SKETCH

OF THE

CIVIL ENGINEERING

OF

NORTH AMERICA;

COMPRISING REMARKS ON THE

HARBOURS, RIVER AND LAKE NAVIGATION, LIGHTHOUSES, STEAM-NAVIGATION, WATER-WORKS, CANALS, ROADS, RAILWAYS, BRIDGES, AND OTHER WORKS IN THAT COUNTRY.

BY

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MDCCCXXXVIII.

CHAPTER X.

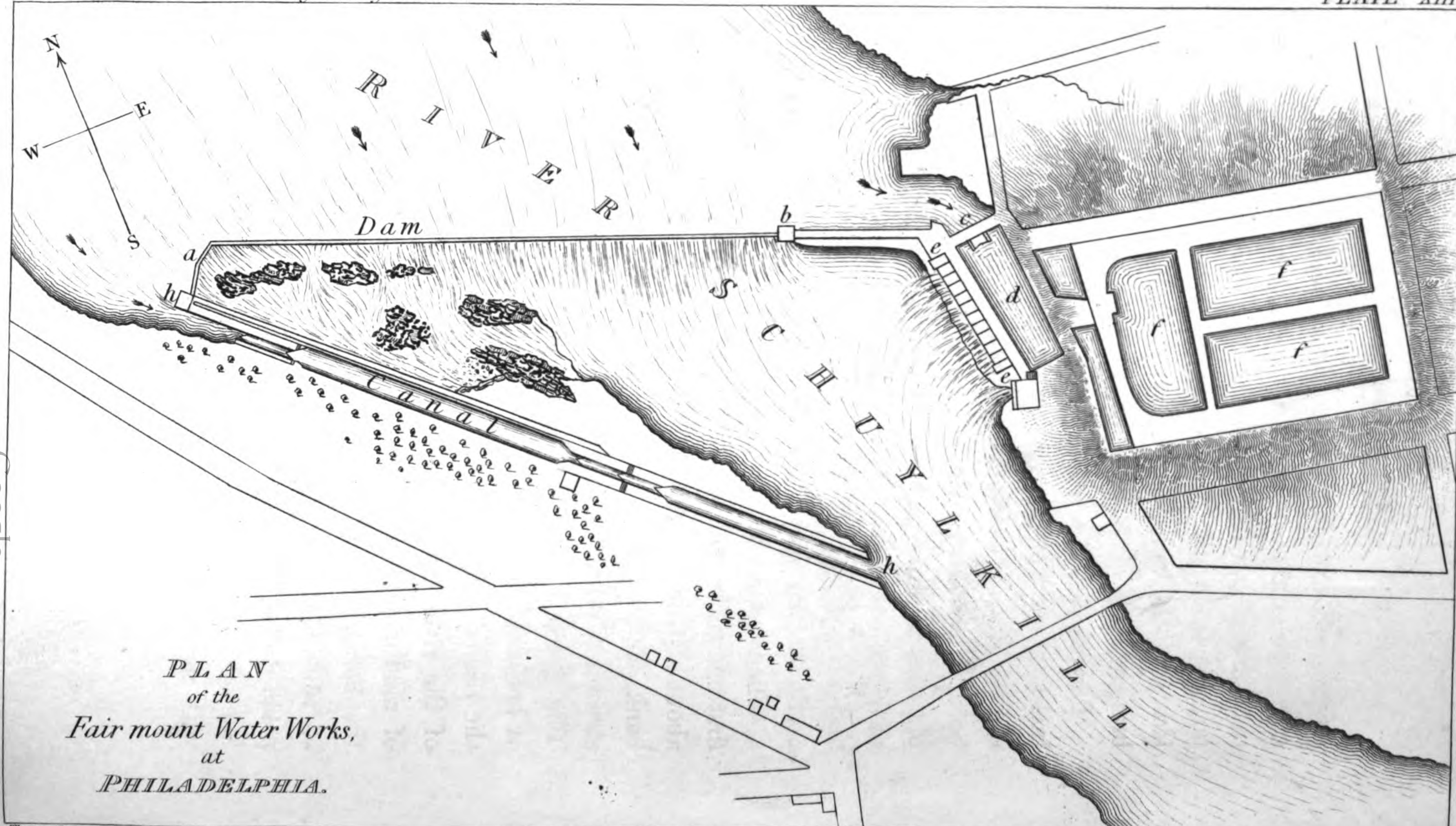
WATER-WORKS.

