PROVIDENCE WATER WORKS.

REPORT

OF THE

CHIEF ENGINEER.

JANUARY, 1871.

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OFFICE OF THE CHIEF ENGINEER,
PROVIDENCE, January 2, 1871.

To Messrs. M. B. LOCKWOOD,
CHARLES E. CARPENTER,
JOSEPH J. COOKE,
Water Commissioners of the City of Providence.

GENTLEMEN:—I respectfully submit the first formal report upon the work done under my direction during the last fifteen months.

Having assumed the duties to which you appointed me, in October, 1869, I first gave attention to those parts of the work likely to require the longest time for their execution, and caused surveys to be made on Sockanosset Hill, with reference to the definite location and plan of construction of the principal reservoir; and on the grounds selected for a pumping station, with reference to their best treatment for that purpose.

In considering the construction of a reservoir, two questions of considerable importance were to be settled. The principal one, as to the necessity for making filter-beds in connection with the reservoir, had received considerable attention from yourselves, and the course of your deliberations tended to a very careful inquiry into all the plans that could be adopted for filtering the water, and to such an arrangement of the work, if possible, as would allow the decision of the question of the construction of expensive artificial filter-beds to be delayed until after the first introduction of water into the city.

During your earnest consideration of the matter, the plan occurred to me of using as a natural filter, the sand, over and through which the river flows, making it available by excavating basins near the river, and below the level of its surface. This plan was favorably received by you, and as our preliminary examinations were satisfactory, the scheme was accepted as a happy settlement of the question; whereupon all discussion of the subject ceased.

The second question, as to whether the reservoir should be constructed in two parts on Sockanosset Hill, or have one part transferred to a suitable location in the city, was somewhat involved with the first: for, in the scheme proposed by the Committee of the City Council, and taken as a general guide for our plans, the line of filter-beds occupied the place of a division embankment between the two portions of the reservoir.

The subject of filtration was discussed in the report to the Committee of the City Council, above referred to; and though the full estimates for each plan of supply included the cost of filter-beds, their construction, while inferentially, was not specially recommended, but was left for future decision, as may be seen by this quotation:—"In regard to any of the waters recommended for the supply of the City of Providence, the amount of soluble matter in them is so very small, so much less than in the best of wells, that it would seem to be superfluous to filter them for the sake of reducing this amount. And, so far as practical utility is concerned, the same may be said of separating the small amount of suspended matter left after passing the settling basin. But, in case extraordinary purity should be desired, the plans submitted embrace provision for filtration, which may be adopted or not at pleasure." Whether there are some subtile and injurious elements, undiscoverable, or at least undiscovered by ordinary chemical tests, and common to all waters, available for public supply, which would be affected by thorough filtration, is not discussed; and, indeed, our present knowledge of the matter is hardly sufficient to allow of its intelligent discussion.

The matter which it seems desirable to have removed from the Pawtuxet water has, for the most part, very little weight or substance, but is simply a coloring matter, coming, I have no doubt, from autumn leaves, and of similar nature, probably, to the coloring matter of that common beverage, tea, and having no injurious quality, so far as known, though it is objectionable to the eye.

This appears only during certain portions of the year, and is of such delicate fineness as to make it doubtful whether filtering, through the ordinary artificial filter-beds, would remove it. To test this, a small filter was constructed, as nearly as practicable, of similar materials and with the same arrangement as would be used in large filters, and having a surface area of one square yard, through which the water of the Pawtuxet river, at the Pontiac Mills, was allowed to flow at about the same rate as would be adopted in practice, or about eight inches per hour. It was also run at a slower rate than this a portion of the time. The water flowing from this filter was at intervals compared with that in the river, and it was found that while the amount of coloring matter was considerably reduced, it was not at any time entirely removed.

A comparison of this water was also conveniently made with the water of a large well excavated in the sand, near the bank of the Pawtuxet river, at Pontiac, and largely supplied, I suppose, by the river water filtered through the sand. It was found that the artificially filtered water had, in comparison, considerable color, though I was much struck by the remarkable clearness of the well water, both as seen in the beaker glass and in a large body. Professor Appleton has since told me that he has found this water to be almost precisely like the Pawtuxet, differing only as water slowly filtering through a large body of sand would be expected to differ; that is, having a little less vegetable and a little more mineral matter, with slightly increased hardness. If, as seems very probable, this well water is in great measure the naturally filtered Pawtuxet water, it furnishes strong evidence that the coloring matter can be removed by natural filtration through sand, on a still larger scale.

While the artificial filter tests were going on, examinations were being made in the sand basin through which the river flows, near the proposed site for the pumping station, by digging test-pits; by drawing the sand up through small tubes reaching a depth of ten or twelve feet; and by sinking artesian wells to the depth of sixty feet, more or less, by the use of eight-inch iron pipes, which were afterwards withdrawn. Eighteen of the latter, and a great number of the other tests were made; and the character of the material to be removed from the water, the probable inclination of the water-table, the probable effect of the motion of the water upon the stability of the sand, and of the distance of sand passed through upon the color of the water, were carefully considered.

