# The New Bedford Water Works.

A Thesis
by
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The abundance of an unlimited supply of good water has become one of the leading questions which every city of any considerable size has to settle sooner or later.

It is an established fact that as a city increases in size, the available portion of the water which falls upon the area covered by the city, constantly diminishes, and the quality of the water is continually growing poorer. As the city is built up, a portion of the water which previously percolated through the soil, and was collected in wells, passes down the gutters of the streets into the river or sea, and another portion finds its way to the sea by following the course of water and gas pipes.

Where a city depends upon wells, the water becomes more and more contaminated by the waste products of houses and barns.

Many cases of poisoning occur by the water of wells becoming polluted in this way, and the injurious properties are not discovered till a chemical analysis of the water has been made, as the injurious material may not cause any unpleasantness to the taste.

The original source of all water supply is the ocean, from which the water is Evaporated, and as it falls upon the Earth in the form of rain, is nearly pure, containing only a very slight amount of gaseous impurities, as carbonic acid or ammonia which it has absorbed while falling through the air. Whatever impurities it contains when adapted for use, it has gathered in its course through the Earth.

The water which falls upon the Earth might be divided into three parts, according to the subsequent course which it pursues. The first and much the larger portion finds its way into rivers and flows directly back into the ocean. The second portion returns into the atmosphere by evaporation, and falls again as rain. The third portion penetrates deeply into the earth, and either finds its way into the sea by some invisible way, or becomes entirely lost from the surface circulation.

The latter theory is advanced by Prof. Friedrich Pfaff, but seems scarcely probable as we cannot think of any place where this water can be continually going to, and the balance between the sea and land must be maintained. At any rate, it is only the first portion, that which finds its way into natural basins, and from them into rivers and streams, that we can count upon to furnish an available artificial supply. The ratio of this amount to the entire rainfall varies very much in different districts. Thus according to Dalton, the combined rivers of Great Britain carry to the sea 39.8 per ct. of the rain-fall. The Seine, according to Arago, 33 1/3 per ct. The Rhine, according to Berghaus, 49.8 per. ct. The Weser, according to the same, 52.9 per ct. and the Lippe 71.6 per. ct. Stated most generally, the amount drained from any area is proportional to the amount of rain-fall, and to the size of the area; but these differences are caused by varying geological formations, character of the soil, and the climate. Basins may obtain water from springs

which draw their supply from more distant areas.
40 per ct. of the rain-fall was all that was calculated upon when it was determined to furnish Boston with water from Lake Cochituate, but after the aqueduct was built, by careful measurements of the amount supplied to the city, of the annual rain-fall, and the waste, extending over a period of ten years, it was found that 54 per ct. of the rain-fall was collected.
From 19 experiments made in England in different drainage areas, and published in a work on Hydraulic Engineering, 66.32 per ct. was shown to be collectible; and from seven experiments made in New York, 57.83 per ct.

From these figures we see that

the average for different districts varies a good deal; but the mean average may be considered as about 53 per ct. of the Entire rain-fall.

Generally the rain-fall is greatest at the Equator, and gradually decreases towards the poles. Humboldt gave the following as an approximation of the depth of rain-fall in different latitudes.

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| At the Equator, | | 90 inches |
| In latitude | 19°, | 80 " |
| " " | 45°, | 29 " |
| " " | 60°, | 17 " |

## Qualities of Water

The water which falls in cities is not so pure as that which falls in the country, owing to the contaminating gases arising from decaying and

dissolving substances.
The water in passing through the soil, absorbs the soluble mineral matters of the soil, and also becomes more or less colored by vegetable matter.
The most common impurities of water are chloride and sulphate of soda and potassium, carbonate of calcium and magnesium, silica, alumina, iron and vegetable matter.
It is impossible to lay down definite rules regarding the necessary qualities of good water, but perhaps it would not be out of place to state the requirements of the Vienna Commission for 1864.
They were as follows:
1. A water to be suitable in every respect for drinking purposes must be bright and clear, free from all suspended matter, without odor, cool and refreshing to

the taste.

2. It should contain only a small amount of "total solid matter" in solution, and should be entirely free from all organic matter either already putre-fying or capable of putrefaction.

