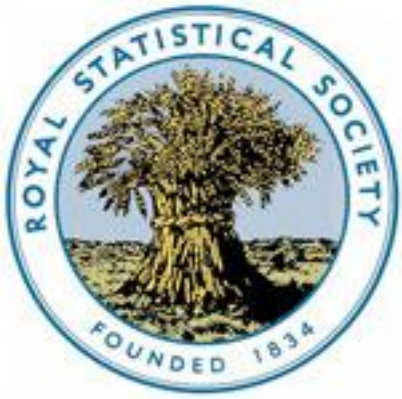

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The INCREASE *in the* NATIONAL CONSUMPTION *of* WATER.

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General introduction.

HAVING been engaged for some years past in an economic investigation of the water resources of one of the principal geological formations from which underground water supplies are derived in this country, the author had occasion to note that the supplies were increasing at a greater rate than the population in established areas and thus, being led to extend the scope of the investigation along this line to the supply of the whole country, found that the same general conditions prevailed.

Although the investigation is in no wise so exhaustive or complete as the author would have wished it to have been, he ventures to think that the data embodied in this Paper may be of some interest, not only to fellow water engineers, but to statisticians generally, as a subject of national importance.

Historical note.

Despite the lack of organised water supply in mediæval times, the history of communal supplies in this country goes back to the time of the Roman occupation. Remains of Roman aqueducts have been found, which led water into the town of Vinovia (Binchester, county Durham) and into a reservoir outside the walls of Epiacum (Lanchester, county Durham); the remains of their wells sunk into the chalk, in some cases to a depth of 200 feet, have been found at Woodcutts, Winterbourne Kingston and other villages in Dorset and Wiltshire and it is very probable that water was delivered in some cases into the houses, since pipes have been found in the ruins of some of their villas.

These works were swept out of existence, or fell into desuetude, in the centuries which followed and it is not until the thirteenth century that one finds any record of the construction of works for local supply, or of the presentation by various local benefactors of springs, streams and wells on their estates, to the use of the community amongst whom they had dwelt. The earliest of such

records is that of London. Gilbert Sandford conveyed water under a grant from Henry III in 1236, from Tyburn into the city, through a lead pipe of six-inch bore. In 1240, Amicia, Countess of Devon, ordered the construction of waterworks and presented them to the town of Tiverton,[1] which thus has the honour of possessing the oldest municipally controlled waterworks in this country.

In 1301, certain estates containing springs were presented to the town by the master and brethren of the ancient guild of Lichfield and the present supply of the town is still administered by a charitable trust, known as the Lichfield Conduit Lands.

In 1310, the Friars Minor of Southampton,[2] granted to the burgesses of that town the use of a pipe with a key, from their supply, the spring head of which at Hill, now within the borough boundaries, had previously been granted to them by Nicholas de Shyrlegh in 1290; in 1420, the old pipes having become defective and the Friars being too poor to repair them, they were repaired by the executors of John Bennett, who had bequeathed the money to this purpose, for the good of his soul. The system was presented to the town by the warden of the friars and the executors, on the condition that the latter should, at their sole expense, but using such of the old material as was available, repair the works and fix two pipes of equal capacity in the conduit, one discharging into a cistern for the use of the community and the other discharging into the friars' cistern, within their cemetery wall. Coventry[3] had a public well previous to 1453, for at the Michaelmas court leet held in that year, it was decreed that no pails or bottles should be thrown into the Broadwell on pain of forfeiture of the same; sixteen years later, a water place was ordered to be made in Catesby Lane and an honest man to have the keeping of the key; in 1483 there were four conduits and eight keepers, who collected a rate for the maintenance and repair of these, levying an extra rate of 6*s.* 8*d.* on any dyer or brewer who used the water for his trade; some years later, it is recorded that several of these traders were so taxed, to double this amount. Thirteen years later, another well was sunk near the door of St. Michael's Church.

The supply at Bath was instituted in 1500 and twelve years later the Chamberlain of Nottingham was charged at a court leet with not duly attending to the town well of Nottingham. In 1559 Lucas Cock, the Mayor of Plymouth,[4] paid Mr. Forsland 16*s.* 10*d.* for "viewinge the ground, wherebie fresh water might have been "brought into the town." Seventeen years later another surveyor is paid thrice this amount for a similar service; in 1585 the Act was passed authorising the construction of the first lengthy aqueduct in this country, the famous leet for conveying the water of the

river Meavy into the town; this work, 24 miles long, although fetching the water a crow fly distance of 7 miles, was constructed by Robert Hampen, under the superintendence of Sir Francis Drake, M.P., who busied himself with the Parliamentary Bill and the surveying and setting out of the works. This served Plymouth till 1828, when the first reservoir was constructed, another was built in 1860, but before 1898, when Burrator dam was commenced, the storage capacity was only 12·8 million gallons, now it aggregates 662,000,000 gallons.

In 1600 the Mayor of Lymington[5] ordered "that the inhabitants "hereafter named should be continuallie contributories apiece for a "quarterlie and yearlie paiement, for the better meynteyninge of "the Towne well, in the High Street, being the Comon well, as also "for the present reparacions to be done unto the same." Eighteen names follow, with a total contribution of 6*s.* 6*d.*, of which :—

3 contribute 2*d.* each.
10 ,, 4*d.* ,,
4 ,, 6*d.* ,,
1 contributes 8*d.*

About the same time Chester[6] was supplied from the River Dee by a company of adventurers, who installed a pumping station below the weir. This served for over two hundred years, but since 1826, when the present company was formed and took over the supply, the intake has been twice shifted up stream, so that the present intake is 1·5 miles above the weir.

In 1615, the Town Council of Oxford[7] granted permission to open the streets to lay pipes for the conveyance of water to Carfax and thence to Christ Church and other colleges; in the following year they granted a site to Otho Nicholson for the erection of a conduit at Carfax, supplied through wooden pipes from springs at Hincksey Hill. As elsewhere, these wooden pipes were bored from trunks of elm and oak and not only frequently occasioned considerable loss of water, by leakage at the joints and occasional bursts, but also discoloured and tainted the water with the products of decomposition and vegetable growth; in 1702 the Corporation renewed the lease of the works on the condition that the lessee laid leaden pipes in place of wooden ones. Twenty-eight years later they took the works under their own management and after running them for other fifty-seven years discontinued this supply and substituted others.

Reading had its first organised supply in 1629, York in 1677, Leicester in 1692 and Windsor in 1696. A company was formed to supply Nottingham in 1707 and in 1709 the first Act of Parliament relating to the supply of Liverpool[8] was passed, empowering the

Corporation to grant Sir C. Moore liberty to supply the community from springs at Bootle. Daventry was supplied in 1716, Stamford in 1768, Bradford and Devonport in 1793 and Wirksworth at the close of the century.

Although cast-iron pipes had been used in the water-supply system of the palace of Versailles in 1664, it was not until 1746 that cast-iron mains were first laid in London and more than seventy years passed before engineers regularly adopted cast-iron mains in any English waterworks.

Even as late as 1810 Murdoch took out a patent for boring stone pipes and such pipes, bored from the oolites of the West of England, were used in considerable quantities in the distribution of the water supply of Manchester and some other towns, but, owing to the high cost and their frequent failure, they were eventually abandoned in favour of cast-iron mains.

In 1829 James Simpson laid out the first waterworks filter bed, 1 acre in extent, at the works of the Chelsea Company, the precursor of the 1·3 million square yards of beds on which the water supply of 35·9 per cent. of the population of England and Wales is at present treated and of the still larger area laid out in the waterworks of Europe and America.

Two years later Thomas Hawksley, under whose firm it was the author's privilege for some time to serve, laid out the first English works for affording a constant supply to the town of Nottingham.

About the middle of the last century there was a general tendency to improve the quality, quantity and conditions of the supply, notably by constructing impounding reservoirs in upland areas, at remote distances from urban centres, by increasing the pressure and by giving greater attention to the bacteriological and chemical purity of the supply. In the last two decades considerable attention was paid to the reduction of waste by instituting systematic inspections of mains, connections and fittings and by frequent metering between the points of collection and consumption.

The movement for the municipalisation of water supply developed during the latter half of the century and at its close over 1,000 public authorities controlled 76·9 per cent. of the total number of installations, representing 58·6 per cent. of the total capital expenditure on waterworks. As the conditions and development of these early waterworks differed so radically from those of the last half-century, it may not be inappropriate, in order to emphasise the contrast, to briefly outline the water history of London, Liverpool, Manchester and Southampton.

London was at first supplied with water dipped from the River Thames and the streams, such as the Fleet river, Walbrook,

Longbourne and Oldbourne, which flowed through its streets; from pools, such as that in Smithfield, that near St. Giles' Church, Cripplegate, or Agnes-le-Clair and Perilous pools, near Holywell and from wells, such as Clement's well, Clerkenwell, Holywell and Skinner's well. When these sources failed or became too foul to be used, steps were taken to convey the waters of remote springs into the urban area.