The result of all these investigations led me to the conclusion that the material was well suited for use as a natural filter, and that the probability of obtaining a sufficient quantity of clear water from basins excavated in the sand, at a depth below the surface of the river, at a comparatively small expense, and without permanent clogging, was so great as to leave little or no doubt of our duty to use it rather than to incur the great expense and constant care attendant upon artificial filter-beds, which did not promise to be so effectual for our purpose; and this, notwithstanding the possible chance of failure in the scheme, and the possible need of constructing the artificial filter-beds at last. Even, however, should it fail as a natural filter basin, it would probably be worth a considerable portion of its cost as a settling basin, from which the water, in this case introduced into it by pipes running through the river embankment, would be pumped.

This project having, as before stated, received your approval, the plans of the Sockanosset reservoir were designed for its construction without filter-beds, but were so arranged as to admit of their construction at some future time, if found necessary, without much interference with the operation of the works, nor much extra expense on account of their being subsequently built. Their proposed location is on the northerly side of the reservoir, where the land is well adapted for them; and openings have been left in both the inlet and outlet chambers for the connection of conduits leading to and from the proposed site.

In regard to the construction of a reservoir within the city, it was necessary to secure a suitable site for it, at such an elevation as would admit of its use in connection with Sockanosset reservoir. Such a site was found at the corner of Hope and Olney streets, and within the square formed with those streets by Barnes and Prospect streets.

One of the chief advantages to be gained by such a reservoir is its action as a regulator in connection with the daily use of water in the city.

Another advantage to be gained by it, is the storage of a considerable quantity of water, near the place of consumption, which could be relied upon for use during a possible stoppage of supply by accident to the leading mains or from other cause.

The use of such a reservoir, as a regulator, will render a thirty-inch main of about equal value for the supply of the city as a thirty-six inch main without such regulator. The reason for this lies in the fact, that the consumption of water in the city, during certain hours of the day, is often about fifty per cent. greater than the *average* hourly consumption, and sometimes much more than that. At times, also, for a whole day the demand is about fifty per cent greater than the *average*; and occasionally for an entire month, it is one-third greater than the average for the year, with exceptions of even greater monthly consumption. Therefore, a leading main from a reservoir, at a distance of several miles on one side is required to be of greater capacity, in order to supply the greatest demand without too much loss of head, under that rate of flow; but, with another reservoir lying beyond the centre of distribution, near at hand, on the opposite side, a leading main may be of such size as to supply the *average* demand; for, when the draft upon the main exceeds the average quantity, so as to lessen the head upon the pipes, a supply begins to flow from the regulating, or storage reservoir, and thus the demand is supplied from both directions, through pipes of a combined capacity, sufficient to maintain the required head. Again, when the draft becomes less than the average quantity, the head upon the pipes increases, and the water overflows into the regulating reservoir and is stored there for use during the greater demand.

The saving of expense by such a reduction in the size of leading mains was estimated to be nearly sufficient, together with the amount saved by the construction of a single, instead of a double reservoir on Sockanosset hill, to construct the additional reservoir, and to pay for the land on which to build it, leaving the other important advantages of this plan to be gained at a very moderate cost. This view of the matter determined you to adopt the plan for two reservoirs, leaving a single, simple reservoir to be built on Sockanosset hill.

Having determined the general character of the reservoir to be constructed at that place, and having obtained the necessary levels and contour lines, and learned something of the character of the ground by test-pits, we endeavored to so plan the work, in shape and dimensions, as to give the greatest capacity for the least relative cost. This required that the high-water level should be placed four and one-half feet higher than was proposed in the report to the Committee, for the receiving portion of the reservoir, and six and one-half feet higher than the distributing portion, or at an elevation of one hundred and eighty and one-half feet above high tide.

The plan of the reservoir is pyriform, to suit the character of the ground; it is about one thousand feet long and eight hundred and sixty feet wide at the base.

The area covered by the reservoir and embankment is - - - - - - - 14.0719 acres.
The area of the reservoir bottom is - - 9.5383 acres.
The area of the high water surface is - 10.9467 acres.
The length of embankment, on the centre line, is 2,885.29 feet.
The length of the high water line, including lines on wing walls, is - - - - 2,873.33 feet.
The capacity of the reservoir is - - 51,156,544 gallons, U. S. standard.

The embankment is of earth, nineteen feet high above the bottom of the reservoir, and fifteen feet wide at the top, except where widened out near the inlet and outlet chambers, with side slopes of one and one half to one, or, in other words, running off a horizontal distance fifty per cent. greater than the height. The high water surface will be four feet below the top of the embankment.

The bottom, of the reservoir, slopes from the foot of the embankment to the bottom of the outlet chamber, which is one foot lower, to give facility for drainage. The embankment is formed of earth taken from the excavation, which, as a whole, is well adapted for the purpose, but lying as it does in masses of very different character, it requires to be very thoroughly mixed to get the best results. So much of the surface soil as was required to cover the outer slope and top of the embankment to a depth of one foot, was reserved in spoil banks for that purpose. The rest of the soil was mixed with other earth for the embankment.

