A DESCRIPTION

OF THE

DUBLIN CORPORATION WATER WORKS.

BY THE ENGINEER,

PARKE NEVILLE, C.E., M.I.C.E., F.R.I.A., M.R.I.A.,

ETC., ETC.

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PRINTED FOR THE AUTHOR,

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1875.

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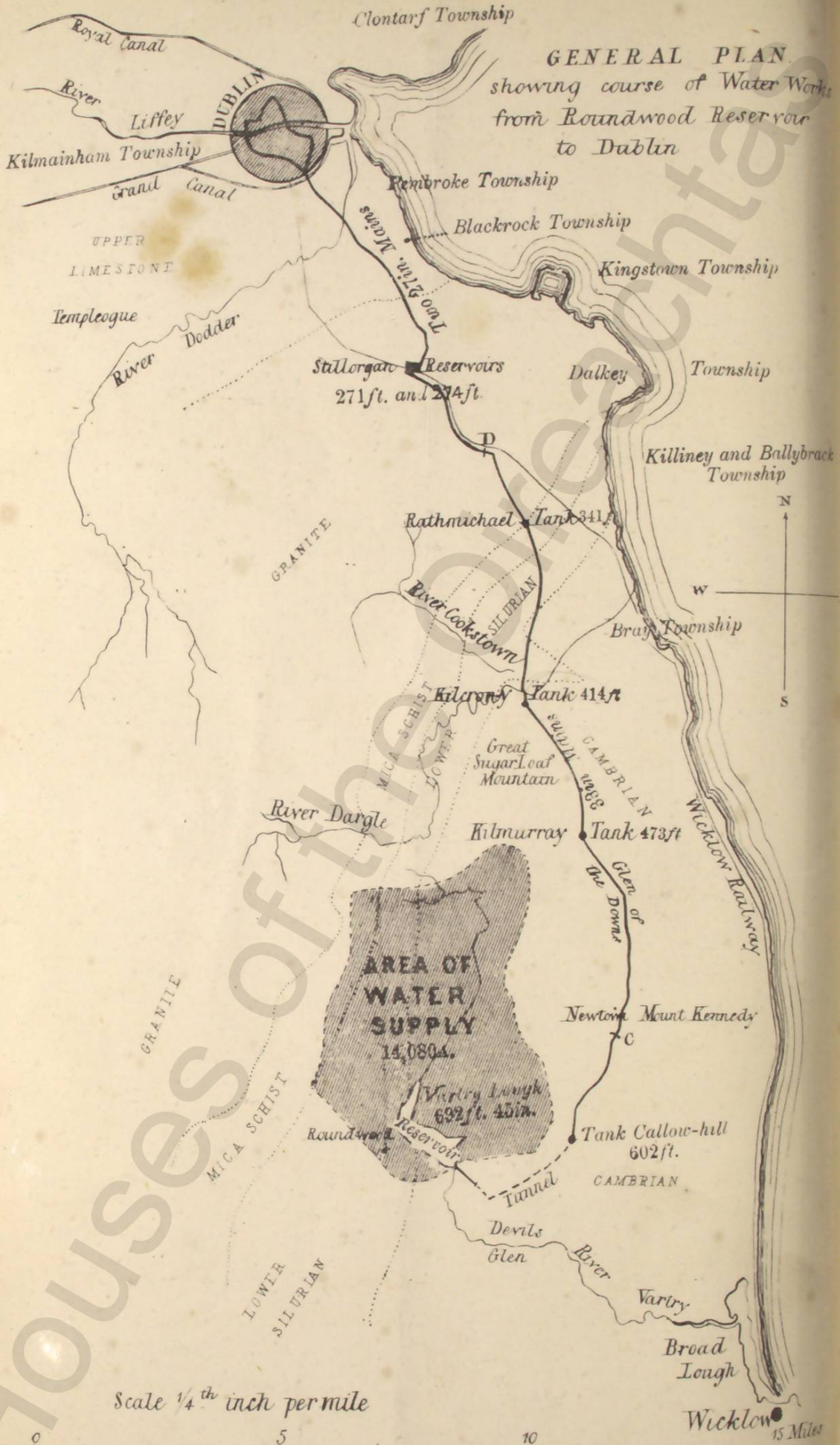

John Falconer Dublin

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DEDICATED

TO THE

Memory of the late Sir John Gray, M.P., T.C.,

IN REMEMBRANCE OF THE ENERGY AND GENIUS

WITH WHICH

HE ADVOCATED AN IMPROVED SUPPLY OF WATER FOR THE CITY OF DUBLIN;

WITHOUT WHICH

THE VARTRY WATER WORKS

WOULD NEVER HAVE BEEN COMPLETED;

AND AS A GRATEFUL ACKNOWLEDGMENT OF THE MANY ACTS OF FRIENDSHIP

EXPERIENCED FROM HIM

BY

PARKE NEVILLE, C.E.

A DESCRIPTION

OF THE

DUBLIN CORPORATION WATER WORKS.

THE supply of water to the City of Dublin for several centuries has been vested in the Corporation of Dublin, and was for a long period obtained entirely from the River Dodder, a weir, known as the City Weir, having been constructed in ancient times across it near Templeogue, at about five miles from Dublin, by which the water of that river was turned into an artificial water-course, called the City Water-course. At a point about one mile outside the present City boundary the water is divided by a structure called the "Tongue" (erected in the year 1555) into two courses, by which two-thirds of the water is diverted into a channel called the Earl of Meath's Water-course (and which, within the City boundary, is known as the Poddle River); this in former times was the supply of water to the manors of Thomas-court and Donore, or what is now called the Liberties, &c.; in later times the water of this course had become so contaminated with sewage as to be unfit for use as a domestic supply; it at present discharges into the Liffey, east of Grattan-bridge, on Wellington-quay. The other third of the water was diverted into a channel called the City Water-course, and was carried westward, at a higher level, to James's-street, to supply higher parts of the City; and from it, in the year 1660, and subsequently 1671, it is recorded that lead mains were laid and other works executed to improve and extend the supply of water to the City of Dublin.

In the year 1721 the Corporation constructed the James's-street Basin or Reservoir, and supplied it from the City Water-course, which had to be raised by masonry and embankments. From this a lead main, 10 inches diameter, was laid to James's-street,

and from it three mains of 6 inches diameter were continued into the City to distribute water to upwards of ninety streets.

During the following fifty years various works were constructed to improve the supply from the City Water-course and City Basin at James's-street; also a supplemental supply was obtained about 1735 from the Liffey at Island-bridge, which was pumped up by the action of a water-wheel; but the supply thus obtained being found quite inadequate, in the year 1775 the Corporation obtained an Act of Parliament to enable them to levy a water-rate, and in this year they entered into a contract with the undertakers of the Grand Canal "for an ample supply of water."