In 1236 Sandford conveyed water from Tyburn into the city and the West Cheap conduit; a cistern of lead, castellated with stone, was erected in 1285, in what is now Cheapside. In 1438 Sir W. Eastfield brought water from Highbury Barn, a distance of 4·3 miles and erected conduits for its distribution in Fleet Street, Aldermanbury and Cripplegate; forty years later, W. Campion, of Fleet Street, was publicly admonished for the crime of tapping the conduit by a pipe leading into his own house.

In 1535 the Common Council of the city granted money for bringing a supply from Hackney, 3 miles away, to a conduit at Aldgate erected for its distribution; eight years later an Act was obtained authorising the construction of works for procuring supplies drawn from Hampstead, Marylebone, Muswell Hill and divers places within a five-mile radius of the city, but reserving certain springs at Hampstead Heath for the supply of the town of Hampstead[9] and in 1546, springs were tapped at Hoxton, doubtless under the powers conferred by this Act.

In 1562 Lord Mayor Harper rode the boundaries and viewed no less than 16 conduits; fifteen years later, over 1,500*l.* was expended in the construction of a conduit from Snow Hill to Holborn; still more may have been spent upon the Great Conduit supplied from Paddington, which stood at the corner of Cheapside, and was richly ornamented with carved work and statuary. In 1582 Peter Morrys, by means of a water wheel fixed in an arch of London Bridge, forced the water up to the Standard Conduit in Gracechurch Street, with later extensions water was delivered in Fleet Street and Aldersgate and in 1594 water was laid on to some of the better class houses. For many years water drawn from the conduits, from wells, or the river, was hawked from door to door, by water carriers or cobs, who retailed it in tankards of 3 gallons each; and such was the behaviour round the conduits at times, that the city authorities forbade the resort thereto of people armed with clubs or staves; at the close of the sixteenth century, there were probably 800 men engaged in this calling, for, in a petition to the city authorities, it is stated, that they and their dependents number over 4,000.

In 1606 an Act was obtained for the formation of the New

River Company; the work of cutting a channel 38·7 miles long from Chadwell and Amwell springs to the New River head at Islington was commenced in 1608 and completed in 1613 at a total cost of about 17,220*l.*; it was not viewed with general favour, for the Rev. W. Bidwell, in his book, "A brief description of the town "of Tottenham," describes the water as "brought with an ill will "from Ware to London." At the time of Sorbière's[10] visit in 1663, a part of the Thames-side district was somewhat inefficiently supplied by an engine, worked by two horses, raising water to the roof of Somerset House.

In 1669 the East London Company was established, followed by the Chelsea Company in 1723, the Lambeth Company in 1785, the West Middlesex Company in 1806, the Kent Company in 1809, the Grand Junction Company in 1811 and the Southwark and Vauxhall Company in 1845; other companies were formed at various times, but were absorbed by those previously enumerated, thus Morrys' works had passed by purchase into the possession of the London Bridge Waterworks' Company, which was acquired by the Southwark and Vauxhall Company in 1822.

During the cholera epidemic in 1848, the Lambeth Company's intake was moved from Lambeth to Thames Ditton and three years later the amalgamation of all the Metropolitan Companies was proposed, in a Bill, which did not become law, but an Act was passed in the following year, that no water supply company should have an intake below Teddington and that all reservoirs within a radius of 5 miles of St. Paul's Cathedral should be covered. Just fifty-one years after the first Bill had been rejected, the Metropolis Water Act was passed and the undertakings of the eight water companies became vested in the Metropolitan Water Board in 1904.

Liverpool obtained its first Waterworks' Act in 1709, empowering Sir C. Moore to supply the town from springs in Bootle-cum-Linacre, but in the middle of the century, the greater part of the supply was derived from a public spring, called the Fall Well, at the head of a small stream, running from the north side of the Great Heath, which laid on the south side of the town; a hundred years later that magnificent piece of municipal architecture, the St. George's Hall, was erected just north of this spring; in 1786 the Corporation obtained another Water Act, but at the end of the century over sixty water carts were engaged in the daily delivery of about 100,000 gallons of water.

In 1799 the sinking of the Berry Street well was commenced and the Liverpool Waterworks Company was incorporated, under an Act of Parliament, to supply the town from springs and wells at Bootle; twenty-three years later a second company, the Liverpool

and Harrington Waterworks Company, was formed to take over the powers contained in the 1786 Act; the new company engaged in a keen competition with its older competitor and, as in London, not infrequently each company laid a line of mains in the same street; but the service was in no wise improved, as the consumers were only supplied twice or thrice per week for a few hours on each occasion and sometimes at early hours in the morning or late in the evening.

Numerous wells were sunk between 1840 and 1847, when the works of the two companies were purchased by the Corporation. Ten years later the supply from Rivington, 24·5 miles away, was introduced; in 1892, a still greater supply was introduced from Vyrnwy, 67 miles away.

Manchester was at first supplied from the works of Sir O. Mosley, the lord of the manor of Manchester, with water pumped from the River Medlock; later, the Manchester and Salford Waterworks Company purchased these works, built a reservoir, collecting the surface drainage of 1,500 acres of land at Gorton and supplemented the supply from this source with water drawn from the Manchester and Stockport Canal and from a well in the red sandstone and thus afforded a daily supply of about 3,000,000 gallons.

The Corporation purchased the company's works, in 1847, for 533,561*l.*, and obtained an Act for the construction of reservoirs in the Longendale valley, 17·8 miles away; the scheme was commenced in 1848 and completed in 1884 by the construction of Audenshaw service reservoirs and afforded a storage of 6,006,000,000 gallons. In 1879 an Act was obtained for a still larger supply from Thirlmere, 95·3 miles away; work was commenced in 1885, the first instalment of 10,000,000 gallons a day was delivered in 1894, followed by a second similar instalment in 1904.

The water supply history of Southampton, from 1290 to 1420, has already been related. Interesting records of the cost of repair and maintenance of the conduits occur in the Roll of Account of John Bentham, steward of the town in 1428-29 and some of these accounts are considerable; in 1490 a new well was made in Houndwell Field, just outside the walls, a watering place for horses and a washing place for women, being also provided. Twenty-five years later John Flemynge, a namesake and probably a descendant of one of Bennett's executors, granted the spring-head in Lobery Mead to the Corporation, together with the right of entry upon his land, for the purpose of cleansing and repairing the watercourse.

In 1536 the names of various burgesses liable for rates for the repair of the conduits were kept in the Boke of the Condyte, and in the Roll of Assessment of 1548 there is an account for bringing water into the town; forty-six years later Roger Pedley undertook, for

certain considerations, to bring a stream of water through the Bargate, or to afford a continuous supply, night and day, from a conduit near the east end of St. Michael's Church, but the scheme must have been a failure, as the leasehold rent was reduced from 2*l.* to 1*l.* per annum in 1617; three years later this was still further reduced to 3*s.* 4*d.* and in 1675 the house where the conduit stood was taken down.

In 1738 some of the inhabitants refused to pay the water rate and in the following year an Act was obtained by the Corporation, vesting the management of the waterworks in a commission of 32 members, the town then possessed a conduit head and pumps at Achard's Bridge, the Houndwell waterhouse and 4 public conduits near churches in the High Street, when these were removed the town was supplied from 40 public fountains; other Acts for water supply purposes were obtained in 1747, 1803 and 1810; under the powers conferred by these Acts, reservoirs were constructed on the Common, to the north of the town. In 1830 a supplementary supply was drawn from the river Itchen, at Woodmill and in 1836, under another Act, repealing all the previous Acts and reorganising the supply, wells were sunk at Northam.

In 1838 the sinking of a deep-well on the Common was commenced, continued for some years and eventually abandoned as futile, after some thousands of pounds had been expended; twelve years later another Act was obtained, authorising the abstraction of water from the river Itchen at Mansbridge, 1 mile above the older pumping station at Woodmill and the construction of the third and fourth reservoirs at the north end of the Common. In 1885 another Act was obtained, authorising the construction of works for obtaining a supply by pumping from the chalk at Otterbourne, 8 miles north of the town. The older works have since been abandoned and the entire supply is now drawn from this source.

Population.

Although the whole period of organised water supply is fully covered by the census, one is tempted to investigate the estimates of the population in the pre-censal period, in order to determine whether the great increases in the population in the nineteenth century are abnormal or otherwise, as upon the answer to this query, one must be guided in the provision of water supplies for future populations.

These estimates are many and varied and excepting for the disconnected records of Domesday Book, the Poll Tax returns of 1377 and the Hearth Tax of 1696, have little or no reliable foundation and are, in fact, nothing more than mere guesses.

Some of the more probable are set out in Table I, and one notes that whilst in the censal period the population increased from 8·9 to 32·5 millions, at the rate of 1·305 per cent. per annum, it only increased at the rate of 0·260 and 0·532 per cent. per annum, from 2·2 millions in 1377, to 5·2 millions in 1700 and to 8·9 millions in 1801.