The material used for puddle was also taken from the excavation, the largest portion of it being of a hard, compact character, the grains forming it being hard and sharp, and varying in size from an almost inpalpable powder to coarse grained sand or crushed stone, and found, by experiment, not to shrink in working. This was thoroughly mixed with a smaller portion of yellowish subsoil, and when well compacted made a very hard and apparently impervious mass. As found in the excavation, the material contained great numbers of stones considered too large to go into the puddle-wall. The most expeditious and effectual way to remove them seemed to be by screening through wire nettings of such sized mesh as to remove all stones more than one inch in diameter, which was accordingly done.

Experiments were made upon the two principal kinds of material found on the work, to ascertain what amount of shrinkage was to be expected from excavation to embankment; observations were also made upon the amount of void spaces contained in certain materials, as a means of judging what amount of finer material it would be necessary to mix with that, to make the most compact mass.

What is called heavy material, on the work, did not shrink at all, in the experiments. This was supposed to form about three-fifths of the excavation. The other, lighter material, supposed to form about two-fifths of the excavation, shrunk about thirteen per cent. of its bulk.

The estimated loss in the removal of stumps was about one thousand cubic yards, and that from the removal of grass roots and other vegetable matter was about eighteen hundred cubic yards.

The total estimated loss and shrinkage of material amounted to about nine and one-third per cent. on the total amount of excavation.

Three samples of sand, brought from a distance and used for concrete and mortar about the inlet and outlet chambers were found, by measurement with water, to have void spaces amounting, in two cases, to thirty-six per cent. and in the other case to thirty-seven per cent. of the whole bulk.

Three samples of stone, suitable for concrete, which had been screened from the earth used for puddle, had in two cases forty-two per cent. and in the other case forty-four per cent. of void spaces.

Three samples of broken stone, suitable for concrete, were found in each case to have fifty per cent. of void spaces.

Three samples of sand, brought from a distance, now on the work and yet to be used, were found to have, in two cases thirty per cent. and in the third, thirty-one per cent. of void spaces.

The surface soil, roots, loose stones, and other unsuitable material, were removed from the site of the embankment, so as to expose a suitable material on which the embankment could be raised. The amount of material thus removed was greater or less in different places.

The trench for the puddle wall was cut deeper than the general surface, for the foot of the embankment, and stepped on the sides to a narrow trench at the bottom.

A trench was also dug for puddle at the foot of the interior embankment slopes, six and one half feet wide and three and three quarters feet deep, from which the puddle was carried, in a layer two feet deep, over the natural earth, until it met and was joined with the vertical puddle wall in the interior of the embankment.

The material for puddle was applied in layers six inches in thickness, then properly moistened and thoroughly compacted by a grooved roller or by ramming, which compressed the layers to a thickness of about four inches.

The earth for embankment was applied in layers seven to nine inches in thickness, which, when properly moistened and well rolled with the grooved roller, were compressed to layers of about six inches in thickness.

The layers were so applied as to keep the sides of the embankment higher than the middle, forming a concave or dishing surface.

The earth embankment and puddle wall have been carried very nearly to the required height for soiling, excepting on the easterly side, between and about the inlet and outlet gate-chambers, and on a portion of the northerly side where the surface is at present about five and one half feet below such required height.

The interior slope of the embankment is to be lined with a layer of broken stone six inches thick, and a close, dry pavement of split stone over that, fifteen inches thick, with a concrete footing and coping.

The inlet chamber is at the south end of the reservoir, and the outlet chamber at the northeasterly extremity. They are to be connected by a brick conduit of four feet interior diameter and about nine hundred feet long, laid in the embankment outside of the puddle wall.

The bodies of the gate-chambers and wing walls are formed of rubble masonry laid in cement mortar, the exposed portion of the wing walls being laid with quarry-faced granite ashlar, and the piers and exposed faces of the chambers in dressed granite ashlar. The chambers are to be lined, after the work is thoroughly settled, with hard brick, of which the division walls and gate settings are also to be constructed.

Three lines of thirty-six inch pipes are laid under the embankment, to be used for force mains, terminating in separate cells within the inlet chamber, from which the water can at pleasure be turned into the reservoir or into the conduit connecting the two chambers. The outlet chamber is arranged with three cells in a similar way, with which thirty-six inch pipes are connected for leading mains. After passing through the embankment, these pipes will be reduced to thirty inch, or one or more of the leading mains may, in the future, be laid of the full size, into the city, if it is found desirable.

Arrangements are made so that water can be drawn into the leading mains from near the surface of the reservoir or near the bottom, at pleasure.

The stone masonry included in the contract is completed except in minor particulars.

It remains for you to contract for the brick masonry and the buildings proposed to be erected over the gate-chamber, the plans for which have been prepared.

The gates, ways &c., are under contract, but not much progress has been made towards their construction, as they will not be needed before next summer.

The general work on the reservoir was closed on the twelfth day of December, but the stone breaker is kept at work crushing stone for concrete, road-metal and slope lining, and men are also engaged preparing stone for the slope-paving. It is proposed that this work shall go on through the winter.

Measures have been taken to secure the reservoir embankment from injury by washing during the winter.