Fairmount Water-works at Philadelphia—Construction of the Dam over the River Schuylkill—Pumps and Water-wheels—Reservoirs, &c.—The Water-works of Richmond in Virginia—Pittsburg—Montreal—Cincinnatti—Albany—Troy—Wells for supplying New York and Boston—Plan for improving the supply of Water for New York, &c.

THE Fairmount Water-works are situate on the east bank of the river Schuylkill, about one mile and a half from the town of Philadelphia. They are remarkable for their efficiency and simplicity, as well as their great extent, being the largest water-works in North America. They were commenced in 1819, and were in a working state in 1822. According to the Water Company's report for the year 1836, the whole sum expended in their execution, up to that date, was L.276,206.*

The water of the river Schuylkill, with which the town of Philadelphia is supplied, is raised by water-

* Annual Reports of the Watering Committee to the Select and Common Councils of the City of Philadelphia.



PLAN
of the
Fair mount Water Works,
at
PHILADELPHIA.

Thomas Stevenson, Delt.

Published by John Weale, 59, High Holborn, 1838.

Geo. Aikman, Sculpt.

power into four large reservoirs, placed on a rocky eminence near the bank of the river; and after passing through gravel filter-beds, it is conveyed in two large mains to the outskirts of the town, and thence led into the various streets by smaller mains and branch-pipes.

Plate XIII. is a ground plan of the water-works, including part of the river Schuylkill and the adjoining country. Letters *a b c* represent a dam which has been thrown across the river in order to obtain a fall of water for driving the water-wheels. Letter *d* is the mill-race, *e e* the buildings in which the water-wheels and force-pumps are placed, and *f f f* are the filters and reservoirs for the reception of the water.

The erection of the dam across the river was the first and most arduous part of this work. It measures about sixteen hundred feet in length from bank to bank, and creates a stagnation in the flow of the stream, which extends about six miles up the river. The greatest depth of water in the line of the dam at low water of spring tides is twenty-four feet, and the rise of tide is six feet. From *c* to *b* the bottom of the river consists of rock covered with a deposit of mud about eleven feet in depth, and from *b* to *a* the bottom is entirely composed of bare rock, part of which, at the western side of the river, is exposed during low water, as shewn in the plate. The line of the dam forms an angle of about 45 degrees with the direction of the stream. In this way a large overfall is formed for the water, and its perpendicular rise above the top of the dam, when the river is in a flooded state, is not so great as it would have been had the dam been placed at right angles to the stream. By adopting this direction the strength of the structure is also considerably increased, for the mass of the dam opposed to any given section of the stream is greater directly as the cosine, or inversely, as the sine of the angle formed by the line of the dam and the direction of the stream inpinging on it.

The part of the dam which was first formed is that which is founded on the mud bottom extending from *c* to *b*. It consists of a large mound composed of rubble stones and earth thrown into the river. It measures 270 feet in length, 150 feet in breadth at the base, and 12 feet at the top, and its upper slope or face, which is exposed to the wash of the river, is cased with rough pitching formed of large stones. The termination of the dam at the point *b*, is protected by a cut-stone pier, measuring twenty-eight feet by twenty-three feet, which is founded on rock, and built in water twenty-eight feet in depth.

The part extending from *b* to *a* is the overfall dam. It measures 1204 feet in length, and is founded on a rocky bottom, which rises pretty regularly from *b*, where there is a depth of twenty-four feet during the lowest tides, towards *a*, where the rock is uncovered at low water.

The current of the river being strong, it was found

Fig. 1.