If, as in Table II, one investigates the rate of growth of the urban population, one finds that the rate of increase is considerably greater than that of the national population viewed as a whole and, owing to the supply of water to places beyond the municipal boundaries, as the author will show later, the population provided with organised water supplies has increased at an even greater rate than that of the urban population. The apparent stagnation of urban and national growth in the middle ages was due to a variety of causes; the restriction of urban areas, the limitation of trade owing to the almost entire absence of suitable means of inter-communication, the incidence of famine, pestilence, civil commotion and war, the lack of sanitation, surgical skill and medical comforts, all served to cut off the non-progressive and weakly fringe of the population, at a time when strenuous progressiveness and vigour were absolutely essential to the continuance of the national existence. Under the more sanitary and humanitarian conditions of the nineteenth century, the span of life has not only lengthened, but the weakly and less virile elements of the population have been preserved, thus tending, by mere numbers, to somewhat minimise the rate of increase; thus one arrives at the conclusion that the nineteenth century was in no wise abnormal and that a steady increase in the already considerable population may be expected throughout the twentieth century.

In Table III the author has tabulated the populations of several towns at various times. Some of these were mere hamlets in the middle ages, owing their existence to the more or less friendly shelter of some cathedral, abbey or castle, or to the accident of a fording place across a stream, or the confluence of two main roads in their immediate vicinity and their expansion to the adoption of some specialised industry; whilst others have more recently sprung into being, owing to the adaptability of their site to the exigencies of some special trade or purpose.

Taking the steel trade alone, the present university city of Sheffield, with an area of 36·9 square miles and a population of 448,000, was, as recently as 1840, under manorial rule, whilst the county borough of Barrow-in-Furness, which now has a population of 69,000 on an area of 32·8 square miles, had a population of only 100 just thirty years before its incorporation in 1867; the

urban district of Scunthorpe, which now has a population of 9,200, had a population of only 600 about thirty-seven years ago; also the transfer of a large steel works from Dronfield to Workington between 1881 and 1891, increased the population of the latter place by over 9,100 and Middlesbrough which was incorporated a municipal borough in 1853, has almost doubled its population in each of the last four decades and now has a population of 100,000 on an area of 4·4 square miles.

Similar growth is noticeable in the towns interested in the carrying trade. Liverpool, which in the twelfth century was but a tiny hamlet, developed an oversea trade with Ireland and the West Indies in the seventeeth century, profited by the insecurity of the Channel and the North Sea during the Dutch and French wars and established its first dock of about 3 acres in 1715 and now, with Birkenhead, has a total dock area of 370 acres, with 35 miles of quayage; it has thus developed from a town of 500 people, on an area of 0·08 square mile in the thirteenth century, to one of 0·29, 20·69, 23·30, and 27·80 square miles, with corresponding populations of 5,100, 629,500, 690,000 and 739,200 in the years 1699, 1891, 1902 and 1908.

Similarly Bristol has undergone four extensions of boundary in 1836, 1895, 1897 and 1904, and now has a population of 363,000 on an area of 26·6 square miles.

Crewe, Swindon, Eastleigh and other towns have grown, or are growing, from insignificant villages to important centres, owing to their favourable situation for administration on important lines of railway; others, such as Grimsby, Fleetwood, Heysham and Fishguard, have been, or are being developed, as the sea terminals of important lines of railway.

Others, such as Southport, Cleethorpes and Blackpool have sprung into existence and developed as holiday resorts; whilst others, such as New Brighton, Croydon and Ealing, have developed as residential districts, to house the better class workers in neighbouring centres of industry.

In the course of promoting a Bill for obtaining the necessary powers to proceed with the construction of proposed waterworks, it has not infrequently happened that other authorities have claimed to be supplied from certain gathering grounds included in the scheme of the promoters, or from the pipe line which it is proposed to carry through their district; thus it has happened, that the water supply population has received a considerable augmentation on the opening of new works and the area of supply has been extended far beyond the municipal boundaries, as shown in Table IV. In some cases the promoting authority have given up their scheme and

joined in the formation of a water board with their erstwhile opponents and other interested parties and this has given rise in the last few years to a new element in water supply administration, which will develop in the future and will alone be able to afford a supply to the more scattered rural elements of the population, considerable numbers of which, are at present, utterly unprovided for, the extent of which inadequacy can only be realised by those, whose professional quests for water, take them into some of the out-of-the-way villages, dotted about in various parts of the country.

Water supply.

The author has tabulated the annual supply of water in various towns and districts, at various times, in Table V, together with the population supplied, the allocation of the total supplies and the average supply per head per day under the several heads of domestic, municipal and trade supplies. The totals sufficiently indicate the considerable increases in the various supplies during the periods under consideration, but the statistics as to the supplies per head, although directly comparable, from year to year, in the same district, are somewhat complicated by a variety of circumstances, which the author proposes to briefly enumerate; firstly, as already pointed out, the boundaries of the water supply area but rarely coincide with those of the municipal area or of the census enumeration district and thus the population supplied, can only be arrived at by an estimate of the number of occupiers per house, based on a careful study of the census returns; not infrequently, the quantity supplied per head within the municipal area, differs from that supplied to the population of the outside areas; also in seaside towns and holiday resorts the number of visitors during the season, which can only be roughly approximated, materially increase the total annual supply and render the estimate of the supply per head somewhat artificial.

As water is retailed to domestic consumers and small traders in unlimited quantities, at a fixed annual charge, varying according to the rental value of the premises occupied and to large traders at so much per 1,000 gallons, passed through a meter, fixed in the consumer's premises, it is somewhat difficult to accurately apportion the domestic and trade supplies and customarily the small trader's supplies are included under the head of domestic and the metered supplies are alone classed as trade supplies; again, although in many of the large installations a most careful record is kept, it is not so well kept in some cases and the supply for municipal purposes is only arrived at by an approximation.

Some time after the supplies were introduced the pressures

were increased and the older fittings proved defective and from this cause, together with more or less careless and wasteful use of the water on the part of the consumers, gave rise to considerable increases in the supply; but by systematic house-to-house inspection, installation of meters, dividing the area of supply into sub-districts, and in other ways, the total supply per head was considerably reduced and thus it may happen that sudden decreases in the supply per head per day may occur in a lengthy record of the water supply of a district.

Systematic inspections[11] to detect waste were commenced in Liverpool in 1859 and in 1868 attempts were made to localise the waste by metering the supply in selected districts; this proved so successful that the metering area was extended and the whole district of supply was cut up into a series of sub-districts; the system was eventually adopted in other towns. The magnitude of the work of waste detection in a large waterworks system at the present time may be appreciated from the following statistics relating to Manchester for the year ending 31st March, 1905:—142,272 taps and fittings were submitted for examination, of which 136,955 were approved and stamped, 912 meters were also approved and stamped; fittings in 51,787 premises were inspected and 40,191 inspections were made to detect waste.

According to Rankine, in the early days of modern waterworks development, the proper allowance should be 10 gallons per head per day, for each of the three divisions of supply—domestic, municipal and trade; but experience has shown, that, whilst the domestic allowance is too small, the other allowances are in general excessive and a better average proportion would be 18, 3 and 7 gallons per head per day, in the three sub-divisions. There are, however, considerable variations from these quantities in various districts, as an examination of Table V will demonstrate.

The increase in the total annual supply is due to a variety of causes, which can be best appreciated by studying the supplies under the various heads in detail. The domestic supply per head per day in a middle-class district has been variously estimated by Parkes, de Chaumont, and others to range from 12 to 21 gallons, made up as follows:—

	Gallons per head per day.
Cooking	0·7 to 1·5
Refreshment	0·3 „ 0·5
Ablutions	3·0 „ 7·0
Scouring	3·0 „ 5·0
W.C.	3·0 „ 6·0

The increase in the domestic supply was at first due to the displacement of older methods of sewage disposal by the introduction of the water carriage system, the fitting of baths and W.C.'s, not

only in the better class houses, but also in the smaller dwellings, the provision of a separate tap within each cottage, instead of a single standpipe in a yard, supplying the block of dwellings enclosing it; in suburban districts, due to the custom of watering lawns and gardens, for which in most districts, a small extra charge is levied, entitling the owner to affix a hose to his tap and although some are supplied by meter, the increase in the number of hotels, hospitals, schools and industrial homes has also given rise to considerable increases under this head. Hospitals not infrequently use from 50 to 90 gallons per head per day, whilst hotels use from 50 to 175 gallons per head per day and as recently as 1907, the consumption at a certain industrial school was such, that the Local Government Board Inspector drew the attention of the managers to it as excessive, the quantities being as follows:—

	Gallons per annum.		Gallons per head per day.
Domestic use, ablutions, flushing....	20,000,000,	equivalent to	59·5
Laundry	1,750,000	,,	5·4
Swimming bath	2,000,000	,,	5·9
Farm	1,250,000	,,	3·7
Total	25,000,000	,,	74·5

The increase in the consumption of water for municipal purposes may be traced to the introduction of public baths and wash houses, the provision of conveniences in public streets, the erection of drinking and ornamental fountains, the adoption of electric light and power stations, gas works and abattoirs, to fire extinction, to sewer and drain flushing and to street watering and cleansing.