In 1806, the supply of water being found "totally insufficient" for the wants of the citizens, the Corporation entered into contracts for a period of sixty years with the Grand and Royal Canal Companies, securing, as far as could be reasonably calculated on at that period, an ample supply of water for the use of the citizens; and in 1809 an Act of Parliament (locally known as the Metal Mains Act) was obtained to enable the Corporation to construct extensive new works, and levy additional water-rates.

During the ensuing five years the old timber mains (which up to this time had chiefly distributed the water through the City) were taken up or abandoned, metal substituted, and the Portobello and Blessington-street Basins or Reservoirs were constructed. The former, 2a. 0r. 8½p. in area, and from 8 to 12 feet deep, was supplied, over an overfall gauge weir, 38 feet long, from the Grand Canal. The latter, 1a. 3r. 3p. in area, and from 8 to 12 feet deep, was supplied by a similar gauge, 38 feet long, from the Royal Canal. The old City Basin, James's-street, 3a. 2r. 13½p. in area, and from 7 to 12 feet deep, was partly supplied by the old City Water-course, supplemented by a supply over a gauge weir, 38 feet long, from the Grand Canal. There were eight 7½-inch mains and two 7-inch mains leading out of James's-street Basin, six 7½-inch mains out of Portobello, and six 7½-inch mains out of Blessington-street Basins.

In 1846 a Dublin Improvement Bill was promoted by the Corporation, one of the principal objects of which was to obtain a better

and more abundant supply of water for the City of Dublin; and, in 1847, a local inquiry was held by surveying officers, when the inadequate and bad state of the water supply to the City of Dublin was proved; but, owing to the proposed Municipal Reform Act, nothing came of this inquiry.

In 1849 the Government passed the Dublin Improvement Bill, under which the Corporation of Dublin is incorporated, and this Act came into force on the 1st of January, 1851.

Immediately after they came into office, the Corporation directed their attention to improve the water supply; and, in 1853 and 1854, they had laid, on the advice of the author, several lines of new water mains, of large diameter, in place of smaller ones, and extended mains into districts of the City at that period without water supply; and by these improvements a large portion of the City was provided with a constant service of water, but at a very low pressure.

In 1854 the Corporation consulted Mr. Hawksley, C.E., upon the several projects proposed for the improvement of the water supply to the City; but, owing to other matters engaging the attention of the Corporation, and to monetary difficulties, nothing was done until 1858, when negotiations were opened with the Canal Companies as to the price at which they would undertake to supply a guaranteed quantity of water sufficient for the supply of the City, and from such levels as would secure high pressure. The Canal Companies declining to enter into any such contract, the Corporation decided on going to Parliament for an independent supply, and on the recommendation of Mr. Hawksley and the author, the plan for obtaining water from the River Liffey, near Newbridge, called the Coyford scheme, was adopted, the necessary Parliamentary surveys were made, and steps taken to obtain an Act in the Session 1859–60.

When the Canal Companies, and the railway interests identified with them, found that the Corporation were really seeking an independent supply, they opposed the Coyford scheme. The Canal party stated there was no source of supply like theirs for quality and cheapness, and, after much negotiation, the Coyford scheme

was abandoned, a Canal plan adopted, and powers sought from Parliament to carry this out. When, however, the Canal interest succeeded in getting rid of the Liffey project, they again declined to guarantee the necessary quantity of water at high pressure, and the altered scheme being thrown out on standing orders, there was an end to obtaining powers to construct new works that year.

It was now proposed, by the parties in opposition to the Corporation, that application should be made to the Government to appoint a Royal Commissioner to examine into all the schemes proposed for improving the water supply to the City, and that whichever he reported in favour of should be adopted and be supported by all parties. This was agreed to, and Mr. (now Sir John) Hawkshaw was appointed Commissioner.

Sir John Hawkshaw visited Dublin in August, 1860, and examined all the plans submitted to him, and the localities from whence it was suggested to obtain supplies of water for the City, viz.:—The Grand and Royal Canals; Lough Owel and Lough Sheelin; the River Dodder; the Dargle and Lough Bray; the River Liffey; the River Vartry. The Corporation advocated no plan, but Mr. Hawksley and the author furnished him, by order of the Corporation, all requisite information, and had prepared all plans, comparative estimates, and details he directed.

In his Report, dated the 20th October, he gave as his opinion—

1st. That the present supply of water to the City of Dublin is bad.

2nd. That there is urgent need of an improved supply.

3rd. That the best source from which an improved supply can be obtained is the River Vartry.*

* The scheme for supplying the City with water from the River Vartry was suggested by Mr. Richard Hassard, C.E. A good and abundant supply of water for the City and Suburbs could have been obtained from the Liffey by the Coyford or Ballysmuttan schemes, as also from the Dodder, and a less cost than the Vartry; but the difficulties that would be sure to arise in arranging with the milling interests on those Rivers, and that the conduits for supply by the Vartry scheme coming into the City from the south, and passing near the extra Municipal Townships of Bray, Killiney, Dalkey, Kingstown, Blackrock, and Pembroke, and thus enabling them to be supplied with Vartry water, influenced the Royal Commissioner in his decision.

On receiving this Report, although the result was unexpected, and the estimated cost more than contemplated, the Corporation, at a meeting held on the 23rd of October, decided to promote a Bill in the Session 1860–1861, to carry out the Royal Commissioner's recommendation, and directed the author, with Mr. Hawksley as consulting engineer, to prepare the necessary Parliamentary plans, &c., &c., expecting that the parties hitherto objecting to any scheme other than getting a supply from the Canals would be in honour bound by his decision; but they were mistaken, as their Bill was vigorously opposed, and the Ballysmuttan scheme was put forward as a competing plan; but the real object was to defeat any scheme depriving the Canals of the supply.

After a severe Parliamentary contest—extending over five weeks in the House of Commons, and afterwards for six days in the House of Lords, and after a futile attempt to throw out the Bill on the third reading in the House of Commons, and being subjected to every possible opposition—the Corporation carried their Bill. Their success in overcoming the most inveterate opposition was mainly due to the vigour and energy of the late Sir John Gray, Chairman of the Water Works Committee, supported by the members of the Corporation sent to London in charge of the Bill, the late Alderman George Roe and Alderman R. H. Kinahan—the latter gentleman, not being in good health, was advised to return to Ireland, but refused to desert the cause of the Corporation, he took dangerously ill in the Committee-room of the House of Commons during the progress of the Bill, and died the following day at his residence in London.

The Corporation Water Bill, for obtaining the supply of water for the supply of the City of Dublin and Suburban Districts from the Vartry, obtained the Royal assent, 21st July, 1861, and the Corporation immediately proceeded to carry out the works authorised thereby; and the first stone was laid at the Prince of Wales' Reservoir, Stillorgan, by the late Earl of Carlisle, Lord Lieutenant of Ireland, on the 10th day of November, 1862.