Owing to the very mild weather during the autumn and early winter, the earth work was carried on much later in the season than could have been reasonably expected; but on many mornings the surface was found slightly frozen, and considerable expense was incurred by the contractor in removing earth from the puddle, and in breaking up the surface of embankment to fit it for proper incorporation with material to be put on during the day. Coarse salt was sometimes strewn over the surface, on leaving the work, and where used in sufficient quantity it was very effectual in keeping out the frost. By preparing enough surface in this way for work in the early morning, time was gained for the sun to act upon other surfaces which were to be covered during the day, and thus the whole expense, compared with the work done, was not excessive.

The whole amount of work done upon the reservoir from the fourth day of May to the twelfth day of December inclusive, as estimated for payment, was:—

91,959	cubic yards	Earth Excavation	at	$ 36
1,626	" "	Rock	"	2 00
16,347	" "	Puddle	"	40
59	" "	Concrete	"	8 00
10	" "	Broken Stone	"	3 00
784	" "	Rubble Masonry	"	9 00
29.5	" "	Cut-faced Ashlar	"	80 00
46.5	" "	Quarry-faced Ashlar	at	50 00
46	lineal feet	Drain Culvert	"	4 00
Setting 18	36 inch Iron Pipes, and 9 special castings		for	550 00

In addition to the above, about forty-five hundred cubic yards of stone, suitable for concrete, slope-lining and road-metal, were broken or screened from puddle, on which thirty-one hundred dollars have been advanced to the contractor, on account. No estimate has been made for the slope-paving prepared, nor for sand delivered.

The work at the pumping-station, and on the line of force-mains, has consisted mainly of excavation for the foundation of the engine house, to the level of the water-table; the construction of a sand embankment along the bank of the river, dividing the channel from the site of the proposed filter-basin, excavation to a small extent within that basin and for a road leading around it; the construction of two brick culverts of five feet and one of four feet interior diameter, with granite heads and wing-walls; the formation of three sections of high embankment for the force-main line, from cuts on the line and borrow-pits near, and the partial excavation of a roadway from the pipe line to the Pontiac road, and the construction of a highway bridge on the Pontiac road over the pipe line.

In addition to the labor of laying out and caring for this work, the engineering party stationed at Pettaconset has made surveys of most of the lands purchased or taken for water works purposes, and laid out for and superintended the construction of so much of the three dwelling-houses, being erected for the employees, as has thus far been executed.

Of the sand used for mortar at the pumping station, two samples were found by measurement to have, the one forty-two and five tenths per cent., the other forty-two and one tenth per cent. of void spaces. The measurement was made by filling a box containing one cubic foot, and accurately measuring the amount of water which the box would contain in addition to the sand. The sand was filled into the box at about the same degree of compactness as if measured for mortar in the ordinary way. Another sample, filled into the box until it was half full and then rammed, and having each shovelful after that rammed as it was put in, was found to have twenty-nine and two tenths per cent. of void spaces.

Two samples of gravel used in concrete were found to have, the one twenty-nine and six tenths per cent., the other twenty-seven nine tents per cent. of void spaces.

A sample of screened gravel from one of the test-pits had thirty-nine and two tenths per cent., and a sample of screened sand had thirty-six and seven tenths per cent. of void spaces.

A cast-iron pipe, eight inches in diameter, was sunk vertically near the middle of one of the proposed filter-basins to the depth of twenty four feet below the present surface of the ground, or about twenty-two feet below what we have assumed as the ordinary low-water stage of the river, and the bottom being open, the water is supposed to stand in the pipe at the same level as in the surrounding ground. A float was placed on the water in the pipe, carrying a point which rose and fell upon a gauge set to indicate the height of the water above tide level. Another gauge, also indicating the height above tide, is established at the river. The pipe is sunk at a point about one hundred and fifty feet from the bank of the river.

The observations upon these gauges at the present state of the river, varying from seven to eight and one-half or nine feet above tide, indicate that the water in the land rises and falls with the water in the river as that rises and falls by the varying quantity turned into it by the mills above, and that it even feels the check of the stream caused by the nooning at the mills, though the nearest of them are two or three miles up the river.

When the river is carrying the least amount of water, as during the night or on Sunday, and running at about seven to seven and one-half feet above tide, the water in the pipe usually stands from ten to seven inches higher than the water in the river. This difference in height depends upon the length of time during which the river is running at a low stage, and consequently upon the time given for the surface of the water in the land to fall from its steeper inclination, caused by the sudden fall in the river, towards the natural inclination which is due to the average supply of water passing from the land into the river at its low stage. But any rise or fall in the river, even with this difference of elevation between it and the water of the well in the basin, is felt at the well within half an hour, causing a rise or fall there.

In order to gain a fair knowledge of what had been adopted by different engineers, and in different places, for the thickness and weight of water pipes, I gathered such formulæ as could be conveniently obtained, and collated them in tabular form, and by profiles, and also compared by profiles the weights of water pipes of various sizes in actual use in many of the cities of the United States.