Public baths and wash houses were inaugurated by Liverpool Corporation in 1794 and 1842 respectively and are now maintained in various districts by about 250 local authorities under the Baths and Wash Houses Act of 1846 and its later amendments.

As gas, power and light stations come more naturally in the subdivision of trade supplies, the author proposes to discuss the supply for these purposes under that heading. The quantity of water used in street watering may be taken at about 20 gallons per square yard of road surface per annum, equivalent to about from 0·12 to 0·2 gallon per square yard per watering and to this must be added a further figure, to represent the water used in constructing new and making up old roads. Bristol used 28·7 million gallons in street watering in 1902 and four Metropolitan boroughs, with a total municipal area of 9·29 square miles, used no less than 95·7 million gallons in 1905.

The quantity of water used by local fire brigades varies from year to year, according to the frequency and intensity of the fires with which they have to contend, but over 1·7 million gallons have

been used in quelling a single conflagration. The London Fire Brigade used 27 million gallons in 1903 and 13·5 million gallons in 1905 and the Liverpool Fire Brigade used 12·8 million gallons in 1899.

The trade supplies owe their increase to the enormous advances which have been made in the development of steam, gas, electric and hydraulic power, to the need for larger quantities of cooling water, to its increased application in various chemical and manufacturing processes, to the material improvement in the sanitation of works and in the care for the health of the employees and not infrequently, to the fact that traders have found it to be more advantageous, with increasing trade, to draw their supply from the local authority, or company, rather than maintain their own pumping plant.

For some time past the author has endeavoured to collect data which might afford some idea of the relative proportion of the water supply of any particular works or industry, used in the process of manufacture and for the auxiliary purposes of power production and works sanitation; but the results at present available are too meagre to base any arbitrary conclusions upon them, although he is convinced that considerable economies could be effected, in various industries, if such records were available for localising and reducing excessive consumption.

In discussing the supplies of a few of the more important industries the author has attempted to indicate the growth in the total consumption of water in particular industries, rather than the growth in the supply of water by particular water authorities to various trades, as the statistics would be somewhat unwieldy and the increases in the total trade supplies in various areas is sufficiently well indicated by an inspection of Table V.

The enormous development of steam power during the past century has given rise to considerable increase in the consumption of water, which would have been even greater, but for various economies effected in its more efficient operation. The increase in the working pressure of the boiler from 60 to 300 lbs. per square inch during the past fifty years has effected a saving of from 1·1 to 1·9 lbs. of steam per horse-power hour, multiple expansion of the steam, increased piston speed and the provision of efficient drains, has almost halved the cylinder condensation; jacketing the cylinders, with from 7 to 12 per. cent. of total steam, has reduced the steam consumption, by, from 9 to 25 per cent., superheating the steam has also reduced the consumption, so that an efficient modern plant can now be operated on a consumption of from 2·5 to 3·5 gallons of water per horse-power hour.

It is somewhat difficult to arrive at an exact or even an approximate estimate of the steam power of the country, either from a consideration of boiler or of engine capacity, but one ready example offers itself, in the railway returns, made under the Railways Regulations Acts of 1840 and subsequent years, for assuming a water consumption of 30 gallons per train mile—it varies from time to time and with different types of engines—one finds that the supply for this purpose alone, exclusive of the further consumption in stations and works, must have increased from 6·5 to 10·7 thousand million gallons per annum in the past twenty-five years, as shown in the following table:—

Railways in England and Wales.

Year.	Number of locomotive engines.	Number of train miles in millions run during year.	Approximate water supply in millions of gallons on the assumption that the consumption is equivalent to 30 gallons per train mile.
1882.....	13,052	217·4	6,522
'87.....	13,825	236·5	7,095
'92.....	12,931	258·9	7,767
'97.....	14,818	304·6	9,138
1902.....	15,358	332·8	9,984
'07.....	15,897	358·5	10,755

Much of this is drawn from the companies' own wells and reservoirs, which are located at various points along their lines, but in some cases, supplies ranging from 264 to 12 million gallons of water per annum, are taken by the railway companies from various local authorities.

A considerable quantity of water is used, not only in the production of gas, but also, when it is used as a source of mechanical energy; it is estimated that the quantity of water used, which varies according to the method of manufacture, is on an average from 2 to 4 gallons per 1,000 cubic feet of gas made; the output of coal gas by the companies and local authorities in England and Wales, increased by 82 per cent. in twenty years, to 139·9 thousand million cubic feet in 1905, whilst in the same period, the output of producer gas has increased from practically nothing to its present considerable quantities. When used in an internal combustion motor, from 9 to 4 gallons of water are required, for each brake horse-power hour developed, the figures varying thus widely, according to whether the water used for cooling the cylinder is run to waste, when the former figure holds; or whether this water is circulated through a cooling system, in which case the lower figure holds; how much gas is really used for power production it is difficult to estimate, certainly only a small percentage of the output

of the coal gas companies and authorities, but to this must be added the motive power generated by gasified oil and producer gas; and one producer gas company alone, had at the beginning of 1903, installed plant on their system, equal to a daily output of 270,000,000 cubic feet of gas, equivalent to 4·5 million horse-power hours.

In electric light and power stations, considerable quantities of water are used for boiler feed, and for cooling and condensing purposes; one generating station, with an output of 2·5 million Board of Trade units per annum, uses 150,000,000 gallons of water per year, and the quantity is likely to be still further increased in the near future.

Hydraulic power[12] is not so generally used in this country, although there are numerous private installations belonging to railway, dock, steel making and other companies, there are only a few public services in operation, details of three of which are set out in the following table:—

District.	Supply of water derived	Established in	Year.	Number of machines in operation.	Millions of gallons of water used per annum.
Liverpool	From Corporation mains	1888	1890	162	125·0
			'99	166	75·1
London	Pumped from River Thames and Regent's Canal	'84	'86	364	66·1
			'98	3,240	623·4
			1908	6,368	1,029·5
Manchester	From Corporation mains.....	'94	'02	1,600	180·6
			'03	1,708	185·4
			'07	1,974	232·3

The consumption of water in breweries varies, approximately in the inverse ratio of the output, from 5 to 25 gallons of water per gallon of beer brewed, taking an average of 16 gallons of water per gallon of beer produced, the percentages of the water used in the various processes are as follows:—

11·0 per cent. actual brewing liquor.
37·5 „ cooling water.
45·0 „ cleansing water.
6·5 „ boiler feed, condenser water, &c.

As the output of beer in England and Wales has increased from 650,000,000 gallons in 1840 to 902,000,000 gallons in 1907, the corresponding consumption of water on this estimate must have varied approximately from 10·4 to 14·4 thousand million gallons per annum in this period of sixty-seven years.

As the number of breweries have considerably decreased during the past twenty years, being 16·1, 8·8 and 5·1 thousands in 1886, 1896 and 1906 respectively, it is more than probable that the

consumption of water, irrespective of steam power, per gallon of output, was higher for the greater number of small concerns in 1840 than for the fewer larger concerns in 1907 and thus the figure 10·4 may need to be somewhat increased.

One firm alone used 600,000,000 gallons of water last year, of which 36·3 per cent. was pumped from their own wells and the balance of 63·7 per cent. was purchased from the local authority. Another firm, with an annual output of 18,000,000 gallons of beer, pumped 20,000,000 gallons from their own wells and purchased 85,000,000 gallons from the local authority.

Similarly the consumption of water in distilleries varies from 30 to 70 gallons of water per gallon of spirit produced and as the production of spirit in England and Wales ranged from 5·5 million gallons in 1847 to 13·5 million gallons in 1907, the corresponding average consumption of water in this business has varied from 275·0 to 675·0 million gallons in the respective years.

In 1852 there were 304 paper mills in this country, which increased to 354 in 1882 and have since declined, owing to the closing down of some of the smaller mills, under the stress of foreign competition. These mills are, for the most part, located on streams, or derive their supply from private wells and hardly any of these concerns take their supplies from public water authorities.

The present annual output is estimated at 900,000 tons of paper and as the production of one ton of paper entails a consumption of from 10,000 to 200,000 gallons of water, according to the class and the processes of manufacture, it follows that at least 94·5 thousand million gallons of water are annually accounted for by this trade.

Steel works also require a considerable quantity of water, but, owing to the varied nature of the products and of the processes of manufacture, it is somewhat difficult to arrive at a correct estimate of the consumption of the whole trade. Many pump their supply from streams flowing through their works, some draw from private reservoirs and others take their entire supply, or supplementary supplies, from the local authority or waterworks company.

One important firm has taken the following annual supplies during the past twenty-five years from a local authority :—

Year.	Annual supply of water.		Year.	Annual supply of water.	
	In millions of gallons.	In terms of 1881 supply as unity.		In millions of gallons.	In terms of 1881 supply as unity.
1881	190	1·00	1896	304	1·60
'86	154	0·81	1901	295	1·55
'91	257	1·35	'06	283	1·49

Another important firm has a contract with a waterworks authority to take a 1,000,000 gallons a day for ten years, and a few firms use an even larger quantity daily than this.