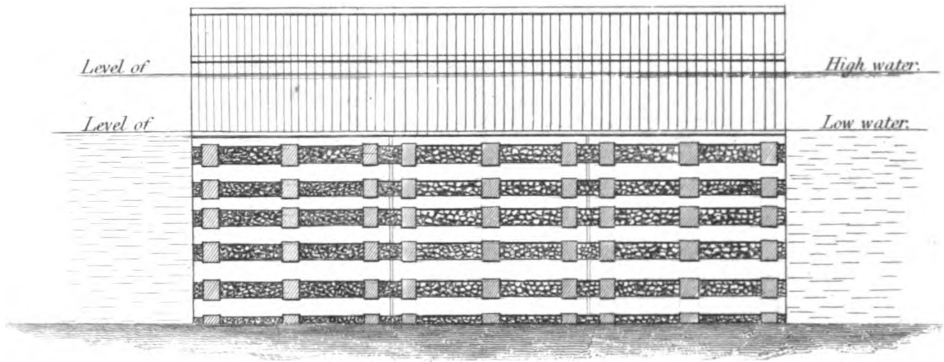
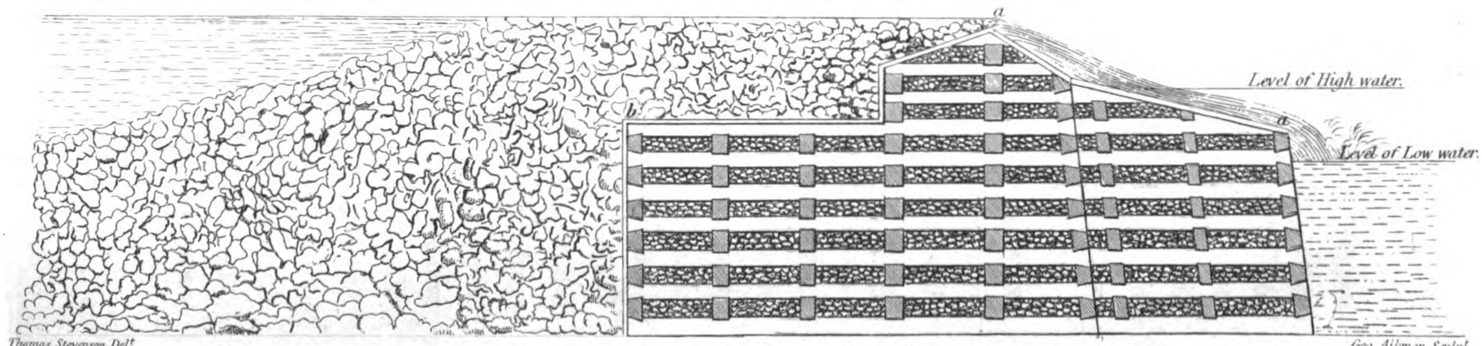


Fig. 2.



Elevation and cross section of part of the dam erected in the River Schuylkill, at Fair mount Water works.

P. ''shed by John Weale, 59, High Holborn, 1838.

impossible to form this part of the dam by constructing a mound of rubble on the rocky bottom, according to the plan followed in founding the first part of the structure, on a bottom composed of mud. The expedient resorted to for retaining the stones on the shelving rock, was extremely ingenious, and has proved very effective.

The overfall dam consists of a strong wooden framework or crib, which was formed in separate compartments, and sunk in small portions in the line of the dam, by filling it with stones. Plate XIV. is a drawing of the dam, in which Fig. 1 is an elevation of a part of its lower front or face, and Fig. 2 is a cross section. These views shew the wooden frames or cribs of which the dam is composed, and also the rubble-stone hearting which prevents them from floating. The cribs are formed of logs of wood, measuring eighteen by twenty inches, connected together by strong dovetailing, notched three inches deep, in the manner shewn in the drawing. The size of the wooden framework, measured in the direction of the stream, is seventy-two feet, and the separate compartments of which it was formed measured twenty feet in breadth. The part of the dam over which the water flows marked *a a*, and also the posterior part of it, *a b*, are covered with planking six inches in thickness. In forming the dam, the cribs were floated one after another to the site which they were to occupy, and large stones being thrown into them, they gradually sank, until at last they rested on the bottom of the river. The upper parts of the several cribs, or those portions of them which stood above the level of low water, were then firmly connected together, so as to form one continuous frame-work, behind which a large mass of rubble hearting and earth was placed, in the manner shewn in the drawing, to give the whole structure weight and stability, and to prevent leakage.

