. DANA HAYES, ESQ.,

MASSACHUSETTS STATE ASSAYER AND CHEMIST,

ON ANALYSIS OF WATER TAKEN FROM THE BROOK AT THE OUTLET OF THE MASSABESIC MAY 17, 1869.

BOSTON, June 18, 1869.

J. B. Sawyer, Civil Engineer,
Manchester, N. H.

Sir:—The sample of water marked "Massabesic Lake," received from you, has been analyzed with the following results:

It is clear, transparent, almost entirely free from odor or taste, and is not so highly colored (yellowish brown) as the water from "Maple Falls." Its specific gravity does not differ from that of pure rain water. Analysis yielded:—

	In one U. S. gallon.	In 100.000 parts.
Vegetable organic matter	1.66	2.77
Mineral matter	1.16	1.93
	2.82 grains.	4.70 parts.

The organic matter is vegetable extract and free from animalculæ or other animal matter. The mineral constituent is principally sulphate of lime with traces of iron. The degree of hardness, on Dr. Clark's scale, is 84-100. And the water will act upon metallic lead as rapidly as that from Cochituate Lake, Mass., that is, the quantity of metal dissolved is perceptible after standing exposed for two weeks.

It will be seen that this water is remarkably pure, being preferable to that now supplied any of the larger cities in the United States, and rather better than the water from "Maple Falls" as regards color only.

Respectfully,
S. DANA HAYES,
State Assayer, Mass.

E.

ACTION OF THE CITY COUNCIL ON THE WATER QUESTION.

In Convention of the City Council, Sept. 7, 1869, His Honor the Mayor presented and read the following communication:

Gentlemen of the City Council:—

At the organization of the present city government, I called your attention to the subject of the introduction of water into the city, stating briefly, so far as I had been able to obtain the information, the prospect of that result being accomplished through the City Aqueduct Company. I desire at this time to recall your attention to the subject with a view to the adoption of such measures as will initiate steps for the introduction of water into the city at the earliest practicable period.

We are now in the midst of a drought of unusual severity, affecting not only the supply of water in our wells, but also in the public reservoirs, and particularly the streams flowing through Hanover and Merrimack Squares, and from which the supply for the extinguishment of fires is mainly derived. The growth of wood upon the hill whence this stream takes its rise having been recently cut off, the quantity of water is greatly reduced by evaporation, so that it has become apparent that this source cannot be depended upon throughout the year for a supply of water for use at fires.

Our exemption from fire for several years past seems almost miraculous. We cannot hope for like exemption in the future, at least unless a full supply of water is furnished our excellent Fire-Department.

As the city grows older, its soil becomes more or less filled with impurities, affecting correspondingly the quality of the water in our wells. From this evil there can from the nature of the case be no relief beyond the furnishing of proper sewerage.

I had reason to suppose, when my inaugural address was submitted, that the City Aqueduct Company would commence the construction of their works at an early day, upon the city's subscribing for one-third or one-half of the capital required; and that communication was based upon information to that effect. It is, however, now generally understood that the company does not intend to commence operations till there shall be a material reduction in the value of labor and materials, unless such guaranties shall be given by the city as will ensure the success of the enterprise.

By the charter of the Aqueduct Company passed in 1865, the city is authorized to subscribe to the capital stock of the company or pledge its credit to the company to an amount not exceeding one-half the capital stock of the company. By an amendment passed in June, 1869, the city is authorized to subscribe to the capital stock of the company to such an amount as the City Council shall by vote deem expedient.

The way is therefore open for the city, through this corporation, by subscribing for the capital stock of the corporation, or by a pledge of the credit of the city to the corporation, to secure a supply of pure water at an early day. The expense of course depends upon the magnitude of the work and the distance over which the water is brought. No one has estimated the expense at less than $100,000, and some whose opinions are entitled to careful consideration fix the ultimate cost at $500,000.

The first and most serious question that arises is, Ought the city, with its present indebtedness, to undertake an enterprise of this magnitude? Reluctant as I am to see the debt of the city increased another dollar, and believing, as I firmly do, that it is the true policy of the city, as of an individual, to pay off its debt at an early day, and hereafter "to pay as we go" for everything except extraordinary expenditures, yet I am fully prepared to recommend that the city subscribe for the whole stock of the Aqueduct Company, borrowing the money to pay the subscription, if the result cannot be secured in any other way. But of the two ways open to us, the preferable one, as it seems to me, is, that the city pledge its credit to the company to an amount sufficient to pay remunerative dividends to the stockholders of the company, the rate of dividend being the subject of agreement between the city and the company. The stock of the company would undoubtedly be taken upon such a pledge of the city. The debt of the city would not thereby be increased, the city merely raising by tax each year a sum sufficient to meet the dividends for which its credit would stand pledged.

As soon as the works shall be constructed, the company would begin to receive water rents, the amount of which must annually increase with the growth of the city, the amount to be raised by the city decreasing as the rents increase from year to year, till at no distant period the rents will be sufficient to meet the dividends, and the city would thereupon be released from any further payment. Or in other words the city would guarantee the stock of the company till its works could be constructed and the water rents become sufficient to pay dividends.