The formulæ used for the comparison of thicknesses as proposed or adopted by different engineers are as follows:—

1. James B. Francis, $t = .000058\ H\ D + .0152\ D + .312$

2. John Neville, $t = .0016\ (n + 10)\ D + .32$

3. M. Dupuis, $t = .0016\ n\ D + .013\ D + .32$

4. John F. Ward, $t = .0002\ H\ D + .30$

5. James P. Kirkwood, $t = \frac{5\ p\ r}{c - p} + .40$

6. " " " $t = \frac{5\ p\ r}{c - p} + \left\{ \begin{array}{l} .34 \text{ for } 6 \text{ inch pipe.} \\ .33 \text{ " } 8 \text{ " " } \\ .32 \text{ " } 12 \text{ " " } \\ .28 \text{ " } 20 \text{ " " } \\ .25 \text{ " } 30 \text{ " " } \\ .24 \text{ " } 36 \text{ " " } \end{array} \right.$

7. Modification of Mons. Dupuis' formula suggested by Mr. Kirkwood, $t = 3.4\ n\ (.0016\ D) + \left\{ \begin{array}{l} .40 \text{ for } 6 \ \& \ 8 \text{ in. pipe.} \\ .39 \text{ " } 12 \text{ " " } \\ .38 \text{ " } 20 \text{ " " } \\ .37 \text{ " } 30 \text{ " " } \\ .36 \text{ " } 36 \text{ " " } \end{array} \right.$

8. J. F. D'Aubuisson, modified, $t = .00025\ H\ D + .39$

9. Wm. J. M. Rankine, $t = \sqrt{\frac{D}{48}}$ } the largest result to be used.

10. " " " " $t = \frac{H\ D}{12{,}000}$

11. Thos. J. Whitman, $t = .0045\ n\ D + .4 - .0011\ D$

12. Thomas Box, $t = \left(\frac{\sqrt{D}}{10} + .15\right) + \frac{H\ D}{25,000}$

13. Molesworth, $t = .000054\ H\ D + \begin{cases} .37 \text{ for under 12 inch} \\ .50 \text{ " 12 to 30 "} \\ .62 \text{ " 30 to 50 "} \end{cases}$

14. Proposed, for diameters greater than 36 inches, $t = .00008\ H\ D + .0125\ D + .33$

15. Adopted, for Providence Water Works, $t = .00008\ H\ D + .01\ D + .36$

t = thickness in inches.
H = head in feet.
D = diameter in inches.
n = number of atmospheres of pressure at 33 feet each.
p = pressure per square inch in pounds.
r = radius of pipe in inches.
c = cohesion of the iron, as allowed, being in No. 5 7,500, and in No. 6 5,000, pounds.

The third formula, adopted in his practice by M. Dupuis, engineer of the Paris Water Works, is in the form given by Mr. Neville in his "Hydraulic Tables," etc.

Mr. Ward would, in no case, take H at less than 100.

The eleventh, twelfth and thirteenth formulæ are found in a little book of useful information issued by R. D. Wood & Co., of Philadelphia.

The thicknesses of pipes as cast by Glasgow founders were also compared with the others, but I have no formulæ for their expression.

The weights of pipes compared, were those adopted as follows:—

By Baltimore,
" Boston,
" Brooklyn,
" Cambridge,
" Chelsea,
" Chicago,
" Newark,
By New Bedford,
" New York,
" Philadelphia,
" Trenton,
" San Francisco,
" St. Louis,
" Warren Foundry, Stock.

I trust that the result of these examinations and comparisons, as expressed in formulæ Nos. 14 and 15, will prove to be perfectly safe in our practice, and that we have not used more iron than ought properly to be used to insure such safety.

The pipes for the force main and for the leading main, are cast in four classes, of different thicknesses, depending on the head of water to which they are to be subjected. Those for distribution are cast in two classes.

The weights are estimated, at 0.261 lb. per cubic inch, for pipes measuring twelve feet in length, including the bells. A variation of four per cent. is allowed in the weights of single pipes, and the gross weight of the pipes of a given contract is allowed to exceed the standard weight two per cent. for each diameter. The weights of the several pipes are marked on them at the foundry, but they are re-weighed for payment, on receipt at the wharf in Providence.

The following schedule gives the thickness and weight for each class of each diameter and the greatest proposed hydrostatic head under which the pipes are to be used:

SCHEDULE.

Nominal Diameter, Inches.	Class.	Thickness of Metal, Inches.	Standard Weight, Pounds.	Greatest Proposed Head.
6	B	$\frac{1}{2}$	402	180
8	A	$\frac{1}{2}$	533	100
8	B	$\frac{9}{16}$	590	180
10	A	$\frac{17}{32}$	700	100
10	B	$\frac{19}{32}$	772	180
12	A	$\frac{9}{16}$	885	100
12	B	$\frac{21}{32}$	1,016	180
14	A	$\frac{19}{32}$	1,082	100
14	B	$\frac{11}{16}$	1,236	180
16	A	$\frac{21}{32}$	1,375	100
16	B	$\frac{3}{4}$	1,533	180
18	A	$\frac{11}{16}$	1,594	100
18	B	$\frac{25}{32}$	1,789	180
20	A	$\frac{23}{32}$	1,852	100
20	B	$\frac{27}{32}$	2,143	180
24	A	$\frac{13}{16}$	2,502	100
24	B	$\frac{15}{16}$	2,850	180
30	a	$\frac{13}{16}$	3,155	60
30	A	$\frac{29}{32}$	3,484	100
30	b	1	3,809	140
30	B	$1\frac{1}{16}$	4,026	180
36	a	$\frac{7}{8}$	4,101	60
36	A	1	4,627	100
36	b	$1\frac{1}{8}$	5,148	140
36	B	$1\frac{1}{4}$	5,667	180