The River Vartry rises at the base of the Great Sugar Loaf

Hill, in the County Wicklow, whence it flows in a direction nearly due south through a thinly populated district of that county, passing by the Devil's Glen, and the village of Ashford, into the Broad Lough, which discharges into the sea at the town of Wicklow. The length of the river from its rise to the sea is 17½ miles, and the total catchment area is 34,890 acres. There are but five mills on its entire length. The only one of these above the works is at Ballinastow, a small structure, working one pair of stones occasionally, for grinding oats. Below the works there are three in the Devil's Glen; two saw mills, used for cutting up the timber from the surrounding woods, and a corn mill, having four pairs of stones, belonging to Mr. Tottenham. The lowest on the stream, at Ashford, works but one pair of stones occasionally, also for grinding oats.

The geological formation of the entire drainage area is the lower Silurian and Cambrian slate, except on the hill-tops to the west, where the granite crops out in spots. It yields a peculiarly soft pure water, during the greater part of the year quite colourless, and analysis shows it to resemble in quality the Lough Katrine water with which Glasgow is supplied.

Considerable difficulty existed in ascertaining the quantity of rainfall which could be relied on in the Vartry district, as no rain gauges existed prior to 1860. From the records of these it was calculated that 29·3 inches was the probable average depth of rainfall in dry years; and that allowing 15 inches to be lost by evaporation and absorption, 14·3 inches would remain for the supply of Dublin. The catchment area draining into the river above the proposed works was 14,080 acres, and 14·3 inches of rain over this area would be sufficient to give 12,000,000 gallons per day, or 25 gallons a head for a population of 400,000, and 2,000,000 gallons for manufacturing purposes. In estimating the above quantity as the probable rainfall, care was taken to arrive at the minimum annual fall, making allowance for the possibility of a succession of dry years. This was the more necessary from the fact that, according to the plans lodged in Parliament, it was designed to construct a compensation reservoir on the river at a

point (Annagollen Bridge) about 2 miles below the works, to provide against the claims of the millers and riparian proprietors on the river below, so that if the rainfall was taken at too high a figure, it would give them more water than they were entitled to. However, prior to going before the Committee on the Bill, this reservoir was abandoned, and it was determined to give money compensation. By this arrangement the Corporation have become, by paying money compensation, the sole owners of all the water which falls on the catchment basin above their works, and no party has any right or title to use or divert any of it. And they have obtained the absolute right to and control over all the water that flows into the river above their works. Since 1860 several rain gauges have been maintained in the district, and have been carefully registered. The average rainfall for each year has been as follows:—

1861	equal	60·86 inches.	1868	equal	56·15 inches.
1862	„	60·65 „	1869	„	49·00 „
1863	„	45·09 „	1870	„	43·68 „
1864	„	47·76 „	1871	„	51·65 „
1865	„	48·69 „	1872	„	69·34 „
1866	„	53·43 „	1873	„	40·08 „
1867	„	46·05 „	1874	„	42·50 „

From these gaugings it is evident that the calculation originally made was erroneous, but fortunately on the right side, as, taking the year on which the gauges registered the least rain, viz., 40·08 inches in 1873, one of the driest years on record, and deducting from this 15 inches for loss by evaporation and absorption, as was done in the spring of 1861, the ascertained rainfall available for the supply of Dnblin for this extraordinary dry year is 25·08 inches against that calculated on in 1861 of 14·3 inches.*

Careful observations have been made of the dry weather yield of water from the catchment basin (14,080 acres) for the

* In case of the Manchester and Liverpool Water Works, owing to the rainfall over the drainage areas being assumed at too high a figure, and the water compensation to be given the millers was fixed by Parliament at one-third of this, when the works were completed the water available for the towns turned out not near as much as calculated on.

years 1869 and 1870, and it has been found to be equal to at least 2,500,000 gallons per day during periods of the greatest drought.

The point selected on the river Vartry as the site of the embankment to form the great storage reservoir is about 7½ miles from its source, and about 1½ mile south-east of the village of Roundwood. The level of the water in the river at this point was 632 feet above Ordnance datum (low water of a 12-feet tide at the Poolbeg Lighthouse, Dublin Bay), and 520 feet above the highest part of the City of Dublin. The level where the river rises is about 1,100 feet above ordnance datum, and the boundary of the catchment basin on the west varies from 2,384 feet, the top of the Douce mountain, to 1,581 feet, and on the east from 1,200 feet to 800 feet. The entire area is very thinly inhabited. It is chiefly under pasture, and contains but a small proportion of peat land, the shallow bogs that formerly existed in several parts being cut out, and the only turbary of any extent is situated on the side of the Douce mountain. Very little coloured water comes from this, and only after heavy floods in autumn.

The main embankment, which forms Lough Vartry (the name given to the reservoir), is 66 feet high at its deepest part, and the greatest depth of water is 60 feet. It is 1,640 feet long on the top, and 28 feet wide. The public road from Wicklow to Roundwood, which formerly passed over land now submerged by the formation of the reservoir, has been carried over it. The base at the deepest part is 380 feet wide, the inner slope being 3 to 1, and the outer slope being 2½ to 1, and the total quantity of earthwork in it is 320,000 cubic yards.

The byewash, at the eastern end of the embankment, is 300 feet long, and the level is 6 feet below the top of the bank, or 692·45 feet above Ordnance datum. When the reservoir is full at this level the area of land covered is 409 acres, the greatest depth being 60 feet, and the mean average depth 22 feet. Its storage capacity is about 2,400,000,000 gallons, or equal to two hundred days supply for the City of Dublin and the suburban districts, at the rate of 12,000,000 gallons per day, or when the

movable planks are fixed on top of byewash, whereby an additional foot in depth of storage is obtained, 207 days supply.

Two other embankments had to be constructed (the Knocka-temple and the Watersbridge) to carry county roads across the reservoir; but the entire water is impounded by the one bank above described.

The reservoir and works are surrounded by a boundary wall of rubble stone 5 feet high, the base of which is carried round the reservoir on a contour line 6 feet above top-water line. This wall is above 11 miles long, and encloses, including embankments, filter beds, and the lands purchased by the Corporation, 550 acres.

The puddle gutter in the embankment is 6 feet wide at the top (1 foot below the top bank), and 18 feet wide at the level of the old river bed. It has been carried for its entire length down into the solid rock, which was reached at the above point 12 feet below the surface; but on the sides it had to be sunk to from 30 to 40 feet below the surface of the ground. There was not much water met with in sinking the trench; that from the springs was led away in iron pipes through the outer slopes, into drains discharging into the old river bed below the works. On either side of the puddle gutter there was punned clay 10 feet wide, well worked, in layers of 1 foot deep. All the stone and coarse stuff was used on the back of the bank, and only clay and fine stuff in the inner side. The materials forming both sides were carried up in regular concave layers of 3 feet in thickness, and during dry summer weather water was pumped on as the work proceeded to assist in consolidating it.