But, it may be asked, why should the city tax its citizens to raise money to be given away to a corporation to be distributed to its stockholders in dividends? The answer would be that it is done in pursuance of the same policy and upon the same principle that the city last year voted $50,000 to the Suncook Valley Railroad to aid in its construction, looking for reimbursement to the business which the opening of this new avenue for travel must bring to our streets. Upon the same principle other towns and cities are freely voting aid to railroads to be constructed through their respective limits which will enhance the value of their farms, afford additional means of transportation to market, and attract capital for investment.

I think there can be no reasonable doubt that the effect of introducing water into this city would be to enhance the value of our property and attract people here to reside and capital for investment.

But waiving such considerations, it is a sufficient reason for pledging the credit of the city for this purpose, that at this time there are no indications, nor even probabilities, that we are to enjoy the blessing of a pure and abundant supply of water except the city in some form aid the enterprise. The question has resolved itself into this: With the aid of the city the supply can be had, and that too as soon as the works can be constructed; without its aid the project is postponed to some indefinite time in the future.

But the advantages that could result from an abundant supply of water cannot be weighed against the cost of the enterprise. The value of pure water in our dwellings for cooking, drinking and bathing cannot be fixed too high as a sanitary measure. Its tendency to prevent the spread of intemperance cannot be lightly estimated. As a security against fire it is indispensable. It is fearful to contemplate what would be our situation should our city be scourged by fire as have some of our sister towns and cities. A single conflagration might sweep out of existence in a few hours property sufficient in value to pay the expense of the whole undertaking, even at the maximum estimate of the cost.

There is still a third mode in which we may secure a supply of water, and which by some may be deemed preferable to either of the other ways, and that is by the work being undertaken by the city. Should these other modes be found impracticable, or should the city be unable to accomplish the result in these other modes upon equitable and satisfactory terms with the Aqueduct Company, the last mode will still be open to the city, authority for which, however, being first obtained from the Legislature. But inasmuch as the city has not received such authority, I will not stop at this time to discuss the comparative advantages and disadvantages belonging to it.

In order that some immediate progress may be made towards achieving a result so desirable and indispensable, I would recommend that a committee of three of our most competent civil engineers be appointed to examine and report to the City Council, the present autumn, the most feasible plan for introducing water into the city, the comparative merits of the several sources whence water may be obtained, with estimates of the cost of the same, and what further legislation, if any, is needed to engage the city in the enterprise.

Although several sources of supply have been heretofore partially examined, public opinion has quite generally fixed upon the Massabesic as the most desirable source for a supply. It is important that the Commission should fix upon *some* source as the most feasible, that our efforts may be concentrated upon it hereafter and no further time or expense be wasted upon the others.

It will be borne in mind that this action of the City Council does not commit the city to either or any mode of aid in forwarding this enterprise, but is simply providing for an investigation by competent men, whose opinion, with such facts as they shall be able to gather up, will be laid before the City Government for its action hereafter.

I submit herewith a joint resolution which I have drawn up, to carry into effect the above suggestions, and which, with this communication, I commend to your favorable consideration.

Isaac W. Smith.

Mayor's office, City Hall, Manchester, Sept. 7, 1869.

The resolution submitted by the Mayor was amended so as to include His Honor the Mayor, and Samuel N. Bell, Esq., as members of the Commission, and passed as follows:—

Resolved, That a Commission consisting of His Honor the Mayor, Hon. E. A. Straw, Hon. James A. Weston, Samuel N. Bell, Esq., and Joseph B. Sawyer, Esq., be and are hereby appointed, with authority to examine and report to the City Council during the present fall the most feasible plan for introducing pure water into the city, the comparative merits of the several sources whence water may be obtained, with estimates of the cost of the same, what future legislation, if any, is needed to enable the city to engage in the enterprise, and to report such ordinances or resolutions as may be necessary to carry into effect their recommendations for the action of the City Council, and that their services and expenses be paid out of the appropriation for incidental expenses.

The Commission thus appointed made the following report:—

To the City Council of the City of Manchester:—

The Commission appointed by a joint resolution of the City Council, passed September 7, 1869, for the purpose of considering the most feasible plan for introducing into the city a supply of water, have attended to the duties assigned them, and beg leave to submit the following

REPORT:

The commission do not deem it necessary to allude in detail to the various sources whence water may be obtained. Sunapee and Winnipesaukee lakes are the most prominent sources of sufficient elevation to furnish a supply without pumping, but the expense of bringing water from such distances makes it impracticable to attempt to recure a supply from either of these lakes.

The Commission are satisfied that both Sawyer's pond, in Hooksett, and the Piscataquog river, will not furnish a sufficient supply, and the public would not be satisfied with water pumped from the Merrimack river. The only other source, then, left, is the Massabesic, and there they find an abundant supply, and water of the purest quality. They are unanimous in recommending that the city confine its labors to that source.

They have also considered the modes which are open to the city for accomplishing this result:

1. By the city's undertaking the enterprise.

2. By a pledge of the credit of the city to the Aqueduct Company.

3. By the city's guaranteeing dividends to the Aqueduct Company.

The first mode is objectionable for two reasons.