The Corporation of Workington, in addition to their Crummock Lake works, maintained solely for domestic and municipal water supply; established in 1885, under an Act obtained in 1883, a separate supply, for works only, drawn from the river Derwent, which at the present time supplies over 660,000,000 gallons a year, mainly to steel and iron works in the district.

The textile industries are also responsible for very considerable increases in the consumption of water, but the amount is somewhat difficult to approximate owing to the varied nature of the processes followed in the several trades; one firm used 20·4 million gallons for wool washing alone last year, of which 8·6 per cent. was taken from the local authority and the remainder was drawn from their own wells; several dye works use as much as 240,000,000 gallons of water per annum. A Yorkshire firm of bleachers used 163,000,000 gallons of water in 1903 and 156,000,000 gallons in 1908, a Lancashire firm in the same trade used 73,000,000 gallons last year, of which 77·5 per cent. was drawn from the stream passing through their works, 20·0 per cent. was pumped from their own wells and 2·5 per cent. was purchased from the local authority and a Midland firm of bleachers used 33·8 million gallons last year, of which only 0·6 per cent. was supplied by the local authority.

In tanning, the consumption of hides has increased over 400 per cent. in seventy-six years, from 48,000,000 lbs. in 1820 to 196,000,000 lbs. in 1896, during which period, there would be a corresponding increase in the consumption of water for this purpose; whilst many firms in this business use becks and streams, others purchase their supply from the local waterworks authority; one northern firm has taken the following quantities of water during the past fourteen years:—

Year.	Annual supply in millions of gallons.	Year.	Annual supply in millions of gallons.
1895	0·1	1905	1·4
1901	0·8	'08	2·4

Of the lesser industries a considerable quantity of water is used in starch and soap making, the output of which latter, increased from 25·4 thousand tons in 1801 to 96·9 thousand tons in 1851 and the duty on this being abolished two years later, there are no reliable statistics upon which to base the present annual output,

which cannot be far short of 200,000 tons; this considerable increase, together with the initiation and development of many chemical industries during the past century, will account for considerable increases in the consumption of water for industrial purposes of this sort. There has also been of late, a tendency to use more water in farming and market gardening, as water-works systems have been extended to or developed in agricultural areas and increasing quantities of water are used on fruit farms, in glass-house cultivation and in dairy work. In the latter business about 3·5 gallons of water are used for cooling each gallon of milk, but the market value of the milk is considerably enhanced.

In this connection the author would point out the strenuous effort now being made, to insert a protective clause, in the agricultural interest, in all Water Bills before the present session of Parliament.

Of course, much of the water used in one industry, especially that pumped from streams, may be returned to the stream and used by another trade at a lower point in the stream, thus increasing the apparent total consumption and a more exact method would be to investigate the consumption for trade purposes in each locality and along each river, but, unfortunately, too little data are at present available to form an estimate in this way.

An estimate of the total trade consumption was made in Liverpool in 1892 and it was found that, excluding the water supplied from the mains, unmetered to the small trader, as domestic water, the total trade consumption was 25·3 million gallons per day, of which 21 per cent. was drawn from the Corporation mains, 30 per cent. was pumped from private wells and the remainder was drawn from river and canal.

In all probability the trade consumption, like the domestic, will continue to increase and if the canal system of the country is ever resuscitated, to such an extent, as to offer any really serious competition to the railways, the water resources of the country will be still further taxed to maintain an adequate supply at the summit levels of the several canals.

Considering the supply under all three heads—domestic, trade, and municipal—the author has shown in Table VI how the water supply obligations have increased in a few districts in various periods and in the following table, which shows the average annual rate of increase in the total annual water supply, during each of the various periods all terminating in 1906, as a percentage of the annual supply in 1906, it is seen that, in general, the rate of increase is greater in recent times than in those more remote :—

Water supply area.	Total supply in millions of gallons in the year 1906.	Average annual rate of increase in the annual water supply as a percentage of that in 1906 in periods of years ending in 1906.					
		55.	45.	35.	25.	15.	5.
Derby	1,051	—	1·53	1·55	1·37	2·08	2·12
Liverpool	10,801	1·54	1·14	1·17	1·64	2·47	2·24
London	82,125	1·42	—	—	1·96	1·19	1·27
Manchester.....	13,511	—	1·58	1·69	1·96	2·41	3·64

Conclusion.

With such increases in the future there will be an increasing competition for the remaining first-class upland reservoir sites, which will become fewer and fewer as time goes on and these will in general be more costly to adapt to the purposes of supply than those first adopted, also with heavier and more frequent pumping of the subsurface water, there is likely to be more litigation and disagreement in densely occupied areas, as to the alleged depletion of the underground water supply.

Now although there are much scattered and discontinuous data on stream flow and underground water levels, they are neither available, nor particularly useful, for exact comparative study and it is therefore highly desirable that steps should be taken at an early date to form some central authority, either as a separate body or as a department of the Local Government Board or the Board of Agriculture, which should be charged with the duty of water conservancy in its widest application and for that purpose should engage in a close and exact study of the water resources of the country.

Such an authority could co-ordinate its work with, and also supervise, that of water supply and sewage disposal authorities, who should be compelled to make yearly returns like gas, electric light and railway companies; also that of river conservancy, rivers pollution and fishery boards, county councils and other authorities who might also furnish some annual returns; the water supply data collected by the officers of the Geological Survey might also be handed over to this authority.

It should collect systematic data on rainfall in upland areas, where rain-gauge stations are not at present established, also data on stream flow—normal, dry weather flow and flood discharges over the various geological formations and data on the underground water levels.

It should also invite voluntary contributions of data as to the water levels at various periods, together with a continuous record of

the quantities pumped from various private wells. These would be supplementary to the officially collected data and perhaps, the continuous record of such voluntary data, occasionally certified by an official inspection, might be taken as evidence in the adjudication of claims for damage by alleged depletion.

It should publish an annual report and there would thus, in the course of a few years, be available a mass of well-digested and reliable information, which would aid and guide all interested in an economical development of the water supply of urban areas or of estates, whilst at the same time there would be a special department available, to advise Parliament as to the economy or otherwise, of the schemes of water supply, sewage disposal and river regulation laid before it, thus ensuring for future generations the mechanism for the most efficient and economical administration of the national water resources.

In conclusion, the author would tender his sincerest thanks to the directors, managers and engineers of various industrial concerns and waterworks who have at various times favoured him with any of the statistics embodied in this paper.

Tables showing :—

I. The estimated population of England and Wales in the pre-censal period.

II. The distribution of the population of England and Wales in pre-censal and censal years.

IIA. The distribution of the population of England and Wales at the taking of the last two census returns.

III. The population in thousands in twenty-four towns at various times from 1085 to 1908.

IV. The area within the municipal limits and water supply districts at various times.

V. The water supply in various towns and districts.

VI. The rate of increase in the annual water supply in various periods.

TABLE I.—*Showing the estimated population, in millions, of England and Wales in pre-censal years, according to various authorities.*

Year.	Population, in millions, according to the estimate of										
	Cunningham.[13]	Finlaison.[14]	Howlet.	King.[15]	Malden.[16]	Marshall.[17]	Mulhall.[18]	Price.[19]	Rickman.[20]	Statistical Journal.[21]	Young.[22]
1066....	—	—	—	—	—	—	2·15	—	—	—	—
'86....	—	—	—	—	1·50	—	—	—	—	—	—
1346....	2·50	—	—	—	—	—	—	—	—	—	—
'77....	—	—	—	—	2·25	—	—	—	—	—	—
'81....	—	—	—	—	—	—	2·36	—	—	—	—
1480....	—	—	—	—	—	—	3·70	—	—	—	—
'85....	—	—	—	—	—	—	—	—	—	2·50	—
1528....	—	—	—	—	4·36	—	4·36	—	—	—	—
'47....	—	—	—	—	—	—	—	—	—	4·00	—
'80....	—	—	—	—	—	—	4·60	—	—	—	—
1600....	5·00*	—	—	—	—	—	—	—	—	—	—
'72....	—	—	—	—	—	—	5·50	—	—	—	—
'80....	—	—	—	5·50	—	—	5·53	—	—	—	—
'88....	5·50*	—	—	—	—	—	—	—	—	—	—
'90....	—	—	—	—	—	—	—	6·60	—	—	—
'96....	—	—	—	5·50	5·50	—	—	—	—	—	—
1700....	—	5·13	—	—	5·00	5·11	—	—	6·04	5·47	—
'10....	—	—	—	—	—	—	—	—	—	5·24	—
'12....	—	—	—	—	—	—	6·28	—	—	—	—
'14....	5·75*	—	—	—	—	—	—	—	—	—	—
'20....	—	—	—	—	—	—	—	—	—	5·56	—
'30....	—	—	—	—	—	—	—	—	—	5·80	—
'40....	—	—	—	—	—	—	—	—	—	6·06	—
'50....	6·02*	6·04	—	—	—	6·48	—	—	6·52	6·47	—
'54....	—	—	—	—	—	—	7·02	—	—	—	—
'60....	—	—	—	—	6·50	—	—	—	—	—	—
'69....	—	—	—	—	—	—	—	—	—	—	8·50
'70....	—	—	—	—	—	—	—	—	—	—	8·50
'77....	—	—	—	—	—	—	—	4·76	—	—	—
'80....	—	—	8·69	—	7·80	9·56	8·08	—	—	7·95	—
'90....	—	—	—	—	—	—	—	—	—	8·67	—

* Authority unknown.