The diameters are nominal, but no pipes or special castings have less interior diameter than that specified as nominal, and the thickest pipe approximates closely to that diameter. The exterior diameters of all classes, or thicknesses, of pipes are required to be the same for each specified nominal diameter, the variations in thickness of metal being made by changes in the interior diameter.

The exterior diameters of the pipes, and the whole of the bells, being the same for every class, there is no trouble in laying pipes of one thickness in connection with those of another thickness.

The depths of the bells are in proportion to the diameters of the pipes, from two inches for the six-inch pipes, to four inches for those of thirty-six inches diameter. The special castings have bells one inch deeper than is due to the diameters of the pipes to which they belong.

All the pipes are cast vertically. The specifications require that they shall be cast with the bell end down, but as the fixtures for small pipes were not fitted for it I allowed one foundry, on condition that a separate core be made for the bell, to make pipes of twelve inches diameter and less with that end up, resulting thus far in quite perfect and handsome castings, with unvarying depth of socket. The plan of using a separate core is liked very much at the foundry, where it will probably be adopted for small pipes in their general work.

After being coated with coal-pitch varnish while hot, the pipes are subjected to hammer inspection while under a hydrostatic pressure of three hundred pounds to a square inch.

The tensile strain of the iron used was required to be at least sixteen thousand pounds per square inch, which is rather less than that usually specified, so far as I know; but we had at first some trouble in getting specimens which would uniformly bear this strain, though as now made the pipes are of rather stronger iron than we care, on account of the resulting change in brittleness, to have used.

Some three hundred samples have been broken, and the ordinary range of strength is from about eighteen thousand to about twenty-eight thousand pounds to a square inch.

The specifications for the manufacture of pipes, on which the iron-founders bid, were carefully drawn, and required good pipe. Much complaint has been made in regard to the strictness of our adherence to the specifications, but no pipes have been rejected which were believed to be safe for our use, and it is hoped that our adherence to the requirements of the contracts may tend to improve the character of all the pipes we receive.

The right of rejection for imperfections is good at all times until the final completion and adjustment of the contract.

Much labor has been spent upon the plans for the location of the pipes, and the determination of their proper sizes. It has been our effort to so arrange the distribution as to deliver the water at its destination by the shortest practicable route, and at the same time to provide for a fair supply to all sections in case of the main arteries to those sections being cut off temporarily by accident or otherwise.

Estimates were made of the probable amount of water needed at present and prospectively in all sections of the city, and the smaller pipes were designed for a liberal supply for many years to come; leaving the larger mains, which will be needed when there is a largely increased demand, to be added from time to time as they are required.

As a guide in the determination of the most economical sizes for pipes, to carry certain quantities of water, I caused calculations to be made of the relative cost of pumping the water to an additional head necessary to carry a certain quantity of water through a small sized pipe, and the cost of an increased size of pipe necessary to convey it at a less velocity, and consequently with less head. These calculations were based on an assumed uniform duty of 500,000 foot pounds per pound of coal, and a cost of nine dollars per short ton of coal burnt in the furnace. The cost of iron pipe is taken at fifty dollars per ton. The difference in cost of laying will not materially affect the question. The loss of head resulting from greater velocity is calculated from Darcy's formula for new cast iron pipes.

The result is as follows:—

Diameters of Pipes.	Greatest allowable velocity.
6 inches	2.526 feet per sec.
8 "	2.405 " "
10 "	2.583 " "
12 "	2.904 " "
16 "	2.929 " "
20 "	2.990 " "
24 "	3.224 " "
30 "	3.488 " "

The 30 inch pipe is compared with a 36 inch. If the demand for water at a given point is such as to require a greater velocity than is given opposite a certain sized pipe, then the next larger sized pipe should be used in that place.

As the velocities given are the greatest allowable for that size of pipe, and as the loss of head is based on experiments upon new pipes, free from rust and accretions, which will increase the loss of head, I have assumed two feet per second as a general guide for the velocity of flow in the distribution, and the sizes of the pipes have been determined accordingly. Perhaps a greater velocity might have been allowed in the larger pipes, but as the influence of those pipes extends over a greater area, and I understand it to be your wish to have all decisions lean towards a thorough efficiency in the work, it was thought best to adopt a uniform rate. This will also, by increasing the sizes of the larger mains, have a tendency to delay the increase in their number, which increase must, however, come at a later time.