This mode of forming dams is very generally practised in America in forming lines of slackwater navigation, and has been found to stand remarkably well. The dam just alluded to, at the Fairmount water-works, withstood a great flood which occurred at the breaking up of the ice, on the 21st February 1832, without sustaining the smallest injury. On that occasion the water of the Schuylkill flowed over the top of the dam in a solid body no less than eight feet eleven inches in depth. As the erection of the dam impeded the navigation of the river, the Water Company had to compensate the Schuylkill Navigation Company by forming a canal, marked *h h* in Plate XIII., for the passage of their coal barges. This canal is about 900 feet in length. It has two locks of six feet lift each, and one guard-lock at the upper extremity.

The water is admitted into the mill-race *d*, by three archways at *c*, which have a water-way sixty-eight feet in breadth, and, when the river is in its ordinary state, admit a body of water six feet in depth. These archways can be shut by means of gates, and the whole of the water can be drawn off from the mill-race, if required, by opening a sluice communicating with the part of the river below the dam. The mill-race, which is excavated in solid rock, was a most laborious and expensive work. It is 419 feet in length, and 140 feet in breadth; its depth varies from sixteen to sixty feet.

From *d*, the water flowing through the wheel-houses *e e*, drives the water-wheels, and afterwards makes its escape into the Schuylkill. The wheel-houses have been built of a sufficient size to admit of eight wheels and eight force-pumps being employed to raise the water. In 1837 only six of the wheels and six force-pumps had been put up. The average daily quantity of water raised by each pump during the last year, was 530,000 gallons, and the whole quantity of water distributed from the reservoirs per day, to 19,678 householders, was 3,122,664 gallons. It has been calculated that thirty gallons of water, acting on the wheel, raised one gallon into the reservoir.

The water-wheels vary from fifteen to sixteen feet in diameter. They are fifteen feet in breadth, and make thirteen revolutions per minute. The spokes, rims, and buckets are formed of wood, but they revolve on cast-iron axles, weighing five tons each. The working of the wheels is impeded during spring tides, by the water rising upon them; but it has been found that their motion is not affected until the back-water rises about sixteen inches on the wheel. They are stopped, however, on an average, about sixty-four hours every month from this cause.

The pumps are common double-acting force-pumps, having a stroke of six feet, worked by cranks attached to the axles of the paddle-wheels. The height to which the water is forced, is no less than ninety-two feet, and the most substantial work is necessary to insure the stability of the pumping apparatus, under the pressure of a column of water of so great a height.

A cast-iron main, sixteen inches in diameter, leads from each of the force-pumps to the reservoirs. The communication between the force-pumps and the reservoirs, can be cut off by a stop-cock, placed on the main, so that, when the pumps are not in motion, they can be relieved from the pressure of the column of water. The shortest main is 284 feet in length.

The reservoirs for containing the water are placed at an elevation of 102 feet above the level of low water, and fifty-six feet above the highest part of the streets of Philadelphia. There are four reservoirs, the aggregate area of which is about six acres. The reservoirs are founded on an elevated rock, but the water is retained by means of artificial walls and embankments. The side walls of the reservoirs are built with stone, behind which there is a backing of clay puddle, two feet in thickness, and the whole is surrounded towards the outside, by an embankment of earth, sloping at the rate of one perpendicular to one horizontal, and covered with grass sods. The reservoirs are paved with bricks, laid with lime-mortar, on a layer of clay-puddle, and well grouted, to prevent leakage. The depth of water in the reservoirs is twelve feet three inches, and when filled, they contain upwards of twenty-two millions of gallons of water. There is a considerable advantage in having four reservoirs. The water, after being discharged from the force-pumps into one of them, passes through all the other reservoirs, between each of which there is a filter, so that any impurities in the water are extracted during its passage from one cistern to another, and prevented from entering the pipes, which distribute it to the town.

The water is conveyed from the reservoirs, and distributed through the town, in 98¾ miles of cast-iron pipes. About one-half of these pipes was cast in America, and the remainder were imported from this country. The two mains leading from the reservoirs to the town, measure twenty-two inches in diameter. The small mains and pipes which have been laid in the streets, measure from three to twelve inches in diameter. The pipes are formed in the usual manner, and the different lengths are connected by spigot and faucet joints. The average cost of the whole of the pipes and mains laid down, was 7s. 1½d. per lineal foot.