3. Of the mineral ingredients, the alkaline earths together should not amount to more than the equivalent of 18 parts of lime in 100,000 parts of water; i.e. the hardness of the water should not exceed 18 (German) degrees.

4. The soluble salts should form only the smaller proportion of the entire solid matter, and above all, the water should contain only very small amounts of the sulphates of magnesia and of the alkalies, and of nitrates.

5. The chemical character of the water as well as the temperature of the same

should vary at different times of the year, only within narrow limits.

6. A water intended for domestic use should be protected from every source of pollution, and even from the direct entrance of surface water.

7. Soft spring water alone fulfills these conditions, and such water only is suitable for a drinking water.

8. The manufacturing industries require for their purposes a water of nearly the same character as that required for domestic use, and with reference to this purpose, the same conditions are to be satisfied.

9. Filtered river water, if it can at all times be obtained free from turbidity, is suitable for manufacturing purposes, but not for domestic use as it fails to satisfy the conditions laid down under "5 & 6."

10. For sprinkling and watering the streets etc. any water will answer which is free from odor and contains no considerable amount of decaying matter."

Probably no one quality is of more importance in water than its hardness; soft water being of prime importance on the score both of health and economy. According to all physicians who have made a study of the subject, soft water is very much healthier than hard.
Statistics which show the importance of having soft water on the score of economy come to us from England. M. Soyer, "the most eminent cook in the world" says that there is a difference of nearly one-half in the time required to cook meats and vegetables in hard instead of soft water, and the latter is absolutely necessary for good cooking. Nearly one-

third of all the tea used in London is wasted by the use of hard water.
It has been estimated that if soft water were used in London instead of hard for washing, there would be a saving in soap and clothes of twenty millions of dollars per year.
In the introduction of a new supply of soft water, people who have been used to drinking well water, must not expect to have water which will not at first taste flat, and although the purest water is not the most desirable for drinking, yet well water has often a great deal of life, and is refreshing to the taste on account of gases it has absorbed which are injurious to the health.
Soft water is satisfactory for drinking when it possesses the qualities of clearness and coolness. The first may be obtained

either by keeping it quiet for some time, or by filtration, and the second by the use of ice, which has become now almost universal. Lakes and ponds vary very much in the character of their water. If they are deep, they are subject to less variation of temperature than rivers, and are less colored by vegetable matter.

## Analysis of Waters.

There are a variety of methods of water analysis. We can argue very little from the appearance of water what its character will be, but there are certain inferences which may be drawn. Water flowing through marshy land for instance becomes colored. The color of water is the first thing to be noticed, but there is no definite comparison of color.

The main impurities are divided into

two classes. — gaseous and solid.
The gases are oxygen, nitrogen and carbonic acid, dissolved in the water in different proportions from which they exist in the air. Natural waters often contain a large amount of carbonic acid and a small amount of oxygen because the oxygen which has been absorbed from the air, is used to oxidize the vegetable matter, producing carbonic acid.
The air in the ground also contains much more carbonic acid than the atmosphere. Carbonic acid increases the corrosive action of water on boilers.
In all methods of analysis, it is universal to determine the total amount of solid matter left after evaporation.
In getting the amount of solid matter it is usual to reduce it to the temperature of boiling water; and this amount to

one place of decimals is all that is certain or necessary.
In case of mineral water it is necessary to determine every constituent of the residue, but this is not required for sanitary purposes. Some results are stated in grains to the gallon, but in this case care should be taken to state whether it is the English gallon of 70000 grains or the United States gallon of 58000 grains. The ordinary way however is to give the amount of residue in parts in 100 000.
The results of analysis are to a certain extent conventional, for we cannot follow the changes when soluble compounds are mixed. The only determination of very great importance is of the chlorine, and this determination is very nearly exact.
Anything above a very small amount of chlorine indicates some contamination.