The pitching on the inner slope varies from 18 inches at the top to 9 inches deep at the bottom, laid on a layer of broken stone 2 feet thick. It has stood remarkably well, although sometimes severely tried by storms from the north-west, which raise high waves on the Lough.

The sill of the waste weir is formed of a double row of granite blocks 6 feet deep by 3 feet thick. The apron is of random rubble pitching, laid on concrete, grouted and pointed with Portland cement. The public road, which passes over the bank, crosses the

byewash by a bridge of three arches of 20 feet span, executed in granite ashlar work.

The byewash is carried round east of the filter-beds in rock cutting to discharge into the old river-course; at first it was formed in a series of deep steps; but the enormous body of water that rolls down in floods has almost obliterated some of them. In winter there is often 9 to 10 inches of water passing over the byewash, and we estimate that about $\frac{2}{3}$th of the rainfall falling on catchment basin is passed down the river; but this is the property of the Corporation, and could be made available, if wanted, by constructing an additional reservoir.

The tunnel under the embankment, used in the first place to pass the river water while the bank was being constructed, and subsequently for receiving the discharge pipes, is situated towards the eastern end. It was formed by cutting an open canal 14 feet wide, with nearly vertical sides, through the solid rock, and covering this with a semicircular arch of ashlar stone, 4 feet thick, well puddled, forming a tunnel 14 feet high by the same width. Through this tunnel a 33-inch pipe and a 48-inch pipe are laid; the latter intended for sluicing purposes, should it ever be necessary to lower the water rapidly in the reservoir; the former for the delivery of water for the supply of the City and suburbs. About midway in this tunnel a stopping of brickwork is built, through which the pipes are passed; it is 38 feet thick, constructed of the best Staffordshire blue fire-brick set in Roman cement, and is toothed into rabbeted recesses left for the purpose in the arch, sides, and floor of the tunnel, and stop walls are built at each end of plugging, projecting 25 feet beyond sides of tunnel, and eight above it, the space between being filled in with cement concrete tied on to the rock, and on this the puddle gutter rests.

The water of the River Vartry was turned from its ancient course through this tunnel on the 30th day of June, 1863, by the late Earl of Carlisle, Lord Lieutenant of Ireland, on which occasion he conferred the honour of Knighthood on Sir John Gray, the Chairman of the Water Works Committee.

The 33-inch pipe is laid from the bottom of the water tower,

which is built at the eastern end of the tunnel on the water side. This tower has three 24-inch valves fixed on pipes laid through the walls, with bell mouths on the outside. The first valve is 10 feet below the top water level, the second 20 feet, and the third 30 feet, to allow the water to be drawn off at different levels. Should it ever be required, water can be drawn off below from the lower level, by opening the 33-inch valve communicating between the 48-inch pipe and the 33-inch pipe in the valve chamber.

The 33-inch pipe is continued through the outer tunnel into the valve chamber, where it is divided into two branches, each of which has a 33-inch valve to regulate the discharge—the pipe for the supply of the City of Dublin, turning off to the west along the outer toe of the bank, discharges into the centre of a circular receiving basin 87 feet in diameter and 6 feet deep, of granite ashlar, from which two conduits lead the water on to the filter beds. This pipe is also continued under the pure water tank No. 1 to the outlet wells from the pure water tanks Nos. 1 and 2, so that, by working the valves, the water can either be conveyed from the central receiving basin on to the filters, or, if necessary, be passed direct into the pure water tanks without filtering.

The 48-inch pipe is laid from the northern end of the water tower, a bell mouth-piece being here fixed on it, into which a ball-valve can be lowered from the tower (by being floated under a derrick fixed to the tower over it). By lowering this ball-valve into the bell mouth end of pipe, it stops all water from passing into the 48-inch pipe from the reservoir, and thus affords an expeditious and effectual way for enabling the 48-inch valves in the valve-chambers being overhauled, cleaned, or repaired, as occasion may require. The 48-inch pipe is carried through the tunnel, valve-house, and along eastern side of the filter beds, and discharges into the byewash.

The filter beds are seven in number, four on the west and three on the east side of the pure water tanks. Each filter is 215 feet long by 115 feet wide at the top, and 187 feet by 89 feet at the bottom. They are 10 feet deep from the floor to the level of the roads, and contain a layer, 6 feet 6 inches thick, of filtering

material—viz., on the bottom, 2 feet 6 inches of stones broken to pieces of about 4 inches diameter, on this three layers of different-sized gravel, and on the top 2 feet 6 inches of washed sand. It was intended to work the filters with about 2 feet head of water, but as under that head the percolation was not sufficiently speedy to supply the demand, there has often been a depth of 3 feet of water on them. As this rapid filtration does not clear the water so well as the slower operation, the Corporation have obtained power to construct additional filter beds, which will meet all the requirements at the rate of filtration originally calculated; and this work is now in progress, and is estimated to cost £12,000.

The sites of the filters are chiefly excavations into the rock, but in parts they are made up by embankments, and in the latter case the slopes are pitched with rubble stone. The slopes are 2 to 1 to the top of the filtering medium, and 1 to 1 below this. The roads all round and dividing the filtering beds are 20 feet wide, 16 feet gravelled, with sodded margins 2 feet wide on each side.

The water is passed from the canals on to the filtering beds through culverts 3 feet square, having iron sluices worked with screws to regulate the flow, and it is distributed by wooden shoots so as not to disturb the sand. It descends through the filtering material, and is collected in two drains of dry rubble masonry, which conduct it into vertical shafts (one for each filter), in which it rises and then flows out through culverts into the pure water tanks.

The pure water tanks are 250 feet long, and 150 feet wide at the top, and 200 feet by 102 feet at the bottom, and are 12 feet 6 inches deep from the surface of the ground, with a depth of water of 11 feet. They were partly excavated out of the rock and partly embanked; in the latter case (as also for the filter beds) puddle gutters excavated far down into the solid rock have been in all cases carried round them.

The total area of land occupied by the filter beds, tanks, and grounds below the embankment is about 50 acres.

All the water from the springs met with in the puddle trench and in the outer tunnel and under the back of the bank has been

carried to the outer side of the embankment by iron pipes into drains; these lead into a well near the receiving basin, whence the water is conducted by a 12-inch iron pipe into the cleansing pipe from the pure water tanks, and by this discharged into the old river bed just outside the works. This well affords a means of daily observation of the increase or diminution of the flow of water from them, and has proved most useful by leading to the immediate discovery of a leak from the receiving basin, and another from the canal opposite the valve-chamber, caused by some dragging or defect in the puddling.

