Thesis

Review of the Fall River Water Works

by
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Introduction.

As in the discussion of any subject matter, it is [illegible] that the [illegible] the origin and character of the [illegible] be made [illegible]. I propose before entering directly into a description of the [illegible] to mention the more important features concerning the [illegible] of Little River, as regards its location, general character, and the probable means of [illegible].

Little River is situated on the [illegible] [illegible] Bay, a branch of [illegible] Bay, about equally distant from [illegible], New Bedford, [illegible] and [illegible].

The location is of [illegible] [illegible]

Introduction

As in the discussion of any subject whatever, it is important to know the whys and wherefores of the important points, I propose before entering directly into a description of the work in question to give a few facts concerning the City of Fall River, as regards its location, general character, and its available sources of water supply.

Fall River is situated on Mount Hope Bay, a branch of Narragansett Bay, about equally distant from Providence, New Bedford, Newport, and Taunton.

The location is of such a nature

that the demand for a supply of pure water is perhaps greater than in the average of cities. Underneath the entire city, which is situated on a side hill rising with a nearly uniform slope to a hight of about 250 feet above mean high water mark in Mount Hope Bay, is a granite foundation, cropping out in many places, in other sections being only from 2 to 6 feet below the surface, while in no part of the thickly populated portion is it necessary to excavate but a few feet before comming to solid ledge.

Of course that portion of the water which falls on the surface, and escapes evaporation, and is not absorbed by the soil, penetrates to the solid rock, and together with the soakage of vaults and other waste must find its way to some extent into the wells.

It is a fact that more deaths occur per annum to the hundred inhabitants in this place than in most places in the Commonwealth, and from an examination of the annexed table which is taken from a report by Prof. J. H. Appleton of Brown University, it is fair to suppose that a lack of water anything like pure has played an important part in the matter, when we take into consideration the fact that its location is elevated, airy, and in nearly all respects unexceptionally healthy.

The table shows the results of analyses of samples taken from 10 wells, situated in different parts of the city, together with a sample from Watuppa Lake, the present source of supply.

The first column shows the total amount of solid residue obtained by the evaporation of one American gallon of the sample. The second shows what proportion of the solid residue consisted of organic and volatile matters. The third shows the proportion of mineral matters; The fourth the hardness.

No. of grains per Amer. Gal.				
Total.	Organic and Volatile	Mineral Matters	Hardness.	
1.80	0.84	0.96	.20°	Watuppa Lake.
26.70	3.03	23.67	13.80	
28.27	6.52	21.75	11.20	
29.05	10.43	18.62	16.00	
31.48	10.96	20.52	9.00	
32.18	5.21	26.97	14.00	
37.07	11.66	25.41	12.00	
49.87	15.74	34.10	21.00	
61.82	6.18	55.64	18.00	
61.85	12.01	49.84	21.00	
83.89	11.66	72.23	30.00	

2° As regards the general character of the city, it is now well known to be the largest cotton manufacturing place in the Union, having within its limits 44 cotton mills with a capacity of about 1,275,000 spindles, together with many other large manufactories, which necessitates an ample water supply for fire purposes.

3° As regards the available sources of water supply; It did not take long to decide that Watuppa Lake possessed advantages over all other available sources of supply. This lake, which is situated about 2 miles east of the centre of the city, and has an elevation of 128 feet above the level of mean high tide in Mount Hope Bay, and having a daily discharge of about 30,000,000 gallons, is at an elevation above that of two thirds of the area of the city. The area of the lake is 5.81 square miles, while that of its water-shed is 28.50 square miles. Its storage capacity is about 10,000,000,000 gallons. Stafford Pond which is a tributary of the lake, is 72 feet higher than the lake, and is about 4 miles from the city; but it is not high enough to furnish the requisite quantity by gravity at a sufficient elevation to supply one half of the present, and future area of the city. Its area is .33 square miles, and that of its water-shed is 1.86 square miles. Its storage capacity is about 1,000,000,000 gallons.

Many experiments have been made to determine the quantity of water that can be obtained from a given district of country. The following is from an article written by William J. McAlpine on that subject. He says "The whole quantity of water which any particular district will furnish depends entirely on the following conditions.