TABLE II.—*Showing the distribution of the population of England and Wales in pre-censal and censal years.*

Year.	Population in millions.			Population in terms of that in the year. 1696 as unity.		Rate of increase of the population per cent. per annum.		Number of	
	Total.	Urban.	Rural.	Total.	Urban.	Total.	Urban.	Houses in millions.	Inhabitants per house.
1696[15]	5·50	1·24	4·26	1·00	1·00	....	....	1·32	4·2
1769[22]	8·50	5·70	2·80	1·55	4·60	0·597	2·111	....	....
1801....	8·89	4·17	4·72	1·62	3·37	0·141	−0·981	1·58	5·6
'51....	17·93	9·16	8·77	3·26	7·38	1·412	1·585	3·28	5·5
'61....	20·07	10·93	9·14	3·65	8·82	1·134	1·788	3·74	5·4
'71....	22·71	12·91	9·80	4·13	10·40	1·246	1·670	4·26	5·3
'81....	25·97	17·29	8·68	4·72	13·94	1·351	2·969	4·83	5·4
'91....	29·00	21·74	7·26	5·27	17·53	1·109	2·321	5·45	5·3
1901....	32·53	25·05	7·47	5·91	20·20	1·154	1·427	6·27	5·2

TABLE IIA.—*Showing the distribution of population in England and Wales at the taking of the last two census returns.*

Range of population.	Number of districts.	Population as a percentage of the total in		Percentage rate of increase in the decade.
		1891.	1901.	
250,000 and over	9	24·4	24·5	12·5
Over 100,000 and under 250,000	24	7·9	10·2	44·6
„ 50,000 „ 100,000	42	9·7	9·9	14·1
„ 20,000 „ 50,000	141	12·8	13·6	19·5
„ 10,000 „ 20,000	219	8·9	9·2	17·2
„ 3,000 „ 10,000	472	9·6	8·3	− 3·5
Under 3,000	215	1·7	1·3	−12·9
Total urban	....	75·0	77·0	....
Total rural	....	25·0	23·0	2·9
Grand totals	....	100·0	100·0	....

TABLE III.—*Showing the population in thousands in twenty-four towns at various times from* 1085 *to* 1908.

1. Barrow-in-Furness.

Year.	Population.
1837	0·1
'46	0·3
'64	13·0
'71	18·8
'91	51·7
1901	57·6
'06	68·8

2. Barry.

1881	1·2
'91	13·4
1901	27·6
'07	32·5

3. Birmingham.

1085	2·0
1685	4·0 [23]
1760	28·0 [24]
or	30·0 [25]
1801	71·0
'21	102·0
'41	183·0
'61	296·0
'71	343·7
'81	400·7
'91	478·1
1901	522·2

4. Bradford.

1801	13·0
'21	26·0
'41	67·0
'61	106·0
'71	145·8
'81	180·4
'91	265·7
1901	279·8

5. Brighton.

Year.	Population.
1801	7·0
'21	25·0
'41	49·0
'61	87·0
'71	103·8
'81	128·4
'91	115·9
1901	123·5

6. Bristol.[26]

1377	9·2 [27]
1607	10·5
'85	29·0
1760	100·0 [25]
'76	80·0
1801	61·0
'21	85·0
'41	125·0
'61	154·0
'71	182·5
'81	206·5
'91	289·3
1901	328·9

7. Burnley.[28]

1311	0·3
1650	0·3
1801	4·8
'11	6·6
'21	10·0
'31	12·2
'41	17·5
'51	24·7
'61	34·4
'71	40·8
'81	58·9
'91	87·0
1901	97·0

8. Cardiff.

Year.	Population.
1851	18·3
'61	32·9
'71	56·9
'81	82·7
'91	128·9
1901	164·3

9. Hull.

1760	20·0
or	24·0 [25]
1801	30·0
'21	45 0
'41	67·0
'61	97·0
'71	121·6
'81	161·5
'91	200·5
1901	240·6

10. Leeds.

1685	7·0
1775	17·1
1801	53·0
'21	84·0
'41	152·0
'61	207·2
'71	259·2
'81	309·1
'91	367·5
1901	428·9

11. Leicester.

Year.	Population.
1377	3·2 [27]
1801	16·9
'11	23·1
'21	30·1
'31	38·9
'41	50·8
'71	95·2
'81	122·4
'91	174·6
1901	211·6

12. Liverpool.[29]

1207	0·5
1350	1·2
1565	0·7
'90	1·0
1644	2·0
'85	4·0 [23]
'99	5·1
1700	5·0
'20	10·4
'50	18·0
'60	25·0
'76	30·0 [25]
or	34·0 [30]
or	40·0 [22]
'81	35·0
'91	50·0
'92	60·0
1801	77·7
'11	94·0
'21	118·0
'31	165·0
'41	286·0
'51	365·0
'61	443·9
'71	493·3
'81	552·4
'91	629·5
1901	685·0

Small figures (22) are reference numbers.
Clarendon figures (10) give order of the tables.

TABLE III.—*Populations in thousands in twenty-four towns—Contd.*

13. London.

Year.	Population.
1377	35·2 [27]
1603	250·0
'66	460·0 [31]
'85	400·0
'96	530·0 [15]
1769	1,416·0
1801	959·3
'11	1,139·3
'21	1,379·5
'31	1,655·6
'41	1,949·3
'51	2,363·3
'61	2,808·5
'71	3,261·4
'81	3,830·3
'91	4,228·3
1901	4,536·5

14. Manchester. [32]

1685	6·0
1724	12·0
'57	20·0
'60	30·0
'74	41·0
1801	77·0
'21	129·0
'41	243·0
'51	303·4
'61	338·7
'71	351·2
'81	341·4
'85	373·6
'90	462·3
'91	505·4
1901	543·9
'04	606·8
'08	649·2

15. Newcastle-on-Tyne.

Year.	Population.
1377	4·3 [27]
1801	28·4
'11	27·6
'21	35·2
'31	42·8
'41	69·4
'51	87·8
'61	109·1
'71	128·2
'81	145·2
'91	186·0
1901	215·0

16. Norwich.

1085	1·3
1377	6·3
1685	28·0
1760	40·0
or	60·0 [25]
1821	50·3
'31	61·1
'51	68·7
'61	74·9
'71	80·4
'81	87·8
'91	101·0
1901	111·7

17. Nottingham.

1685	8·0
1760	17·7 [33]
1801	28·9
'11	34·2
'21	40·4
'31	50·7
'41	52·0
'51	57·4
'61	74·7
'71	86·6
'81	111·6
'91	213·9
1901	239·7

18. Sheffield.

Year.	Population.
1685	4·0
1760	20·0 [25]
or	30·0
1801	46·0
'21	65·0
'41	111·0
'61	185·0
'71	239·9
'81	284·4
'91	324·2
1901	380·8

19. Southport.

1809	0·1
'46	3·9
'51	4·8
'61	10·1
'71	18·1
'81	32·2
'91	41·4
1901	48·1

20. Swindon.

1871	11·5
'81	20·0
'91	32·8
1901	45·0

21. Wallasey.

Year.	Population.
1801	0·7
'11	0·9
'21	1·2
'31	2·7
'41	6·3
'51	8·3
'61	10·7
'71	14·9
'81	21·2
'91	33·1
1901	54·6
'08	70·0

22. Warrington. [34]

1085	0·3
1847	22·0
'91	55·3
1901	64·2

23. Worcester.

1685	8·0
1760	11·5
1881	40·4
'91	42·9
1901	46·6

24. York.

1377	11·4
1685	10·0
1881	59·6
'91	67·7
1901	77·8

TABLE IV.—*Showing the area within the municipal limits and in the water supply districts at various times.*