A sand-washing machine has been erected at the filters. It is nearly the same in design as that in use at the Liverpool Water Works at Rivington, and was manufactured by the same maker, Mr. Sampson Moore, of Liverpool. It is worked by a small turbine wheel, the head of water being derived from the reservoir. It acts remarkably well, and washes about 50 cubic yards of sand per diem, without the dirt, smoke, and expense for coal, engine, man, &c., attendant on the use of steam power as at the Liverpool works.

The water is conveyed from the pure water tanks to the tunnel through an iron pipe. This is for the first 150 yards 33 inches in diameter, and for the remaining 670 yards 42 inches, the fall from the top water level in the tanks being equal to 45·5 feet per mile.

The tunnel to convey the water from the valley of the Vartry under the range of hills dividing it from the districts to the east, which slope towards the sea, is 4,332 yards long. At the commencement it takes a south-easterly direction, but is curved round in its course, so that at the discharging point, at Callow Hill, the direction is north-east, thus diverting the water from flowing southwards towards Wicklow to nearly north towards Dublin. The tunnel was driven from twenty-one shafts, each 200 yards apart. The first shaft was commenced on the 4th of January, 1863, and the last heading was opened out in September, 1866; thus the total time taken to drive the tunnel was three years and eight months. The contractor thought he could execute the works by sinking only eight shafts, and these he made rather small.

But in August, 1863, from the slow progress of the works, he was compelled to sink the number originally designed. The quantity of water met with rendered it necessary to substitute steam power at several of the shafts for the horse gins first used for working the pumps.

The difficulties met with in driving the tunnel were—1st, the hardness of the rock; 2ndly, the irregularities of the stratification and the thinness of the layers, which were frequently horizontal; and, 3rdly, the quantity of water.

The rock was of the lower Cambrian or Silurian system. The layers varied from 1 inch to 24 inches in thickness, the thinner prevailing, and of different hardness. Frequently several beds would be crossed in all directions like lattice-work with quartz veins, and then would come green stone or highly indurated slate, next, a layer of almost pure and highly crystallised quartz, and afterwards, perhaps, a layer of soft clay slate. The green stone and quartz blunted the jumpers after a few strokes, and the miners had often to wrap tow round the jumpers to protect their hands from the sparks. From thirty to forty drills of the best steel, costing £38 per ton, were frequently blunted in making an 18-inch hole. In one heading it took one ton of steel to pierce 280 yards of tunnel. These particulars applied to the tunnel between shafts Nos. 1 to 11. The rock from shafts 11 to 20 was of a more slaty character, contained fewer quartz veins, and was more easily worked.

Seams charged with water were in several instances encountered, crossing the beds at nearly right angles; some of them appeared to be fed from caverns or subterranean reservoirs, and several remarkable cases were met with. A shot fired in a heading from shaft No. 5 opened a large fissure, from which water rushed out with great force, immediately flooding the heading, and a strong stream continued to flow from it. In another case, in heading No. 1, shaft 10, where the jumper was suddenly driven into soft rock, the pressure of the water violently forced it out again, and the water continued to flow as from a pipe under the pressure of several feet of water. Between shafts Nos. 4 and 7 it was

seldom a hole could be bored without tapping more or less water, entailing a great deal of trouble, delay, and waste of powder.

By the contract the tunnel was to be 5 feet high by 4 feet wide, egg-shaped, with the large end downwards, with a regular fall of 4 feet per mile, and it was commenced of these dimensions. Soon, however, the contractor found it advantageous to enlarge the size, as the work was thereby carried on more quickly. For the greater part the tunnel has been excavated about 6 feet high by from 4 feet to 5 feet wide. The bottom has been dressed off smooth, but the upper part of the sides and the roof have been left rough, and wherever there was soft rock of a treacherous character, that part has been lined with brick set in Portland cement.

The average rate of sinking the shafts, which varied from 180 feet to 90 feet in depth, was 3·7 feet per week, and for the tunnelling 3·68 feet per week at each face. The average cost of sinking the shafts was £19 1s. 9d. per lineal yard, and for driving the tunnel £9 19s. 6d. per lineal yard. The total cost of the tunnel, without lining or towers, was £57,766. The dip of the rock was in most parts 25° to 35°, and the rock was more easily separated by blasting in sinking the shafts than in tunnelling; but on account of the greater difficulty in keeping the bore holes in the shafts clear of water the average progress in both was nearly equal.

A boring machine, invented by Mr. Robert Low, was for a time employed at the Callow Hill end of the tunnel, but did not act effectively. It was designed to work two jumpers at once, but from the size of the tunnel only one could be used. It was not found to act satisfactorily; and the contractor, having made some alterations, got two made and they were placed in the heading between shafts Nos. 5 and 6. The one in the heading from shaft 5 was soon discontinued, but that in heading No. 1, shaft 6, was worked for upwards of six months, with a rate of progress in the tunnel of 5 feet 3 inches per week. In the opposite heading from the same shaft the men worked three shifts of eight hours each, and as greater energy was exerted there than at any other part of

the tunnel, the average progress was at the rate of 5 feet 6 inches per week. There was in this a saving in engine power, candles, &c., and the result was that hand labour was more successful than the best of the machines tried.

A boring machine, invented by Major Beaumont, R.E., M.P., was also tried, and the experiment was continued for about eight months, at great cost to the inventor.

The power used in working both machines was compressed air; this has the advantage of keeping the atmosphere in the tunnel in a cool and healthful condition for the miners.

At the northern end of the tunnel, at Callow Hill, a cast-iron gauge weir, with a sharp edge of the most approved section, has been erected for registering the quantity of water passed down daily for the supply of the City and suburban districts. The water is measured six times daily by a floating meter. The weir is divided into two bays 10 feet each in length, over which the water falls into a circular basin 86 feet in diameter and 10 feet deep. The level of the water in this tank, when full, is 602 feet above Ordnance datum, and from it a main 33 inches in diameter conveys the water to the service reservoirs at Stillorgan. Several carefully made experiments have proved that the quantity of water, calculated by the usual formula for ascertaining the flow of water over weirs, was larger than the amount actually discharged by about 8 per cent.

The length of the 33-inch main is 17 miles 4 furlongs 142 yards, or 30,942 yards, and the falling hydraulic line is 20 feet per mile.