1° The amount of rain fall.

2° The area and character of the water-shed

3° The losses by evaporation from the ground, by absorption of vegetation, and by evaporation after collection in the storage reservoirs." As none of the fluid is lost in the present case, the evaporation, absorption and discharge of the streams must be equal to the rainfall.

"Practically it has been found that a square mile of water-shed is capable of furnishing 1,000,000 gallons daily, if the water is properly stored. Some experiments would seem to show that a greater amount could be furnished; but allowing something for unavoidable waste, and the leakage of dams, and fixtures, perhaps the available supply given above is large enough. This amount per. square mile is a perfectly safe amount, for it is more often exceeded than not."

From the facts just given we see that Watuppa Lake is capable of supplying about 28,500,000 gallons daily, and together with Stafford Pond will furnish about 30,360,000 gallons daily.

The quantity of water discharged from Watuppa Lake can also be got at in the following manner. The stream which forms the outlet of the lake discharges 121.5 cubic feet per second, or 4,811,400 cubic feet in a day of 11 hours, which is equal to 36,085,500 gallons; but as the stream runs only 6 days in the week, we must take six sevenths of this amount for an average daily discharge, or 30,930,429 gallons which agrees very nearly with the results obtained by Mr. McAlpine's method.

In small cities it has been found that the average daily consumption is about 60 gallons for each inhabitant, but the large use of water for manufacturing purposes in this city may increase that amount; but if the demand was as high as 100 gallons per inhabitant per. day, we have a supply for a much greater population than there is any need of providing for.

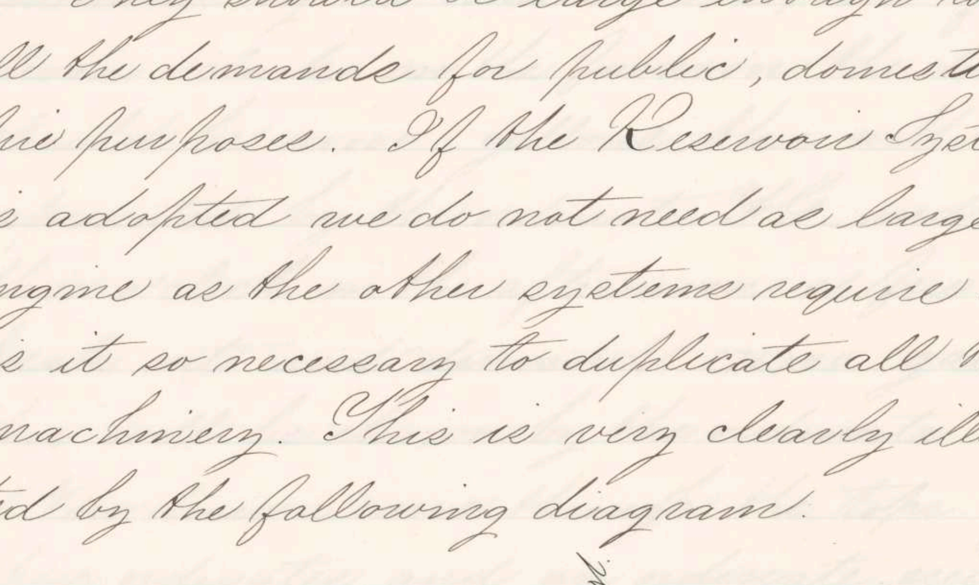
I have not thought it necessary to

discuss the merits of the other source of water supply which were considered.

Having once fixed upon a source of supply, numerous questions arise as to the character of the works to be constructed.

1° Probably the point of most importance is the adequacy of the works

They should be large enough to meet all the demands for public, domestic and fire purposes. If the Reservoir System is adopted we do not need as large an engine as the other systems require nor is it so necessary to duplicate all the machinery. This is very clearly illustrated by the following diagram.



Take the line AB for a datum, and let its length represent one day. Suppose that we have an engine capable of pumping 100.000 gallons per hour, and let this be represented by the figure ABCD. Now if we suppose the demand at midnight to be 10.000 gallons, this will be represented by the ordinate AE, and if at eleven o'clock in the forenoon the demand should be 150.000 gallons, this will be represented by the ordinate FG, and if at three o'clock in the afternoon a fire should break out and demand 175.000 gallons this will be shown by the ordinate HI.