The very small cost at which the town is now supplied, is an ample ground for having substituted, even at considerable outlay in the first instance, the system of raising by means of water, instead of steam power; steam having been used at the Fairmount works previous to the year 1822. The expenditure, including repairs and salaries connected with the works, for distributing a daily supply of 3,122,664 gallons of water, was, in 1836, L.2800. The following information regarding the details of this most interesting and efficient work, are drawn up by Mr Graffe, the superintendent, and printed in the Water Company's annual report for the year 1836:—

	Gallons.	Gallons.
The Reservoir No. 1. was finished in 1815, and contains, ...	3,917,659	
The Reservoir No. 2. was finished in 1821, and contains, ...	3,296,434	
The Reservoir No. 3. was finished in 1827, and contains, ...	2,707,295	
Containing, . .		9,921,388
The first section of Reservoir No. 4. was finished in 1835, and contains, ...	3,658,016	
The second section of Reservoir No. 4. was finished in 1836, and contains, . .	4,381,322	
The third section of Reservoir No. 4. was finished in 1836, and contains, ...	4,071,250	
		12,110,588
The Reservoirs contain together, .		22,031,976

Reservoir No. 1. cost, ...	D.32,508.52
Reservoir No. 2. cost, ...	9,579.47
Reservoir No. 3. cost, ...	24,521.75
First, second, and third sections of Reservoir No. 4. cost,	67,214.68
Total, .	D.133,824.42

The whole expense of the reservoirs amounted to 133,824 dollars, which is equal to about L.26,765.

"The water of the reservoirs covers a surface exceeding six acres. The reservoirs are each 12 feet 3 inches deep, and are elevated above the water in the dam 96 feet perpendicular.

"The water flowing from the reservoirs for the supply of the city and districts, per day, at different periods of the year 1836, was as follows :—

	Gallons.
From February 1st to the 21st, in very cold weather,	1,769,800
... February 21st to March 20th,	2,113,257
... March 20th to June 3d,	3,046,120
... June 3d to July 22d,	3,942,643
... July 22d to September 9th,	4,152,917
... September 9th to October 28th,	3,679,800
... October 28th to December 31st,	3,154,114

"The average daily supply, in 1836, was 3,122,664 gallons. The above supply of water is distributed to 16,678 tenants by private pipes, and to 3000 families by public pumps, making the total number of families supplied 19,678.

"The quantity of iron pipes laid for the distribution of the water is as follows :—

	Miles.
In the city,	58
In the district of Spring Gardens,	$11\frac{5}{8}$
In Southwark,	$10\frac{1}{4}$
In the Northern Liberties,	$12\frac{7}{8}$
In Moyamensing,	$2\frac{5}{8}$
In Kensington,	3
Together,	$98\frac{3}{4}$

"The water rents collected for the year 1837 are as follows :—

In the city, ...	D.57,080.50
Including rents on the Girard estate, and rents due by H. J. Williams and others at Fairmount, .	1,048.50
In Spring Gardens, ...	13,674.25
In Southwark, ...	10,517.50
In the Northern Liberties, ...	20,009.37
In Moyamensing, ...	1,956.00
In Kensington, ...	2,146.25
Total,	D.106,432.37

Amounting, in all, to about 106,432 dollars, which is equal to about L.21,286.

"The expenses for the water-power works connected with the applicable parts of the former steam-works, were, December 31. 1831, ...	D.1,138,323.54
Add the expenses for reservoirs, iron pipes, &c. in 1832, ...	65,195.58
Do. Do. in 1833,	37,354.06
Do. Do. in 1834,	65,163.36
Do. Do. in 1835,	73.288.38
Do. Do. in 1836,	71,706.51
	D.1,451,031.43
From which deduct for the support of working machinery, materials, salaries, &c. 14,000.00 dollars per annum for the last five years, . .	70,000.00
Leaves the expenditure for the permanent works, up to 31st December 1836, . . .	D.1,381,031.43

The expenditure for permanent works, therefore, amounts to 1,381,031 dollars, which is equal to about L.276,206.