Three relieving tanks are constructed on the line of main at different points, to diminish the pressure, viz.:—

	Feet above Ordnance datum			Yards
At Kilmurray, - -	473	distant from	Callow Hill,	11,809
„ Kilcroney, - -	414	„	Kilmurray,	5,121
„ Rathmichael, - -	341	„	Kilcroney,	6,444

The tank at Rathmichael is 7,431 yards from the Stillorgan reservoir. At each tank, as also at Callow Hill, there are self-acting drop valves to shut off the water in case of the pipes bursting. The

main is laid for 9,894 yards along the public roads, and the rest, 21,048 yards, across the country. Where it passes through the Glen of the Downs there is a high pressure, in some places above 300 feet of water; and it had to be carried over rough ground in crossing the valleys of the Dargle, Cookstown, and county boundary rivers, and thence to the Rathmichael tank.

The pipes, valves, and iron-work were manufactured by Messrs. Edington and Son, of Glasgow; they also took the contract for the pipe-laying, and completed their work in the most satisfactory manner. On this long line of pipe there have been only sixteen cases of burst pipes, twelve of them while the contractor was in charge of the work, and four since. Only in two cases, one at Newtown Mount Kennedy, and another at Kilpedder, was serious damage done; there were, in addition, a few cases of drawn joints.

The distributing reservoirs at Stillorgan (called the Prince of Wales's Reservoirs) are 4 miles 5 furlongs 150 yards from the City boundary at Eustace-bridge. The top water level in the upper reservoir is 274 feet, and in the lower 271 feet above Ordnance datum, or about 250 feet above the level of the quays and streets in the lowest parts of the City, 230 feet above the average level, and 170 feet above the highest part of it. The lower reservoir contains 43,166,548 gallons, with an average depth of about 22 feet of water; the upper reservoir contains 43,057,424 gallons, with an average depth of about 20 feet of water. The total area of land under reservoirs, embankments, water-courses, and ground, within the boundary walls, is 26 acres 30 perches. The reservoirs are formed partly by excavation and partly by embankment, the deepest excavation having been about 15 feet, and the highest embankment 26 feet; the excavations were chiefly in hard yellow and blue clay, and in soft rotten granite rock. The puddle gutters were carried down into the solid granite rock, in every case but one, where there was a fault. In this instance, at a depth of 30 feet, there being no change, the excavation was filled up with cement concrete to the level of the bottom of the trench under the puddle on each side. The banks are 12 feet wide

on the top, which is 4 feet above top water level, and the slopes are 2 to 1, the inner slope being pitched with granite rubble. The pipes are laid in such a manner that the water can be admitted into either of the reservoirs at pleasure, or it can be passed direct, without entering them, into the screen chamber. This is a handsome octagonal building, of granite ashlar, situated at the south-eastern angle of the lower reservoir. It is 46 feet wide at the bottom, and 49 feet at the level of the floor, each side being about 20 feet long on the floor line. The screens are distant $10\frac{1}{2}$ feet from the walls towards the centre of the chamber; they also are arranged octagonally on plan, to correspond with the building, each side being 10 feet long. The depth from the bottom of the chamber to top water is 27 feet, and to the floor line 31 feet 8 inches. The pillars and framework of the screens are of cast iron. The screens are of copper-wire gauze, having thirty strands to the square inch, and the entire area of the screens, through which the water is passed, is 1,500 superficial feet. Seven 33-inch valves are placed on the mains in this chamber to allow the water to be drawn from either of the reservoirs as necessary, and also from either side of the screens. Two 27-inch mains, controlled by two 27-inch valves, convey the water from this chamber to Dublin, and a 15-inch main is laid out of it for the supply of Kingstown and Dalkey. There is also a scour pipe, 12 inches in diameter, from the chamber into a sewer to enable it to be cleansed or the screens repaired, and the overflow is through a vertical 27-inch pipe with a bell mouth. The valves are worked by gearing fixed against the walls, so that the centre of the chamber is clear. All the valves here, as also at Roundwood and along the line (except the self-acting valves) are fitted with slow motion gearing, so that it requires about thirty minutes to entirely open or close any of the valves. On each valve brass indices, graduated both by inches and turns of the screw, register the exact number of turns of the screw, or the number of inches the valve has been moved up or down. The floor of the chamber is of cast-iron plates of a handsome pattern, and so arranged that any one plate can be taken up at pleasure. The height of the walls of the

chamber to the wall plate is 15 feet, and the chamber is covered by an ornamental iron roof slated over.

The Corporation have obtained powers to enlarge the storage capacity of the distributing reservoirs by the construction of a new one adjoining the above, capable of containing about 70,000,000 gallons, at an estimated cost of £15,000, which, when made, will be a great security towards the effective maintenance of the supply, now that all the Townships are supplied and constant fresh applications making for extending pipes into new districts.

The two 27-inch mains which convey the water to Dublin from the screen chambers are carried under the embankment in a culvert, at the outer end of which there is a vaulted chamber, where self-acting valves are placed on the mains, and from thence their course is along the high road to the City at Eustace-bridge. At Merrion-avenue, Simmon's-court, and at Leeson-street, groups of valves enable the lines to be connected, so that in case of accident one section of either main can be emptied while a burst pipe or blown joint is being repaired, without interfering with the supply of water to the City. At these points, also, branch mains for the supply of water to the Blackrock and the Pembroke Townships are taken off, the valves in all cases being placed in vaulted chambers of easy access.

The 33-inch main was calculated as being capable of conveying from 15,000,000 to 16,000,000 gallons of water, per diem, to the City, &c., but in practice it has been found capable of conveying above 20,000,000 gallons.

At the north side of Eustace-bridge, in Leeson-street, the lines of 27-inch main separate. One is carried in a north-westerly direction by Stephen's-green South, Kevin-street, and the Coombe; then turning north through Meath-street to Thomas-street, where its diameter is reduced to 24 inches; it continues by Bridgefoot-street, and crosses the river Liffey at the Queen's-bridge to Queen-street, where the diameter is reduced to 18 inches, and at North King-street it joins an old 12-inch main. The other main is carried in a north-easterly direction by Fitzwilliam-street, Merrion-square, Holles-street, and Sandwith-street, to Great Brunswick-

street, where it turns west to Carlisle-bridge, across which it is carried into Sackville-street; here its diameter is reduced to 24 inches, and continued north by Cavendish-row, where there is a further reduction in size to 18 inches, then by Frederick-street to Dorset-street, where it joins an old 12-inch main, which continues westward through Bolton-street and North King-street, to join the other line of main at the top of Queen-street as before described; thus forming a great encircling artery from which all the minor distributing mains and pipes are fed. At the intersection of every street a screw valve enables the water to be cut off with great facility and rapidity in cases of burst pipes, or for repair; or, in the event of a fire, increased pressure can be rapidly brought to bear in the particular district requiring it. Since the Vartry water has been introduced into the City, the necessity for maintaining fire-engines has ceased. In every case of fire which has occurred (and there have been several serious ones), the water thrown from the mains by simply attaching a stand-pipe and hose to the hydrants, has been found sufficient to extinguish the largest fire with a facility and rapidity which no number of steam or hand fire-engines could effect.