Now draw a curve through the tops of these ordinates, and an ordinate erected at any point of the line AB to this curve would represent the demand at the time represented by the point of the line AB.

From this we can see that if we had a reservoir which was storing up the surplus water during that part of the day when the demand did not equal the amount supplied by the engine, that our engine would be large enough; but on the other hand if our system was one of direct supply we should require an engine of much greater capacity.

Great care should be taken with the distribution of the water. It sometimes happens that pipes are laid which in a short time prove too small to deliver the necessary amount of water. This has happened in New York. In the upper part of the city during some parts of the day, when the demand is considerable, it is impossible to get water in the upper parts of some of the buildings. In New Bedford also notwithstanding the fact that the works has only been completed about two years, they have been obliged to substitute 16 inch for 12 inch pipes in some localities.

When water is made to flow with considerable velocity through a pipe, as was the case in the two examples just mentioned, there is a great loss of head on account of friction. Perhaps while speaking of loss of head by friction it would not be out of place to stop here and take an example of this. The one that I have chosen is the "Low Service" force main from the pump to the stand pipe. The length = 1500 feet. The diameter = 2 feet. I have used Mr. Kirkwood's formula for the loss of head by friction which is $H = \frac{V^2 L}{2304 D}$ in which H = loss of head in feet. V = velocity in feet per second. L = length of pipe in feet. D = diameter of pipe in feet. I have taken the maximum amount pumped by the engine in 24 hours or 4.750.000 gallons.

If the engine pumps 4,750.000 gallons in 24 hours, it would pump $\frac{4.750.000}{7.4805 \times 24 \times 60 \times 60}$ cubic feet in one second = 7.35 cu. ft. per sec. The area of the cross-section of a 24 inch pipe = 3.1416 sq. feet. $V = \frac{7.35}{3.1416} = 2.34$ feet per second ∴ $H = \frac{5.4756 \times 1500}{2304 \times 2} = 1.78$ feet.

2° Perhaps next to the consideration of adequacy is that of economy.

Where the system is one of direct supply like the present one, or whatever system we have, a great saving can be made in the pipes by properly dividing the district to be supplied into "High Service" and "Low Service".

Horizontal engines require less expensive foundations than vertical engines, because in a vertical engine the thrust is in a vertical direction, and must be resisted by a very firm foundation.

3° As regards the safety of a works, the reservoir system is the most reliable; but if our system is one of direct supply, and we have the pumping machinery and the mains duplicated, and so arranged that we can pump into either main with either engine, as is the case in the present example, we may consider ourselves tolerably safe.

Although much of what I have said

thus far forms no part of the description of the work as constructed yet it is important in connection with it and I thought it best to give it before entering into a description

Description of the Works.

The necessary arrangements for obtaining the supply from the lake are as follows

1° A Pump well, Pumping Engine, and House in the lake.

2° A Force main to the Stand Pipe

3° A Stand Pipe.

4° A Supply main to the centre of the city

5° The Distributing Pipes, Water Gates, Hydrants &c.

The most convenient point from which to take the water, was found to be on the western shore of the lake at a distance of 9472 feet from the centre of the city.

The first work done was the construction of a road and pipe trench about a mile in length, extending from the lake in a straight line towards the centre of the city. About 950 feet of this was through solid granite rock, 18 feet in height in some places, and in one place a ravine was crossed which for a distance of 300 feet required a fill of 17 feet.

The rock was excavated to a depth of 7 feet below the grade of the road, and with a width of 10 feet.

After this, came the construction of the foundations for the engine house, boiler house, coal house, boilers, and engine. The shore of the lake around the point selected for the pumping station was very steep, and rocky, and in order to avoid a very heavy grade for the road, and very deep rock cuttings, it was thought best to locate the engine house in the lake about 60 feet from the old shore line.