First, because works could not be built so cheaply by the city as by a private corporation, nor managed so advantageously when built.

Second, because in order to raise the capital to complete the enterprise it would be necessary to increase the present indebtedness of the city very largely, which it is desirable should never be done.

The second mode is deemed impracticable. It would throw upon the company the bonds of the city to a large amount, probably to be disposed of at a discount, and the same objection to increasing the debt of the city would exist as above named.

The Commission are unanimous in recommending the third mode as entirely practicable and feasible. The reasons for the same are fully set forth in the special message of the Mayor to the City Council, of September 7, 1869, and need not here be repeated. The two prominent features that recommend it are:

1. That the debt of the city will not thereby be increased; and

2. Because the city will only be required to assess by tax and pay annually an amount sufficient to make up the dividends of the Aqueduct Company in excess of its water-rents, which contribution will cease as soon as the company becomes self-supporting.

The Commission having decided on these two points, to wit: to look to the Massabesic for a supply of water, and a guaranty of dividends to the Aqueduct Company as the mode for obtaining that supply, had an interview with the officers of the company, to exchange views with them upon the subject. At that interview, both the officers of the company and the members of the commission agreed with entire unanimity that it is expedient that the city should enter into a contract with the company, embracing substantially the following terms:—

1. That the city guarantee dividends to the Aqueduct Company at the rate of seven per cent. per annum upon a capital not exceeding $600,000, payable semi-annually.

2. That the city elect two of the five directors of the Aqueduct Company, and in the same proportion of any larger number, so long as any demand is made upon the city for contribution to dividends.

3. That whenever the water-rents of the company, in excess of ordinary expenses and repairs, shall be sufficient to pay annual dividends of seven per cent., the city to be no longer held upon its guaranty.

4. Hydrants for the city to be put in at the expense of the company.

5. The books of the company to be always open to the examination of duly authorized agents for the city. An annual report of the expenditures and doings of the company to be made to the city for publication in its annual reports, or such other disposition as the city may choose to make.

6. That an accurate survey and working plans be at once commenced, and completed as soon as possible, that the works may be commenced as soon as the state of the ground will allow in the spring, the expense of said survey and plans to be defrayed by the city, and to be reimbursed by the company to the city.

The foregoing is only a skeleton of such contract, but contains most of the substantial elements necessary to be embraced in it. The Commission entertain no doubt that with the guaranty by the city of seven per cent. dividends, the necessary capital stock would be readily taken up, and such progress made with the construction of the works next season as to ensure their completion at an early day.

The cost of the undertaking can, of course, be only approximately estimated. The following is a rough estimate made by Mr. Joseph B. Sawyer, a member of this Commission:—

Land and water damages	$50,000
Pumping station	50,000
24,862 feet 20-inch pipe, 9,726 feet 14-inch pipe, equal to 2,000 tons	160,000
Reservoir	60,000
55,000 feet 5-inch pipe	55,000
400 hydrants at $60	24,000
20,000 feet service pipe, at $50	10,000
80 gates	8,000
Laying cast-iron pipe, with trenching, lead, &c.	25,000
Contingencies and omissions	100,000
Total	$542,000

The Commission would recommend that the question whether the city shall enter into such contract be submitted to the voters at the annual city election in December next, it being desirable, in a matter of such magnitude and importance, to obtain the expression of the people as fully as possible.

They submit herewith a joint resolution, authorizing an accurate survey and working plans to be made, at the expense of the city, the amount to be refunded by the Aqueduct Company whenever the city shall guarantee dividends to the company substantially upon the foregoing terms.

The Commission also submit herewith a report by Mr. Joseph B. Sawyer, on the quantity and quality of the water in Lake Massabesic, its capacity to supply abundant water throughout the year, and several matters of fact and important statistics, of much interest to the community.

The Commission, in pursuance of the authority conferred upon them, will from time to time, as there shall be occasion, report such further resolutions, and make such further suggestions, as may be necessary.

All of which is respectfully submitted.

Isaac W. Smith,
E. A. Straw,
James A. Weston,
S. N. Bell,
Joseph B. Sawyer,
Commission.

Manchester, October 5, 1869.

This report was accepted, and at the same meeting it was by the City Council

Resolved, That the City Aqueduct Company be and they hereby are authorized to make an accurate survey and working plan for the introduction into the city of water from Massabesic lake, the expense to be defrayed by the city out of the appropriation for incidental expenses, the same to be refunded by said Aqueduct Company whenever said company shall commence the work for bringing water from said lake into the city, and this resolution shall take effect whenever said company shall agree to the terms thereof.

October 28th, the directors of the Aqueduct Company accepted the terms of the foregoing resolution, and the survey provided for was immediately commenced.

November 2d, the City Council

Ordered, That the sense of the qualified voters be taken at the annual city election, on the second Tuesday of Decmber, 1869, upon the following question:

Is it expedient that the city contract with the City Aqueduct Corporation, for the purpose of introducing pure water from Massabesic pond into the city?