Town or district.	Year.	Area in square miles			Population in thousands		
		Within the municipal boundaries.	Supplied with water		Within the municipal boundaries.	Supplied with water	
			Outside the municipal boundaries.	Total.		Outside the municipal boundaries.	Total.
Birmingham	1891	14·7	....	....	....	....	....
	'96	19·8	112·5	132·3	450·3	152·4	602·7
	1906	19·8	112·5	132·3	508·8	271·2	780·0
Bradford	1897	16·8	101·7	118·5	231·3	205·0	436·3
	1908	....	....	....	298·0	152·0	450·0
Derby	1848	2·8	1·1	3·9	....	....	....
	'80	5·4	23·4	28·8	....	....	....
	1909	8·2	30·0	38·2	124·0	3·8	127·8
Halifax	1897	12·8	95·3	108·1	87·0	130·0	217·0
	1908	21·3	....	....	108·0	120·0	228·0
Huddersfield	1897	18·5	62·4	80·9	....	37·9	146·9
	1907	19·0	....	....	95·0	57·0	152·0
Hull	1896	13·2	10·8	24·0	220·6	3·5	224·1
	1906	14·4	11·2	+25·6	240·3	6·1	246·4
Liverpool	1300	0·1	....	....	....	....	....
	1699	0·3	....	....	....	....	....
	1835	20·7	....	....	....	....	....
	'96	20·7	87·9	108·6	641·0	149·0	790·0
	1902	23·3	....	....	....	....	....
	'05	27·8	....	....	739·2	167·6	906·8
London	1200	0·3	....	....	....	....	....
	1560	2·5	....	....	....	....	....
	1745	6·0	....	....	....	....	....
	1818	9·7	....	....	....	....	....
	'34	29·7	....	....	....	....	....
	'67	73·6	....	....	....	....	....
	1908	116·9	....	537·4	....	....	....
Manchester	1841	6·7	....	....	243·0	....	....
	'85	9·3	....	....	....	....	....
	'90	20·2	....	....	....	....	....
	'97	20·2	69·8	90·0	529·6	319·5	849·1
	1904	31·1	....	....	606·8	....	....
	'08	31·1	207·1	238·2	649·3	600·7	1,250·0
Newport (Mon.)	1847	1·5	....	....	....	....	....
	'88	4·3	1·8	6·1	....	....	....
	'97	7·7	3·7	11·4	69·0	3·4	72·4
	1908	7·8	3·6	11·4	....	....	87·8
St. Helens	1880	10·3	8·6	18·9	....	....	56·0
	'97	11·4	7·5	18·9	82·9	2·1	85·0
	1908	11·4	7·5	18·9	90·0	8·0	98·0
Sheffield	1897	30·7	94·3	125·0	....	....	415·0
	1906	37·0	....	....	447·9	29·5	477·4
Torquay	1884	6·1	6·5	12·6	....	....	....
	1908	6·1	6·5	12·6	33·6	19·4	53·0

TABLE V.—*Showing the increase in the consumption of water in England and Wales.*

Water supply authority.	Year.	Population, in thousands, in area of supply.	Annual supply, in millions of gallons.					Daily supply, in gallons, per head of population.			
			Total.	In area of supply.			In bulk to other authorities.	Total.	Domestic.	Trade.	Municipal.
				Domestic.	Trade.	Municipal.					
Aberdare U.D.C.	1902	48·0	350·0	—	—	—	—	19·98	19·98	—	—
	'06	50·0	401·5	—	—	—	—	22·00	—	—	—
Alton U.D.C.	'02	4·5	49·9	42·7	*	7·2	—	30·38	26·00	*	4·38
	'06	5·0	60·0	47·4	*	12·6	—	32·87	26·00	*	6·87
Ashford U.D.C.	'02	12·8	54·7	—	—	—	—	11·72	—	—	—
	'06	13·4	63·1	—	—	—	—	12·90	—	—	—
Bakewell U.D.C.	'02	2·8	30·7	30·7	—	—	—	30·00	30·00	—	—
	'06	3·0	37·0	33·0	3·1	0·9	—	33·79	30·14	2·83	0·82
Banbury W. Co.	'02	13·0	115·0	80·5	34·5	—	—	24·30	17·00	7·30	—
	'06	13·0	124·0	76·6	47·4	—	—	26·13	16·13	10·00	—
Bangor Corp.	'02	11·7	—	—	—	—	—	—	—	—	—
	'06	13·1	138·5	109·8	28·7	—	—	29·00	23·00	6·00	—
Barnsley T.C.	'02	96·0	547·0	455·5	91·5	—	—	15·61	13·00	2·61	—
	'06	110·0	700·0	521·9	178·1	—	—	17·43	13·00	4·43	—
Barrow-in-Furness Corp.	1897	65·3	845·1	—	—	—	—	35·46	—	—	—
	1902	75·2	1,278·6	612·1	559·9	106·6	—	46·58	22·30	20·40	3·88
	'06	76·9	1,334·2	611·9	572·6	149·7	—	47·53	21·80	20·40	5·33
Barry U.D.C.	'01	28·5	227·0	202·0	25 0	†	—	21·82	19·42	2·40	†
	'06	32·5	268·0	237·2	30 8	†	—	22·59	20·00	2·59	†

* In domestic.

† In trade.

NOTE.—U.D.C. is an abbreviation for Urban District Council.
Corp. „ Corporation.
T.C. „ Town Council.
G. and W. Co. „ Gas and Water Company.
W. Co. is an abbreviation for Water Company,
W. W. Co. „ Water Works Co.
J. B. „ Joint Board.
W. B. „ Water Board.

TABLE V.—*Showing the increase in the consumption of water in England and Wales—Contd.*

Water supply authority.	Year.	Population, in thousands, in area of supply.	Annual supply, in millions of gallons.					Daily supply, in gallons, per head of population.			
			Total.	In area of supply.			In bulk to other authorities.	Total.	Domestic.	Trade.	Municipal.
				Domestic.	Trade.	Municipal.					
Basingstoke Corp.	1902	10·0	125·5	80·3	43·8	1·4	—	34·40	22·00	12·00	0·04
	'06	11·0	145·0	92·3	52·2	0·5	—	36·11	23·00	13·00	0·01
Batley Corp.....	'02	30·6	430·0	180·0	240·0	10·0	—	38·50	16·12	21·49	0·89
	'06	31·3	450·0	185·0	250·0	15·0	—	39·39	16·19	21·88	1·32
Bilston U.D.C.....	'02	32·6	260·6	218·5	42·1	*	—	21·87	18·34	3·53	*
	'06	34·3	291·8	224·4	67·5	†	—	23·31	17·92	5·39	†
Birkenhead Corp.	1897	103·0	973·6	—	—	—	—	25·90	—	—	—
	1906	110·5	1,324·0	—	—	—	—	32·81	22·75	10·06	—
Birmingham Corp.	1893	567·4	—	—	—	—	—	25·75	17·00	8·75	†
	'95	584·8	5,251 2	3,993·9	1,257·3	†	—	24·60	18·71	5·89	†
	'96	680·1	5,794·0	—	—	—	—	23·33	—	—	—
	1901	700·6	5,973·6	3,572·4	2,401·2	—	—	23·36	13·97	9·39	†
	'02	725·6	6,785·2	5,153·3	1,343·2	288·7	—	25·62	19·46	5·07	1·09
	'06	780·0	6,559·8	3,687·0	2,872·8	—	—	23·04	12·95	10·09	—
	'07	800·2	7,810·0	—	—	—	—	26·74	—	—	—
Blackburn Corp.	'02	130·0	1,254·0	793·4	460·6	—	—	26·43	16·72	9·71	—
	'06	134·4	1,240·4	676·0	564·4	—	—	25·27	13·78	11·49	—
Blaydon U.D.C.	'01	19·3	82·1	—	—	—	—	11·45	—	—	—
	'06	22·5	120·3	—	—	—	—	14·37	—	—	—
Bolton Corp.	1897	250·0	2,007·5	—	—	—	—	22·00	—	—	—
	1901	265·0	2,320·0	1,475·0	700·0	10·0	135·0‡	23·99	15·25	7·24	1·50
	'02	273·0	2,190·0	—	—	—	—	21·98	—	—	—

* In domestic. † In trade. ‡ Distributed amongst other totals.

TABLE V.—*Showing the increase in the consumption of water in England and Wales—Contd.*

Water supply authority.	Year.	Population, in thousands, in area of supply.	Annual supply, in millions of gallons.					Daily supply, in gallons, per head of population.			
			Total.	In area of supply.			In bulk to other authorities.	Total.	Domestic.	Trade.	Municipal.
				Domestic.	Trade.	Municipal.					
Boston W. W. Co.	1902	19·6	100·0	—	—	—	—	14·00	12·00	2·00	—
	'06	20·0	110·0	88·3	21·9	—	—	15·10	12·10	3·00	—
Bournemouth G. and W. Co.	'02	80·9	759·0	—	—	—	—	25·70	—	—	—
	'06	81·0	785·0	—	—	—	—	26·55	—	—	—
Bradford Corp.	1871	—	2,920·0	—	—	—	—	—	—	—	—
	'81	—	3,650·0	—	—	—	—	—	—	—	—
	'91	—	4,015·0	—	—	—	—	—	—	—	—
	'97	436·3	4,048·2	—	—	—	—	25·42	—	—	—
	1901	—	4,380·0	—	—	—	—	45·10	24·70	20·40	—
	'06	450·0	—	—	—	—	—	40·30	19·80	20·50	—
	'08	—	4,745·0	—	—	—	—	—	—	—	—
Bridgend G. and W. Co.	'01	6·1	69·9	61·5	5·8	0·8	1·8	31·64	27·82	2·62	0·36
	'06	6·7	102·0	—	—	—	—	41·83	—	—	—
Brighouse Corp.	'01	21·7	141·1	80·6	60·5	†	—	17·79	10·16	7·63	—
	'06	22·2	180·1	91·4	88·7	†	—	22·18	11·26	10·92	—
Brighton Corp.	1897	165·0	2,142·5	—	—	—	—	35·57	—	—	—
	1906	180·0	2,302·0	1,776·4	525·6	—	—	35·04	27·04	8·00	—
Brompton, Chatham, Gillingham, and Rochester W. W. Co.....	'01	105·9	580·0	—	—	—	—	15·00	—	—	—
	'06	137·0	750·0	—	—	—	—	15·00	—	—	—
Burnley Corp.	1897	104·4	836·5	—	—	—	—	21·94	—	—	—
	1906	104·0	932·0	743·3	188·7	—	—	24·55	19·58	4·97	—

† In trade.