This necessitated the building of a coffer dam, within which the foundations could be laid. The frame of the dam, consisting of two parallel rows of sheet piles, fixed at a distance of 10 feet apart by 68 iron rods, 12.5 feet long, 2.5 inches wide, and .5 of an inch thick, was constructed on the ice in the winter, and lowered to its position on the melting of the ice. The rods were passed through the stringers and keyed on the outside, so that the planks could be driven until they reached hard bottom. Sand bags were used to fill all holes that could not be stopped by planks.

The space between the piles was filled with earth. After excavating for the foundations the soil was found to be so springy that it was necessary to put in a layer of concrete, 18 inches deep, before laying the foundations. The foundation walls were 2 feet 10 inches wide on top, with a batter of 1.5 inches to the foot, on each side.

The conduit extending from the gate house to the engine house, is 87 feet in length. Starting from the gate house for a distance of 73 feet it has a width of 6 feet, and a depth of 4 feet; thence to the engine house its width is 4 feet, and depth 10 feet. It is covered by a brick arch with an inside radius of 3 feet.

The gate house, a plan of which I have shown in drawing number (1), is situated 105 feet east of the engine house. Its outside dimensions are 18 feet, by 16 feet. The thickness of the walls is 4 feet. The gate chamber is 10 feet in length, and 8 feet in width. The bottom of the chamber is 10 feet below high water mark in the lake, and 1 foot below the bottom of the pump well.

The gate chamber has in it, besides the gates, three screens to prevent substances from passing into the pump well.

The gates are constructed of 3 inch plank, fitted loosely into cast iron frames, and are arranged so that water can be let into the pump well from near the surface, or near the bottom of the conduit.

The main conduit inside of the engine house is divided into four branches, as is shown in drawing number (1). Each of these branches is intended to supply water for one of the four engines which the house is built for.

I have shown this in drawing number (1), and have also shown three of the branches closed by gates. This is because at present only one engine is completed and in use. The gates by which the other three branches are closed are made of 3 inch plank fitted into cast iron frames.

The engine house of which I have shown a plan in drawing number (1), is built of rough ashlar granite masonry.

The foundation I have described.

The walls are 2 feet thick, laid in regular courses, and the trimmings are of cut stone. The engine room is 80 feet, by 55 feet 10 inches, the boiler room 53 feet 3 inches, by 23 feet, and the coal house is 88 feet by 21 feet.

The engine room is intended for four engines, two "High Service" and two "Low Service" engines as shown in the plan of the engine house. The one now in use is one of the "Low Service" engines and was built by the Boston Machine Co. It is similar to the one in operation at Boston Highlands. It has two pumps 16 inches in diameter, and two steam cylinders 28 inches in diameter.

It is a double horizontal condensing engine. Both cylinders and pumps have a stroke of 42 inches, and work from one crank shaft, with a fly wheel weighing 15 tons, and 15 feet in diameter.

The two parts of the engine are symmetrical, and one or both can be run.

The engine commenced pumping into the mains on the 5th of January, 1874, and the average quantity pumped per day from July 1st, 1874, to January 1st, 1875, was 752,684 gallons, as is shown by the following table, but it has been found that the average amount consumed by the city has not exceeded 350,000 gallons per day; for it is economy to take the water for condensing directly from the force main, when the city is consuming but a small amount, otherwise this amount would run from the overflow of the standpipe back into the lake. When however the whole capacity of the engine is required to supply the city, as in case of fire, the "donkey pump" must furnish the water necessary for condensing.

The "donkey pump" pumps on the average 25.000 gallons per hour. The water cylinder is 12 inches in diameter, and has a stroke of 12 inches

The engine runs continually from 6 A.M. till 8 P.M. The condenser during this time is supplied from the main, and requires about 350.000 gallons. During this time there is from 50.000 to 100.000 gallons discharged over the weir connected with the stand pipe.

From this we see that about 400.000 gallons find their way back to the lake daily, and subtracting this from the whole amount pumped, we see that the daily consumption by the city is about 350,000 gallons.

Table showing work done during the year 1874.