Cochituate water has about three-tenths of a part in one hundred thousand.
In Western Massachusetts, uncontaminated streams will contain less than one-tenth of a part in one hundred thousand.
Nearer the sea where the water is exposed to sea fogs and winds, it will contain two or three parts.
Hard water is one which destroys the lather-making properties of soap, and the degree of hardness is very simply determined from that fact. Soap may called stearate of sodium which is soluble in water; but if the water contains calcium salts, an addition of soap will form stearate of calcium, and sodium sulphate or carbonate as the case may be.
The stearate of calcium is insoluble, and it is only after all the lime has been thus precipitated that the soap can

have any useful effect on the water. In England the hardness is obtained in the following manner. A grain of carbonate of lime is dissolved in seventy thousand grains of pure water. The water is then said to have one degree of hardness. The quantity of soap required to precipitate the lime and cause the water to foam when shaken is ascertained. Then every additional degree of hardness represents an additional grain of carbonate of lime.

In Germany one degree represents one part by weight of calcium oxide in one hundred thousand. In France, one part of calcium carbonate in one hundred thousand.

The organic matter is determined by the amount of permanganate of potash which will oxidize the organic matter.

The organic matter may be of vegetable or animal origin. The vegetable matter contains a larger proportional amount of carbon, and the animal contains a larger amount of nitrogen. The nitrogen is obtained in the form of ammonia, the tests for which are very delicate. The chemist can easily test for one part in a billion.
Nitrates in water are recognized as harmless. They show that the water must have been contaminated previously with nitrogenous organic compounds; usually spoken of as "previous sewerage contamination"; but this is no indication that the water is unfit for use.

## History of the New Bedford Water-Works

We shall now give a short history of the works, and take up in more or less order the special cases of some of those points of which a general discussion has already been given.

The first step in relation to the introduction of water into the city was taken in 1860, when in March of that year an order was introduced into the City Council that a committee be appointed to consider the practicability and expediency of introducing a permanent supply of fresh water into the city, and report a plan with the probable cost. In July 1860 an expenditure of $300.00 was made "for the purpose of testing the practicability of introducing a permanent supply of fresh water."

In December 1861 the report of the Engineer and the City Surveyor were made. They show that the introduction of water is practicable, and give the preference to the Acushnet River as the source of supply. They prove that from that source a supply sufficient for double the population of the city can be obtained, allowing an average daily consumption of two barrels for each man, woman and child.
The expense is estimated at one-half million dollars. The committee of that year recommend very strongly the introduction of water and speaks of it as mechanical necessity.
Captain Bigelow who was the United States Engineer having charge of the government fortifications of the harbor, and who was employed by the City to examine

into the question of the introduction of water, considers in his report that the most important advantage which would result, would consist in an ample supply for mechanical uses, hardly any city being so poorly provided for in the respect as New Bedford.

In the whole southern part of the city scarcely enough water could be procured in any one locality for running a steam engine; and Captain Bigelow goes on to say: "This difficulty meets any enterprize, requiring steam power for its accomplishment upon the threshold and in part has been and will be an insurmountable one, except by means of a public aqueduct."

The City Surveyor shows in his report that a daily supply from the Acushnet of 2,806,039 gallons could be relied on, which would give 60 gallons each to 46,767 inhabitants. The present population of the city is about twenty-six thousand.

During the year 1862 nothing further was done. In January 1863 an appropriation of $300.00 was made for further investigation. In April of that year, the necessary act was obtained from the Legislature for providing the City with water. Professor Chase of Brown University was Employed to make an analysis of the water along the line of the stream.

He found it of unusual purity.

A sample of the water taken near the head-waters of the stream, when subjected to the proper tests gave .815 degrees of hardness. Previous to concentration it showed no indication of the presence of chlorine, sulphuric acid, lime, iron or of any of the salts. A gallon (58,372 grains) Evaporated to dryness gave the following analysis.

Amount of solid residue = 1.756 grains

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|---|---|---|---|
| consisting of, | Organic matter, | .526 | " |
| | Salts | .116 | " |
| | Silica | 1.114 | " |

Samples of the water taken lower down in the course of the stream contained an increased amount of organic matter and of salts.

In 1865 the city obtained the valuable services of Wm J. McAlpine as Consulting Engineer. He examined the different sources from which a supply might be obtained, in order to see which was the most practicable, and made plans and Estimates of the various methods of supplying the city.