The hydrants are of the pattern known as Bateman and Moore's patent. They are about 100 yards apart, and the total number put down has been 1,399.

The total length of new mains laid in the City, and of old ones taken up, cleansed, and relaid, has been as follows:—

5,179	lineal	yards	of 27-inch	main;
466	„	„	24	„
3,169	„	„	18	„
1,442	„	„	12	„
495	„	„	10	„
5,223	„	„	9	„
3,911	„	„	7½	„
6,361	„	„	6	„
1,900	„	„	5	„
35,174	„	„	4	„
24,882	„	„	3	„

or about 50 miles, which, added to a length of 60 miles of old mains

utilised, makes the total length of the pipes within the City 110 miles. About 21 miles of the old pipes have been taken up; of these, about 9¾ miles, after cleansing and being proved, were relaid, and are included in the above return. They were chiefly 3-inch and 4-inch pipes.

Wells for the use of the poor have also been erected in several parts of the city, and in small courts and streets.

The number of screw valves put down of different sizes has been 1,350, and all the old clack valves and Gavin plug hydrants have been taken up.

Every part of the City is now effectively supplied with water, and the service affords universal satisfaction.

The old mains, and the lead service pipes, were all to a greater or less degree coated on the inside with a calcareous deposit of lime and iron derived from the canal water. In the larger pipes this used to accumulate to the thickness of an inch, and reduce their bore by a third or a fourth, thus interfering with their powers of supply. When the soft Vartry water was let into the pipes so coated, it acted as a solvent, and detached the coating from the pipes; so that a dirty, muddy deposit was found, which was worked up in the water by the current and by the action of opening and shutting the valves. This was, for some time, a cause of great complaint, the public attributing the evil to the "bog water" the Corporation had brought into the City; but the annoyance lasted but a few months.

Prior to introducing the Vartry water into the City, notice was given to the public informing them that the water was about to be laid on at high pressure, and calling on them to have their service pipes, taps, cisterns, and other fittings examined and made suitable, and sample fittings were exhibited in the Corporation offices. But few persons took notice of the caution; and when the water was let on street by street, the commotion it caused was great, and the rate of pay for plumbers rose to a large premium. For months the waste from this cause was enormous, requiring for some time 18,000,000 to 19,000,000 gallons per diem to keep up the supply, or double what it ought to be. The waste was gradually dimi-

nished by the introduction of new fittings, and by the efforts of the waste water inspectors. The consumption now is, for the City and out townships, about 14,000,000 gallons of water per diem ; this is still from 3,000,000 to 4,000,000 gallons per day too much, and chiefly arises from the carelessness of the public in allowing water taps to remain open (often on purpose, with the idea that it flushes the drains), the use of dill closets, and the overflow pipes from the cisterns.

By the old system the charge for water in Dublin for manufacturing purposes was made according to the diameter of the pipe, without regard to the size of the main tapped or the pressure. On the introduction of the Vartry water into the City, this was of necessity changed, and the manfacturers and large consumers have been charged by meter. At first considerable resistance was made to the alteration, and the waste discovered in some establishments was enormous—the consumer having, under the old system, no interest in economising the water, and maintaining his fittings in a perfect state. Matters, however, have gradually improved, and the result of the new system has been a large increase to the Corporation rental from this source.

The prices charged by the Corporation for Vartry water are as follows:—

All quantities under		500	gallons, at the rate of		12	pence	per 1,000 gallons.
500	and under	1,000	„	„	11	„	„
1,000	„	5,000	„	„	10	„	„
5,000	„	7,500	„	„	9	„	„
7,000	„	10,000	„	„	8	„	„
10,000	„	20,000	„	„	7	„	„
20,000	„	25,000	„	„	6	„	„
25,000	„	75,000	„	„	5	„	„
75,000 gallons and upwards				„	4	„	„

The meters are of Siemens' pattern, and the cocks and taps are of the patterns patented by Messrs. Guest and Chrimes.

All lead pipes are required by the Corporation to be alloyed with 4 per cent. of tin, and they allow no lead pipes, taps, cocks, or other such fittings to be used, unless made in conformity with

their standard patterns as to quality of material, weight, and manufacture; and all cocks and taps, before being used, are brought to the Corporation office, examined, and, if approved, stamped with their brand and numbered, and the name of the manufacturer registered, and for each article so registered there is a charge of 1*d.* It has also been made compulsory on all parties, on getting in new fittings, to place a stop-cock on the pipe where it passes from the main under the footpath, so that the water can be turned off the house for repairs without in any way interfering with the street main, and this cock is protected by a metal cover leaded into a granite flag laid in the path. These covers are hinged, to allow access to the cock, and when parties are detected wasting water, and delay taking measures to prevent it, the water can be turned off, and a lock secured to the lid to prevent access till the fittings inside have been made watertight.

The Corporation now supply water to the following townships outside the municipal boundary:—

Name of Township	Area of Township	Population by Census of 1871	Valuation on which Rate for 1875 was struck	Rate the Townships are bound to pay for Water on the Valuation	Quantity of Water the Corporation are bound to give per head of population
	A. R. P.		£ s.	*d.*	
Pembroke . .	1,489 3 17	20,982	81,939 5	3½	20 gallons.
Black Rock . .	1,070 3 9	8,089	47,515 10	3½	„
Kilmainham .	536 0 83	4,956	7,530 0	4	„
Kingstown . .	1,464 3 27	17,528	70,344 10	5½	„
Bray . . .	1,047 0 9	6,087	21,364 10	4	„
Dalkey . .	572 0 3	2,584	12,120 10	4	„
Killiney and Ballybrack	1,005 2 21	2,290	9,287 5	4	„
Clontarf . .	1,292 0 39	3,442	14,460 10	4	„

In the cases of the Pembroke, Black Rock, Kilmainham, and Clontarf townships, the Corporation incurred no expense in connecting their mains with those laid by the townships, except the necessary branch pipes and valves, as their mains reached to or passed along the township boundaries.

In the case of Kingstown, the Corporation had to lay a 15-inch main from the Stillorgan reservoir, which cost £6,660, but this is

made available for the supply of water to Dalkey, at an additional cost of £1,700. The line of pipe to supply Bray cost £1,944 1*s.* 8*d.*, and that for supplying Ballybrack and Killiney will cost about £800. All these mains can be utilised for affording supplies to districts outside the township boundaries. The townships have in every case to lay down the distributing pipes in their districts and to maintain them, the Corporation only delivering the water in bulk at their boundary.