Date 1874	Single Engine 69 gallons per revolution	Double Engine 138 gals. per revolution	Per. Month	Average per. day
Jan. 1st to July 1st	77,135	300,000	7,770,389	259,014
July,		72,922	10,063,236	324,620
August,	2,964	118,102	16,502,592	532,342
September,	36,191	178,792	27,170,475	905,683
October,		212,504	29,325,552	945,992
November,		188,705	26,041,290	868,043
December,		212,977	29,390,826	948,091
Totals and Averages July 1st, 1874 to Jan. 1st, 1875	39,155	984,002	138,493,971	752,864

The average duty of the engine for the last six months is 27.833.973, and for the last three months 31,000,000.

The following formula has been used in calculating the duty, and by duty I mean the number of pounds of water raised 1 foot high by 100 pounds of coal.

$D = \frac{P \times V \times H \times 100}{F}$ in which D = duty, P = number of pounds of water delivered per stroke, V = number of strokes made during the trial, H = head in feet including friction in the mains. F = number of pounds of coal consumed during the trial, not deducting ashes or clinkers, and not reckoning the coal used in getting up steam, or banking fires.

Distribution.

The distributing mains are all of cast iron. The area included in the low service is divided into four classes. A, including those portions where the head does not exceed 80 feet. B, including those portions where the head varies from 80 to 140 feet, C, where it varies from 140 to 200 feet, and D, where it varies from 200 to 260 feet.

In calculating the thickness of the pipes an examination was made of the formulae used by some of the best engineers; and a table made in which the formulae of Rankine, Dupuis, Kirkwood, Shedd, and Ward were compared. The results taken were those obtained by Ward's formula, which is $t = 0.0002 H D + 0.30$ in which t = the thickness in inches. H = the head in feet, and D = the diameter in inches.

As an example of this take an 8 inch pipe in class D, and we have

$t = .0002 \times 260 \times 8 + 0.3 = .416 + .3 = .716$ inches.

Rankine's formulae give a less thickness in almost every case.

The exterior diameter of the pipes is the same for every class of the same size. The variation in thickness makes the interior diameter vary slightly in the different classes. There is no trouble in laying pipes of one thickness, or class, in connection with those of another class, for the interior diameter of all the bells is the same for each size.

There is an 8 inch pipe or "rider", laid alongside of the 24 inch main, and connected with it at intervals of about a thousand feet, so that it is not necesary to insert taps for service pipes in the main.

In drawing number (1) I have shown the "High Service", and "Low Service" pipes near the engine house. Those tinted dark are the "High Service" and those tinted lighter are the "Low Service". It is plainly shown in the drawing that the two sets of pipes are so arranged that we can pump into either set with either engine number (1), which is a "Low Service" engine, or number (2), which is a "High Service engine.

Stand Pipe.

Drawing number (2) shows a plan and part elevation of the stand pipe together with a plan and elevation of the weir.

The "Low Service" stand pipe is 31 feet 4 inches in height, and has a diameter of 3 feet 6 inches. It is made of boiler iron, and rests on a 24 × 24 three way branch, which rests on a solid granite block, and is steadied by four iron bolts, 9 feet in length, and 2 inches in diameter.

The "High Service" stand pipe, which is to be similar in construction and 50 feet higher, will not be constructed until the "High Service" engine is delivered, which is a duplex pumping engine, guaranteed to perform a duty of 65,000,000. It is similar to those now in operation in Cambridge, Salem, and Charlestown.

The stand pipe house is to be built of brick, and will be 90 feet in height, and cylindrical in form, as shown in drawing number (2)

Mercury Gauge.

A mercury gauge has been erected

in the Engineer's office, and connected with one of the mains. A model of the "Low Service" stand pipe is connected with this gauge so that the height of the mercury opposite the model shows the height of the water in the "Low Service" stand pipe.

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Hydrants.

The hydrants used are those known as the Flush Hydrant, with a portable hydrant head, containing four nozzles 2.5 inches in diameter, with a separate valve for each. These hydrants are connected with the mains by 6 inch pipes.

In drawing number (3) I have shown two sections, a plan, and side elevation of a Man Hole, and Blow Off, together with a section of the culvert at the engine house.

There is now under consideration the building of a reservoir, having a capacity of about 25.000.000 gallons which when completed will add greatly to the safety of the works.

My endeavor has been in this memoir, to give a general description of the works in a brief form, and at the same time to touch on some of the most important details.

Respectfully submitted,

Samuel E. Allen.