The first of these plans was by a harbor

dyke which was to built across the harbor at Dog Fish bar about a mile and a half above the New Bedford and Fairhaven bridge shown on the map.
This is about two miles below the highest point in the river to which tide-water reaches, and the tide here is about four and one half feet.
The proposed dyke at this point would have to be about 1300 feet long, and built up to a height of four feet above high-tide. The salt water of the sea would thus be shut out, and the fresh water of the Acushnet River would fill the upper basin.
A large waste weir would be constructed at one end of the dyke, and there would be a lock in the dam to allow small vessels to pass into the basin.
A roadway could be constructed on the

dam which would be convenient for many passing between New Bedford and Fairhaven. The lock would in that case have to be closed by a small draw-bridge. It was proposed to have the water in the basin one foot above high-tide. But the great mass of vegetable matter which has been deposited on the bottom of the harbor, and which being continually covered by salt water has never decayed, would probably, so soon as the salt water had all flowed out of the basin, begin to decay and very seriously injure the quality of the water for domestic purposes.
The immense mass of this vegetable matter would render impracticable any attempt to remove it, and entirely on this account the plan was abandoned.
A pumping Engine would have been stationed

on the west side of the basin, and the water forced into a distributing reservoir on the heights in the north part of the city.
The Estimates of the cost of introduction by this plan amounted to $293,607.50

Another plan was to draw the supply from Long Pond by constructing a bulkhead in the pond to draw the water from a level below low-water. The water would then be conducted in an open canal as far as the Acushnet valley, and then conducted by a brick conduit to a receiving reservoir and from there forced into a distributing reservoir situated on the heights previously mentioned. The Estimates of the costs by this plan amounted to $369,612.25
As there are valuable mill privileges on this pond, the city could probably not

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have got legislative authority to use the water. This and several minor plans were therefore abandoned, and the city decided in favor of the Acushnet plan as recommended by Mr. McAlpine.

The drainage area above where the dam was built contains 3300 acres. The material of the soil is sand and gravel. The water comes to the surface in the form of springs.

From gauges taken before the dam was constructed, it is shown that the minimum daily supply at this point is not less than two and one half millions of gallons. The mean daily average is about five millions of gallons.

The Storing Reservoir and Dam.

The storing reservoir is two and a half miles long and varies from one-eighth

to one-half mile in width. It has an available capacity of 400 000000 gallons of water above the level at which the conduit can conduct five millions of gallons per day. The Dam elevates the waters of the Acushnet to 40 feet above mean high-tide.
The Dam is 650 feet long. The west bluff of the river at this point is fifty feet high, and the East bluff twenty-five feet.
The character of the ground at the site of the dam was as follows:
On the surface a layer of muck varying from a few inches to thirteen feet in depth. Below this was a stratum of hard-pan from one to four feet thick, and below this a mass of silicious quicksand in some places thirty feet deep.
The muck was all removed, and a

trench from five to ten feet deep and from six to twelve feet deep wide was dug. This was filled with puddle which was carried up with the dam in layers of six inches to within three feet of the top. The puddle is stepped as shown in the drawing.
The top of the dam is four feet above high water, and the top of the puddle is one foot above high water.
The dam is twenty feet wide on top, and both the inner and outer slopes are in the ratio of two to one.
The inside slope is faced with a revetment wall. The top and outside slope are turfed.
At the East End of the dam is a waste-weir fifty feet wide, situated about seventy-five feet from the Eastern bluff.
A channel one hundred and fifty feet

in length passes from the waste into the reservoir, and is continued below the waste, through the bluff to the river. The over-fall of the waste is of hammer-dressed stone, the rest of rubble hydraulic masonry. The whole rests upon a timber and plank foundation, and below that is a foundation of puddled Earth.

The Gate-house is at the western end of the dam, and is placed in the reservoir about fifty feet from the top of the dam, being reached by a light foot-bridge.

The Gate-chamber is built of hammer-dressed stone laid in hydraulic cement mortar. It is seventeen by twenty-two feet, and is built up four and one-half feet above high water line.

It rests upon a timber and plank

foundation extending three feet beyond the masonry on all sides.
The timbers are ten inches square, two feet from center to center, the spaces filled with concrete. On top of the timber is a layer of two-inch plank, on which is a coat of hydraulic mortar, and above this a layer of inch boards followed by a course of two-inch planks. The whole is spiked strongly to the timbers. On the up-stream side of the platform, is a row of sheet piling six feet deep. Underneath and around the platform, the ground is puddled, and two walls of masonry three feet deep and two feet wide are built under the platform and carried up over the conduit to prevent the water from following along the timber and masonry.
There are several gates entering the

gate-chamber from the reservoir, so that the water may be drawn from different levels.