During the preparation of the working plans, and subsequently while the works were in progress, several alterations and additions were made, not included in the parliamentary plans or estimates, with the view of rendering the works more efficient and complete. Among the most important were, the enlargement and alteration in the byewash and tunnel at Roundwood reservoir, increasing the size of the main from Callow Hill to Stillorgan from 32 inches to 33 inches in diameter, nearly doubling the size of the Stillorgan reservoir, laying a double line of pipes between Stillorgan and Dublin, constructing filter beds, building the water tower and bridge at Roundwood reservoir, laying 48-inch and 33-inch sluicing pipes from the Roundwood reservoir, and several other minor works, altogether costing about £63,000.

The total cost of the works up to January, 1874, including every expenditure, has been £541,400, to which, if added, the amount expended laying mains from Grand Canal at the Fifth Lock, and constructing tank and filter-beds there for the use of certain manufacturers, £7,040, and then the old pipe-water debt, chiefly borrowed in 1809, to lay mains and build the Blessington-street and Portobello Basins, &c., £72,000, makes the total cost of the Water Works to the City equal £620,440; and, as the population supplied is 330,000, is equal to about £1 17s. 6d. per head, which is a remarkably low price as compared with the cost per head for the water-supply to Glasgow, Liverpool, Manchester, &c.; and in the Vartry case, the Gathering Basin yielded double the quantity of water calculated on, while in Liverpool, Manchester, and other cases, the supply was short by from one-third to one-half that calculated on.

The rating powers conferred on the Corporation, by the Water-works Act of 1861, was but 1s. 3d. in the pound on the Government Valuation, being 1s. for domestic water-rate and 3d. as a public water-rate, and, notwithstanding the large expenditure on the works, and payments made for land and water rights, this rate has never been increased, but, on the contrary, it was voluntarily reduced by allowing 1½d. in the pound to be deducted from it for the establishment and maintenance of the Fire Brigade, under the provisions of the Dublin Fire Brigade Act, 1862; this left but 1s. 1½d. for water-rate, and it is anticipated that, out of this rate, the works will be completed in every respect, including the enlargements of the filter beds and of the Stillorgan reservoirs, as already referred to in this paper.

In concluding this short description of the new Dublin Corporation Water Works, whereby the City and all the extra Municipal Townships and several adjoining districts (except Rathmines, which has an independent water supply obtained from the Grand Canal) have been afforded an ample supply of pure water at high pressure and constant service from the River Vartry, and which has proved one of the most successful and effective works of the kind ever executed, and has given universal satisfaction to the citizens, and to all those who have the benefit of the supply, I must beg leave to call to mind the name of the late Sir John Gray, Chairman of the Water Works Committee of the Corporation of Dublin, to whose great ability, scientific knowledge, and indomitable energy and perseverance, the citizens of Dublin are mainly indebted for obtaining the great boon of an abundant supply of pure water.

From the year 1860 he devoted a large portion of his valuable time, working late and early, to promote the success of the scheme, and up to the very last period of his life his anxiety to make the works as nearly perfect as possible continued. The last time I saw him, the day before he left Ireland—about a fortnight before he died—he made most earnest inquiries in reference to the progress of the works now in hand, in making additional filters, and several other matters connected with the works; and expressed a strong hope that he might see them and the addition to the Prince of

Wales' Reservoir at Stillorgan completed before he died, as he believed that everything in connexion with the Vartry scheme might then be considered perfect.

To me he was a friend indeed, and I can never forget his unvarying kindness and ready support on all occasions during the period mentioned, while I had the whole responsibility, as Engineer-in-Chief, of preparing the working drawings, and subsequently superintending the construction of the works.

I should also be wanting in gratitude if I did not record my grateful thanks to Alderman Jameson, late Deputy-Chairman, and now Chairman of the Committee, as well as to its other members, for the uniform kindness, support, and confidence they always afforded me.

PARKE NEVILLE, C.E.

P.S.—This description of the Dublin Corporation Water Works was written with the view to its private circulation by the author, and especially with the object of presenting it to the Members of the American Rifle Team, and to the Members of the Corporation and the Citizens invited to meet them, by Alderman Jameson, at the *déjeuner* he gave at Vartry Lodge, on the 19th of June, 1875. The gentlemen who formed themselves into a Committee, with the object of promoting the erection of a memorial to Sir John Gray, in testimony of the vast services rendered by him to the Citizens of Dublin, in procuring a pure and abundant supply of water for their use, having asked the author for permission to use this paper in furtherance of their praiseworthy efforts, it has been gladly placed at their disposal.

TOTAL COST OF WORKS.

	£	s.	d.	£	s.	d.
Expended on all Works outside of the City Boundary, including Superintendents' Houses, Lodges, Planting, Road-making, and Forming Grounds, - - - - - -	—			331,000	0	0
Compensations and Purchase of Lands, Way-leave and Water-rights :—						
Kingstown Water Works Company, for their Rights and Powers, - - - -	5,889	19	2			
Paid the Earl of Meath, for his exclusive rights to supply the Liberty with Water, and Costs,	6,314	19	3			
Paid Earl of Fitzwilliam, - - -	2,000	0	0			
Paid for Land and Way-leave for the Construction of Works, - - - -	28,812	19	8			
Paid riparian Proprietors, below Works, for Loss of Water, and including Mr. Tighe, -	38,162	7	8			
				81,180	5	9
Engineering Staff, Draughtsmen, Overseers, Puddle Pressers, Pipe Inspectors, &c., -	13,978	5	10			
Paid Engineers, Surveyors, and Valuators, employed to Report, also as Witnesses on Records and Arbitrations, - - - -	4,954	15	11			
				18,933	1	9
Parliamentary Costs, including those incurred on the Coyford scheme, £2,707 15s. 4d. ; the Royal Commission, £1,951 12s. 6d. ; and the Act of 1861, £11,017 12s. 4d. ; and all Law Costs up to August, 1870, - - -	—			27,186	13	4
Damages Paid, including Law Costs for Injury to Property by Burst Pipes, - - -	—			1,100	0	0
Cost of Works in Altering, Extending, and Re-laying the Pipage within the City Boundary, to distribute the Vartry Water, including Street-wells, Meters, - -	—			70,000	0	0
Cost of Laying Mains from the Corporation Works to the Boundaries of the Bray, Kingstown, Dalkey and Killiney, and Ballybrack Townships, - - - - -	—			12,000	0	0
Two-thirds of the Expenditure on Laying a Main from 5th Lock of the Grand Canal, and Constructing a Tank and Filter to comply with the Agreement with Brewers and Distillers who desired to be supplied with this Water for the purpose of Manufacture (they paid one-third the Cost), - - -	—			7,040	0	0
Debt Due by the Corporation on the Moneys Borrowed in 1809, to Lay Mains and Construct Basins, - - - - -	—			72,000	0	0
				£620,440	0	10