The supply of water for the town of Richmond in Virginia, is procured from the James River, in the same manner as at Philadelphia; but the works are on a much smaller scale. The water is raised 160 feet by two water-wheels into two reservoirs, measuring 194 feet in length, 104 feet in breadth, and ten feet eight inches in depth, which are capable of containing upwards of two millions of gallons of water. Before leaving the reservoirs, the water is purified by passing through two gravel filters. The water-wheels are eighteen feet in diameter, and ten feet in breadth, and the fall is ten feet. The barrels of the two force-pumps are nine inches in diameter, and six feet in length of stroke, and, in the ordinary state of working, when only one wheel is in operation, raise about 400,000 gallons of water in twenty-four hours.

The cast-iron main which leads from the pumps to the reservoir is eight inches in diameter and about 2400 feet in length. Mr Stein was engineer for the work, which is said to have cost about L.20,000.

Pittsburg, on the Ohio in the State of Pennsylvania, is supplied with water from the river Alleghany. It is raised by a steam-engine of 84 horses power into a reservoir capable of containing 1,000,000 gallons of water, and elevated 116 feet above the level of the river. The main leading from the pumps to the reservoir is fifteen inches in diameter, and the pump raises 1,500,000 gallons in twenty-four hours.

Montreal also is supplied in the same manner from the water of the St Lawrence, which is raised by steam power to an elevated reservoir, and then distributed through the town.

The following account of the water-works which have lately been established at Cincinnati, on the Ohio in the State of Ohio, is given by Mr Davies the Superintendent.

"The Cincinnati water-works were constructed in 1820. The water was taken from the Ohio river, by a common force-pump, worked by horse-power, placed upon the bank of the river, sufficiently near low water-mark to be within the usual atmospheric pressure, and thrown from that point to the reservoir, 160 feet above low water-mark, from which it was conveyed to the town in wooden pipes. The town at that time afforded no inducement for a larger supply of water than could be brought through wooden pipes of three inches and a half in diameter, consequently the works at the river were only calculated to supply a pipe of that size. Only a short time, however, was necessary, to prove the necessity of an increase, and a change from horse power to steam.

"The works now consist of two engines, one propelling a double force-pump of ten inches in diameter, and four feet stroke, throwing into the reservoir about 1000 gallons a minute; the other propelling a pump of twenty inches in diameter, eight feet stroke, and discharging about 1200 gallons per minute. The reservoirs are built of common limestone; the walls are from three to six feet thick, and grouted. The water is conveyed immediately to the town, without being permitted to stand or filter. Iron pipes of eight inches in diameter convey it through the heart of the town, from which it branches in wooden pipes of from one and a half to three and a half inches in diameter. From these it is conveyed into private dwellings in leaden pipes at the expense of the inhabitants, who pay from eight to twelve dollars* per annum, according to the purposes for which it is used. Each family, of course, use any quantity they choose, their hydrants communicating freely with the main-pipes. The iron-pipes are made in lengths of nine feet each, and connected together by the spigot and faucet joint run with lead, which occupies a space round the pipe of three-eighths or half an inch in thickness."

Albany on the Hudson is principally supplied with water procured in the high ground in the neighbourhood, and conveyed in a six-inch pipe for a distance of about three miles to a reservoir near the town.

Troy, on the eastern or left bank of the Hudson, about fourteen miles above Albany, is also abundantly supplied with good water collected in the high ground in the neighbourhood. The reservoir stands about one-third of a mile from the town, and is seventy feet above the level of the streets. It is capable of containing 1,900,000 gallons, and the water is conveyed from it to the town in a main twelve inches in diame-

* From about L.1, 12s. to L.2, 8s.

ter. The works are said to have cost L.23,000. The annual expense of conducting them is L.160.