## The Conduit.

The conduit from the dam to the receiving reservoir extends in a southerly direction and is a little over ~~over~~ five and one-half miles in length.

It is made of brick in the form of an oval, the vertical diameter being four feet, and the horizontal diameter three feet. The exact form is shown in one of the plates. The bricks are nine inches long, five inches wide, and two and one-half inches thick.

The construction of a large part of the conduit was attended with a good deal of trouble on account of the beds of quick-sand encountered. Wherever this diffi-

culty presented itself, continual bailing and pumping had to be resorted to.
Piles were driven for about a mile to save excavation, and wherever the quicksand occurred, a foundation was formed of planks ten to fifteen feet long, and six to eight inches wide. Near the dam where the quicksand was very troublesome, the arch was made of double thickness as shown in the drawing.
Where the conduit passed under a highway the upper arch was made of double thickness of bricks to withstand the shocks caused by heavy teams.
No excavations in earth were made deeper than twenty feet, and in rock deeper than fifteen feet. The bottom of the trench was roughly shaped to the conduit, and spread with cement mortar one inch in thickness. The top and

sides of the arch were covered with a half inch layer of the same.
Very little puddled earth was required along the line. Where the conduit passed from masonry to earth foundation, timbers about fifteen feet in length were used, one end resting on the masonry, and the remainder on the earth to distribute the pressure and prevent the arch from breaking off.
There are thirteen culverts on the line, the plan of the larger being shown with sufficient clearness in the drawings.
There are three waste-weirs on the line for the discharge of surplus water, the largest of which is connected with a chamber seven and a half feet high, seven feet wide and eight feet long, from which the water passes by a culvert into a stream below.

The conduit is well supplied with ventilators and man-holes, the style of which is shown in the drawings. The conduit has a regular slope of six inches to the mile. It will discharge three millions of gallons per day when running half full, and with a ten inches head, six millions. The conduit empties into a receiving reservoir situated just to the Eastward of the B. C. F. & N. B. R. R.
All the soil was removed from the reservoir site, and the finest material selected to be used as puddle for the inner slopes of the Embankments. The most impervious part of the remaining material was placed next the lining of the inner slope, and the least impervious outside. The top of the Embankment is fifteen feet ~~high~~ wide. The outer slope is

two to one, and the inner slope one and a half to one.
The puddle lining of the inside slope is four feet wide at top water line, ten feet wide at the bottom of the reservoir, and is continued three feet below the bottom with a width of three feet. The inside slope is paved with granite blocks twelve inches thick, and the interstices filled with gravel.
When filled to top water line, the depth is twelve feet. The capacity is three millions of gallons.
The water is led to the pump-well, a distance of two hundred and seventy feet, by means of an arched culvert of rubble stone masonry three feet in diameter.
A small stream which supplied the Wamsutta Mills and New Bedford Copper Works intersected the culvert a short distance from

the reservoir. This had to be carried over the arch, which could be done either by damming the brook so as to conduct the water in it over the culvert at a higher level, or by placing the culvert lower down. The latter plan was adopted and the bottom of the culvert was placed two feet below the bottom of the reservoir. This made, when the reservoir was full, a pressure on the crown of the arch of ten feet of water; or 10 × 62.5 = 625 lbs. pressure per square foot.
The arch stone was of granite fifteen inches thick. Taking the weight of granite at 170 lbs. per cubic foot, the pressure exerted by the arch stone would be 1¼ × 170 = 212 lbs. per square foot. About twenty-five feet of the culvert had only two feet of earth over it. Taking

the weight of Earth at 95 lbs. per cubic foot, the pressure resulting from it would be 190 lbs. per square foot. This would give a total downward pressure of 402 lbs. per square foot, leaving an upward resultant of 625 − 402 = 223 lbs. per square foot.
To distribute this pressure over a large surface and prevent percolation, well seasoned pine plank three inches thick and five inches wide were used, the Edges beveled parallel to the radius of the arch. A groove five-eighths inch wide and three-quarters inch deep was cut in the Edges of the plank into which a tongue fitted. The planking was put together directly upon the centering of the arch, and covered with a thick layer of cement mortar. The stone arching was then built up, the mortar filling all