The contract for laying pipes required that

1,800 feet of 36 inch force main,
27,150 feet of 30 inch leading main, and
3,000 feet of 24 inch leading main,

be completed on or before the first day of December last; but numerous causes, among them the non-receipt of pipes in the order required, have tended to interfere with the work, and it closed on the 30th of December, with the following amounts laid:—

FORCE MAIN, 36 INCH PIPE.

From Station 21.26 to Station 38.004.

29 pipes of class B,	- - -	352.42 feet.
81 " " " b,	- - -	984.37 "
10 " " " A,	- - -	121.53 "
18 " " " a,	- - -	218.74 "
138 pipes.	Total, -	1,677.06 feet laid.

Average per pipe, 12.153 feet..

LEADING MAIN, 30 INCH PIPE.

From Station 3.582 to Station 27.50.

37 pipes of class a,	- - -	449.81 feet
40 " " " A,	- - -	486.28 "
117 " " " b,	- - -	1,422.37 "
3 " " " B,	- - -	36.47 "
197 pipes.	Total, -	2,394.93 feet laid.

Average per pipe, 12.157 feet.

From Station 39.89 to Station 91.38.

159 pipes of class B,	- - -	1,935.70 feet
264 " " " b,	- - -	3,213.56 "
423 pipes.	Total, -	5,149.26 feet laid.

Average per pipe, 12.173 feet.

From Station 108.09 to Station 123.

118 pipes of class b, - - -	1,435.42 feet.
4 " " " B, - -	48.65 "
122 pipes.	1,484.07 "
Add for two branches, - -	7.00
Total, -	1,491.07 feet laid.

Average per pipe, 12.164 feet.

From Station 145.96 to Station 154.88.

69 pipes of class b, - - -	839.96 feet
4 " " " B, - - -	48.69 "
73 pipes.	888.65 "
Add for one branch, - - -	3.67 "
Total, -	892.32 feet laid.

Average per pipe, 12.173 feet.

Total length of Leading Main laid, 9,927.58 feet.

SUMMARY.

Total number of pipes laid, - -	953
Total length of pipe laid, - -	11,593.97 feet.
" " " branches, - -	10.67 "
Total length of pipes and branches, -	11,604.64 feet laid.

Force main,	1,677.06 ft. 36" pipe =	0.3176 miles.
Leading "	9,927.58 " 30" pipe =	1.8802 "
Total, -	11,604.64 "	2.1978 miles.

The stationing is measured horizontally.

Notwithstanding the delays which have occurred in laying the pipes during the past year it is supposed that we shall receive all that are proposed to be laid next season in ample time for the purpose, and that by employing four gangs of pipe layers we shall be able to put in, by the first of August, all that are now contracted to be laid.

Though the pipe-laying is stopped for the present, the work of blasting for pipe trenches, on the force main and on the leading main, is still going on, and it is hoped that both these lines may be connected with the reservoir during the winter.

About thirty-three thousand cubic yards of earth have been removed in grading for the highway on the line of leading main between the Reservoir and the Stonington Railroad.

About eight thousand feet B.M. of sheet piling have been driven. About two hundred cubic yards of rubble and about six cubic yards of granite ashlar have been laid for the abutments of a bridge over the Pochasset river. These abutments were, by contract, to have been completed on the first day of November. About one fifth of the masonry is yet to be laid. The other materials, excepting two wrought iron girders, are ready for the completion of an iron bridge as soon as the abutments are finished.

Very careful and elaborate investigations have been made in regard to pumping engines, and considerable progress has been attained in the plans for them. A mistake in this matter might be disastrous, and any gain in efficiency or simplicity, without loss in other respects, would be very valuable and well worth great efforts to obtain. We shall gain time for thorough and complete designs, by putting up a temporary engine for the first supply of the city. Such an engine is now in process of construction by Mr. Henry R. Worthington, of New York, under contract for its completion in running order on the first of next August. Your conclusion to put up this temporary engine has, I think, made the introduction of water into the city during this year very probable, and has relieved us of many disadvantages which would attend the construction of permanent engines, with adequate wells and foundations, within so short a time.

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Designs have been made in our office for the valves, or gates, to be used in the distribution and on the mains, and specimens of eight inch and twenty-four inch sizes for use in North Main street are in process of construction.

Bids have been received from three competent manufacturing parties for making the whole number required, and bids are expected from two others within a few days. It is believed that such data as you will require, in order to contract for these important parts of the work, can be furnished within a short time and in good season for their completion before they will be needed.

The valve is designed to be parallel-faced, with a single disk, which will drop below the pipe for all sizes more than twelve inches in diameter, and rise above it for those of twelve inches and under. In these respects the valve is not new.

We have also made designs for the construction of a hydrant, which it is hoped will combine many of the advantages, and be free from some of the disadvantages, of the hydrants now in use.

Its location will be on the sidewalk, just inside the curb-stone, and it will be supplied with water through a branch to the street main, eight inches in diameter, forming a portion of the body of the hydrant. No part of the permanent portion of it will be above the surface of the sidewalk, to make an obstruction there, but, for use, a movable head, or chuck, one of which will be carried by each hose-company and one with each engine, will be attached to it, making in effect a post-hydrant, for the time being, capable of supplying four lines of hose with separate gates for shutting off each at pleasure.