The only supply of water which the inhabitants of New York at present enjoy is obtained from wells sunk in different parts of the town. The water is raised from these wells by steam-power to elevated reservoirs, and thence distributed in pipes to different parts of the town. Some of the wells in New York belong to the Manhatten Water Company, and some to the corporation. One well, belonging to the corporation, is 113 feet in depth. For the purpose of collecting water, there are three horizontal passages leading from the bottom of the well, which measure four feet in width, and six feet in height; two of them are seventy-five, and the third is one hundred feet in length. This well cost about L.11,500, and yields 21,000 gallons in twenty-four hours. There are many other wells in the town, some of which are said to produce 120,000 gallons in twenty-four hours. This mode of collecting water in subterraneous galleries has been successfully practised in this country, on a great scale, at the water-works of Liverpool, by Mr Grahame, the engineer to the Harrington Water Company. The supply at New York is far from being adequate to the wants of the inhabitants; and the water in most of the wells being hard and brackish, is not suitable for domestic purposes.

New York is built on a flat island, which is nearly surrounded by salt water, so that the method that has been resorted to for the supply of Philadelphia and most other towns in the United States is altogether impracticable in that situation. Many plans have been proposed, and, among others, that of throwing a dam across the Hudson, so as to exclude the salt water ; but as a free passage, by means of locks, must be preserved for the numerous vessels which navigate the river, the success of such a plan seems very doubtful.

Many engineers in the United States, of great reputation, have made surveys of the country in the neighbourhood of New York, in order to devise a plan for the supply of the city with water, and they have proposed to effect this object, so important to its inhabitants, by conveying the water of the river Croton in a tunnel to New York. The point from which the water is intended to be withdrawn, is about thirty miles distant from the city. The estimate for the entire execution of the work, is upwards of one million Sterling.

The situation of Boston is somewhat like that of New York. It is surrounded by the sea, and the supply of good water is far from being sufficient for the inhabitants. Mr Baldwin, civil-engineer, has made a survey and plan for the supply of the town, in which he contemplates bringing water from some springs in the neighbourhood.*

* Report on introducing pure water into the City of Boston. By Loammi Baldwin, C. E. Boston, 1835.

At present the town is supplied chiefly from wells. According to Mr Baldwin's report, there are no less than 2767 wells in Boston, thirty-three of which are Artesian. Only seven, however, out of the whole number, produce soft water; and of these, two are Artesian.

Great difficulty has been experienced in forming many of the wells on the peninsula of Boston, in some of which, on tapping the lower strata, the water is said to have risen to seventy-five, or eighty feet above the level of the sea.*

The following very interesting remarks regarding two of these wells, are quoted by Mr Storrow in his Treatise on Water-works.

"Dr Lathrop gives the following history of a well dug near Boston Neck.† 'Where the ground was opened, the elevation is not more than one foot, or one foot and a half above the sea at high water. The well was made very large. After digging about 22 feet in a body of clay, the workmen prepared for boring. At the depth of 108 or 110 feet the augur was impeded by a hard substance; this was no sooner broken through and the augur taken out, than the water was forced up with a loud noise, and rose to the top of the well. After the first effort of the long confined elastic air was expended, the water subsided about six feet

* A Treatise on Water-works. By Charles S. Storrow. Boston, 1835.

† Memoirs of the American Academy of Arts and Sciences, vol. 3.

from the surface, and there, remains at all seasons ebbing and flowing a little with the tides.'

"Dr Lathrop observes, that the proprietors of this well were led to exercise great caution in carrying on the work, by an accident which had happened in their immediate neighbourhood. 'A few years before, an attempt was made to dig a well a few rods (16½ feet) to the east near the sea. Having dug about 60 feet in a body of clay without finding water, preparation was made in the usual way for boring; and, after passing about 40 feet in the same body of clay, the augur was impeded by stone. A few strokes with a drill broke through the slate covering, and the water gushed out with such rapidity and force, that the workmen with difficulty were saved from death. The water rose to the top of the well and ran over for some time. The force was such as to bring up a large quantity of fine sand, by which the well was filled up many feet. The workmen left behind all their tools, which were buried in the sand, and all their labour was lost. The body of water which is constantly passing under the immense body of clay, which is found in all the low parts of the peninsula, and which forms the basin of the harbour, must have its source in the interior, and is pushed on with great force from ponds and lakes in the elevated parts of the country. Whenever vent is given to any of those subterranean currents, the water will rise, if it have opportunity, to the level of its source.'"