irregularities of the stones.
This device has proved very successful as no leak has yet appeared. For the rest of the way there were from four to ten feet of Earth which sufficiently resisted the upward pressure.
The water passes into the culvert from a gate-chamber in the reservoir so that it can be shut off from the pump-well when the pumps are not working.
The pump-well is Seventeen feet in depth, thirty-one feet long, and twelve feet wide with four recesses five by six feet for the pumps. From the well, the water is pumped into a distributing reservoir directly west of the Engine house about 2000 feet. The mode of construction of the distributing reservoir was the same as of the receiving reservoir.
The banks are from Eight to Eighteen feet

above the natural surface of the ground. Both the inner and outer slopes are in the ratio of two horizontal to one vertical. The inner slope has a puddle lining seven feet wide one foot above high-water mark, and fifteen feet wide at the bottom of the reservoir. It extends five feet below the bottom and is made in steps. The puddle was made from the most impervious portion of the excavated material mixed with 25 or 30 per ct. of its bulk of loam. It was carted on in layers of six inches, thoroughly moistened, and compacted by cutting and cross-cutting with spades.
The inside slope is faced with quarried stone eighteen inches thick at the bottom and twelve inches at the top, which is two feet above high water mark.
The bottom of the reservoir was of impervious

material, and only required to be leveled. The water surface has an area of three and one-eighth acres, and when filled to high-water mark has a depth of eighteen feet and a capacity of fourteen million gallons.

From the pump-well the water is pumped through a force main of cast iron sixteen inches in diameter. Instead of passing into an influent chamber and flowing over a weir into the reservoir, the water is conducted by a cement pipe from the influent chamber to about the center of the reservoir. At the pumps, the force-main has a level of 35 1/3 feet above high tide, and at the point of delivery in the bottom of the reservoir of 13 7/2 feet above tide. The gate-chamber is on the East side of the reservoir, and is divided into three sections; one for the force-main, the drain-pipe and the gates, another for the gates regulating the discharge into the distributing pipe, and the third for the screens and two 16-inch distributing mains.

Before selecting a pumping Engine, the city committee, realizing how important an item in the Economy of the works the pumping engine would be, not only in the first cost but in the annual running Expenses, accompanied by Mr. McAlpine, visited the chief cities of the country where large Engines are in use, to find which was the most satisfactory Engine.
They decided upon an Engine designed by Mr. McAlpine himself and built by Geo. W. Quintard of New York.
A committee of Expert Engineers consisting of such men as J. C. Hoadly, Chas. H. Haswell,

Jas. B. Francis &c. who met in New Bedford in Dec. 1869 for the purpose of testing the Engine, proved that it was a machine of superior qualities.

The water was let into the distribution pipes about Dec. 1. 1869. For the first few years the water had a good deal of color, and for a short time in the Summer was unpleasant to the taste. This was no doubt caused by the decaying vegetable matter in the shallow parts of the storing reservoir. The water has continually improved and many cures have been reported which it has Effected in people who had always been used to drinking hard well water. Twice during the Summer of 1876, owing the long drouth, the water-board found it necessary to issue retrenchment notices. The consumption of water was then three

millions of gallons per day, and the water was falling in the storing reservoir at such a rate that the full supply could only have lasted seven or eight weeks longer.
To provide against any future failure of the water, and enlargement of the source of supply will probably be made either by connecting with Long Pond or Little Quittacas Pond. The water in both of these ponds is of unusually good quality.

In the present thesis I shall not enter into a discussion of the pumping engine, nor take up the subject of the distribution of water through the city. The former belongs more properly to the Mechanical Engineer and as I have not yet had the time nor opportunity to make a study of the Steam Engine, I could only transcribe the statements of others.

You are therefore referred to "A Review of the Mc. Alpine Pumping Engine, by Roswell E. Briggs, Civil Engineer"

The subject of the distribution of water requires more space than I could here give to it, and in its multiplicity of details, and questions of practical importance, is deserving of a thesis in itself.

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