One of these hydrants is now nearly completed for trial, and it will be thoroughly tested in every way, so that any necessary changes may be made in order to have it as nearly perfect as possible before being adopted on the work.

Many of the tools necessary for its manufacture have been made, as they were almost indispensable even for the first one, and will be worth their entire cost to any one who is successful in competing for the contract to furnish the works with such number of hydrants as you may think best to call for.

Some, at least, of those who are expected to bid for the work, have ample facilities for making all that will be required, in good season for use.

While making the underground examinations in the basin at the pumping station, we found a peculiar material lying at varying depths below the surface in a large bed on the westerly side of our proposed excavation. On being poured from the bucket in which the material was brought up, the water, coming with it, carried upon its surface what seemed to be an oily substance, with quite bright and variegated colors. The material is formed of very fine particles, nearly black, and when dry it is compact and impervious, but on being acted upon and diluted by water it runs somewhat like oil, and when the eight-inch pipe used in sinking the artesian wells was left over night in it, the surface of the material would, in the morning, be found several feet higher in the pipe than it was the night before.

Though its depth below the surface, and its position in reference to our proposed excavation, is such as to give us no great fear of trouble from it, yet it may be that water flowing over its surface will afterwards reach the basin and mingle with the waters supplied to the city. In view of this possibility, I sent to Professor Appleton two samples of the material, and one sample of a mixture of the material with water, as drawn from one of the wells which was sunk into it, with the request that he would ascertain whether any injurious matters were contained in, or accompanied, the specimens. He found no reason to think that any harm could come to the water from a mixture of this material, even if that should take place to a much greater extent than seems possible, and the fact that neighboring wells are sunk in it, and have their visible supply of water held entirely in the material, without causing any trouble, except that the water is hard and slightly brackish, sustains this view.

I have appended Professor Appleton's written report in regard to this subject.

Examinations are now being made by Professor Appleton to ascertain the action of the Pawtuxet water on various kinds of pipes used, or proposed to be used, for service pipes. This is being done in accordance with your vote authorizing such experiments to be made on the Pawtuxet water, and on water supplied to other cities.

It is proposed, also, to send a sample of the water to Professor Chandler, of New York, whose experience in such matters is well known, with the request that he will make such tests as he thinks may be useful, in regard to its action on pipes.

It is understood to be your wish that great care be exercised in gaining a knowledge of every essential element to a right decision in regard to the kind of service pipes to be used on these works, as the question is a very important one, and should be decided independently for every separate water supply, on account of the great difference which is known to exist between different waters in their action on metals.

Your quarterly reports have given information in regard to the engineers whom you have appointed as assistants on the work. I think the city is fortunate in obtaining such good service as has generally been rendered by them, upon which so much of the success and good character of the work depends.

I am your obedient servant,

J. HERBERT SHEDD,

Chief Engineer.

BROWN UNIVERSITY LABORATORY,
PROVIDENCE, Jan. 28, 1870.

J. HERBERT SHEDD, Esq.,

Chief Engineer of Water Works.

DEAR SIR:—I received from you, Nov. 30th, 1869, two samples of soil or earth for chemical examination. They were marked respectively A and B.

Sample A.

Contained of moisture,	- - -	6.28 per cent.
of matter soluble in water,	- -	.15 " "
made up of { soluble organic and volatile,	-	.06 " "
made up of { soluble mineral matters,	- -	.09 " "

Sample B.

Contained of moisture,	- - -	5.00 per cent.
of matter soluble in water,	- -	.25 " "
made up of { soluble organic and volatile matter,		.16 " "
made up of { soluble mineral	"	.09 " "

As the most important point with respect to these soils was the action of water upon them, the thing to be determined was the amount of soluble matter in them, that is, the amount of matter that would be dissolved by the action of water.

It will be seen from the statement above, that in each case this amount was extremely small—so small as in my opinion to give no ground for fear of contamination of water from this source.

These soils were further examined by aid of the microscope. By this means they appeared to consist of two parts:—

1. A fine part, of no characteristic appearance.
2. A coarse part, which seemed to consist of quartz and fragments of coal.

Dec. 18th, 1869, I received from you a sample of water for analysis. It was from the same neighborhood as the soil above mentioned and was very turbid from the presence of a large amount of mineral matter.

The total amount of matters, suspended and dissolved, was about 393 grains per American gallon, but of this large amount only 11 grains came under the head of organic and volatile matters. Further, these latter materials, upon ignition, evolved no flame, showing absence of any appreciable amount of oily matter.

A portion of the water was carefully filtered, and the filtrate was evaporated for the purpose of determining the amount of matters dissolved, as compared with those merely suspended.

The results were,

Total matters,	- - - - -	16.6	gr. to Am. gal.
made up of	organic and volatile - -	1.2	" "
	mineral, - - - - -	15.4	" "

But these results are a little too high because of the extreme difficulty of making the water perfectly clear: nevertheless they are sufficiently accurate for the purpose.

Yours, respectfully,

JOHN H. APPLETON,

Professor of Chemistry.