TABLE V.—*Showing the increase in the consumption of water in England and Wales—Contd.*

Water supply authority.	Year.	Population, in thousands, in area of supply.	Annual supply, in millions of gallons.					Daily supply, in gallons, per head of population.			
			Total.	In area of supply.			In bulk to other authorities.	Total.	Domestic.	Trade.	Municipal.
				Domestic.	Trade.	Municipal.					
Cardiff Corp.	1901	195·0	1,752·0	1,108·0	525·0	101·0	18·0	24·61	15·57	7·38	1·41
	'06	218·0	2,060·9	1,109·4	951·5	†	†	25·90	13·94	11·96	†
Carlisle Corp.	'02	50·0	508·4	—	—	—	—	28·42	19·15	9·27	†
	'06	53·0	505·4	—	—	—	—	26·12	17·06	9·06	†
Chester W. W. Co.	'02	50·2	660·0	—	—	—	—	36·00	—	—	—
	'06	53·0	685·0	—	—	—	—	35·40	24·40	11·00	—
Colchester Corp.	'02	41·0	241·6	—	—	—	—	16·14	—	—	—
	'06	43·0	282·9	—	—	—	—	18·02	—	—	—
Colne Valley W. Co.	'02	60·0	686·0	—	—	—	—	31·33	24·00	—	—
	'06	82·0	900·0	—	—	—	—	30·10	24·00	—	—
Coventry Corp.	1897	60·1	526·3	—	—	—	—	24·03	—	—	—
	1902	71·0	610·0	—	—	—	—	23·54	—	—	—
	'06	87·0	703·0	—	—	—	—	22·14	18·14	4·00	—
Deal and Walmer J. B.	'02	14·0	122·4	—	—	—	—	23·95	—	—	—
	'06	18·6	172·2	—	—	—	—	25·36	19·36	6·00	—
Derby Corp.‡	1853	18·8	166·0	139·6	26·4	†	—	24·14	20·29	3·85	†
	'56	29·4	237·1	203·6	33·4	†	—	22·05	18·94	3·11	†
	'61	37·0	326·6	287·2	39·4	†	—	24·17	21·25	2·82	†
	'66	42·8	346·7	273·7	73·0	†	—	22·17	17·50	4·67	†
	'71	50·4	482·3	370·7	111·6	†	—	26·19	20·13	6·06	†
	'76	58·8	618·3	494·7	123·6	†	—	28·81	23·05	5·76	†
	'81	75·9	690·7	485·3	205·4	†	—	24·92	17·51	7·41	†

† In trade. ‡ Purchased by Corp. in 1880.

TABLE V.—*Showing the increase in the consumption of water in England and Wales—Contd.*

Water supply authority.	Year.	Population, in thousands, in area of supply.	Annual supply, in millions of gallons.					Daily supply, in gallons, per head of population.			
			Total.	In area of supply.			In bulk to other authorities.	Total.	Domestic.	Trade.	Municipal.
				Domestic.	Trade.	Municipal.					
Derby Corp. (*contd.*)	1886	92·1	723·6	505·1	218·5	†	—	21·53	15·03	6·50	†
	'91	102·2	723·8	467·9	255·9	†	—	19·40	12·54	6·86	†
	'96	109·3	936·6	638·5	298·1	†	—	23·47	16·00	7·47	†
	1901	125·1	939·7	555·0	384·7	†	—	20·57	12·15	8·42	†
	'06	125·4	1,051·0	664·7	386·3	†	—	22·96	14·52	8·44	†
	'08	127·8	1,146·6	764·1	382·5	†	—	24·58	16·38	8·20	†
Devonport Corp.‡	'02	69·7	762·9	—	—	—	—	30·00	19·00	11·00	—
	'06	70·0	819·3	—	—	—	—	32·06	19·45	12·61	—
Doncaster Corp.	'02	41·3	362·8	294·2	18·6	50·0	—	24·07	19·52	4·55	—
	'06	44·4	344·5	—	—	—	—	21·75	21·02	0·73	—
Dorking W. Co.	'02	9·9	81·0	—	—	—	—	23·30	—	—	—
	'06	14·4	103·0	—	—	—	—	19·60	—	—	—
Dover Corp.	'01	41·8	432·5	301·0	111·5	20·0	—	28·35	19·72	7·31	1·32
	'06	43·6	446·3	348·3	78·0	20·0	—	28·04	21·85	4·90	2·29
	'07	45·0	445·0	362·0	71·0	12·0	—	27·09	22·04	4·32	0·73
East Surrey W. Co.....	'01	75·0	555·0	—	—	—	—	20·27	—	—	—
	'07	81·0	764·0	—	—	—	—	25·84	—	—	—
Ebbw Vale U.D.C.	'02	22·0	144·5	—	—	—	—	18·00	—	—	—
	'06	40·0	215·0	—	—	—	—	14·72	—	—	—
Ely U.D.C.	'02	9·8	60·5	—	—	—	—	16·95	—	—	—
	'06	9·9	71·3	—	—	—	—	19·73	—	—	—
Exeter Corp.	'02	60·0	700·0	—	—	—	—	31·96	—	—	—
	'06	61·0	720·0	—	—	—	—	32·34	—	—	—

† In trade. ‡ Devonport W. Co. previous to 1906.

TABLE V.—*Showing the increase in the consumption of water in England and Wales—Contd.*

Water supply authority.	Year.	Population, in thousands, in area of supply.	Annual supply, in millions of gallons.					Daily supply, in gallons, per head of population.			
			Total.	In area of supply.			In bulk to other authorities.	Total.	Domestic.	Trade.	Municipal.
				Domestic.	Trade.	Municipal.					
Exmouth U.D.C.	1901	10·4	119·6	—	—	—	—	31 57	—	—	—
	'06	11·3	100·7	95·0	3·7	2·0	—	24·31	22·93	0·90	0·48
Faversham W. Co.	'01	12·0	74·0	—	—	—	—	16·89	—	—	—
	'06	13·9	102·4	—	—	—	—	20·18	18·30	1·88	—
Filey U.D.C.	'01	3·2	37·4	35·0	0·9	0·6	0·9	31·55	29·50	0·76	0·53
	'06	3·4	41·0	—	—	—	—	33·04	—	—	—
Folkestone W. W. Co.	'00	29·9	333·4	295·8	24·4	13·2	—	30·55	27·10	2·24	1·21
	'02	31·3	361·1	305·5	19·5	36·1	—	31·61	26·74	1·71	3·16
	'04	33·7	388·6	322·5	19·6	46·5	—	31·59	26·22	1·59	3·78
	'06	35·5	360·1	286·7	26·1	47·3	—	27·79	22·13	2·01	3·65
	'08	35·6	424·3	365·7	29·3	29·3	—	32·67	28·16	2·25	2·26
Frimley and Farnborough District W. Co.	1902	15·0	160·6	126·0	20·0	2·6	12·0	29·33	23·01	3·65	0·47
	'06	26·0	268·0	185·0	60·0	5·0	18·0	28·24	19·49	6·32	0·53
Frome U.D.C.	'02	11·0	114·0	—	—	—	—	—	—	—	—
	'06	12·0	124·5	—	—	—	—	—	—	—	—
Gainsborough U.D.C.	'02	20·0	182·5	—	—	—	—	25·00	—	—	—
	'06	21·1	258·7	—	—	—	—	33·50	23·00	10·50	—
Gloucester Corp.	1897	43·0	281·0	—	—	—	—	17·90	—	—	—
	1901	53·0	400·0	—	—	—	—	20·68	15·50	3·00	2·18
	'06	56·0	408·8	—	—	—	—	20·00	15·00	3·00	2·00
Godalming T.C.	'02	11·0	139·9	131·0	5·0	3·9	—	34·83	32·63	1·24	0·96
	'06	12·6	150·0	—	—	—	—	32·61	27·50	5·11	—
Gosport W. W. Co.	'02	30·0	181·8	—	—	—	—	16·60	—	—	—
	'06	30·5	257·0	238·0	12·0	7·0	—	23·08	21·38	1·07	0·63

TABLE V.—*Showing the increase in the consumption of water in England and Wales—Contd.*

Water supply authority.	Year.	Population, in thousands, in area of supply.	Annual supply, in millions of gallons.					Daily supply, in gallons, per head of population.			
			Total.	In area of supply.			In bulk to other authorities.	Total.	Domestic.	Trade.	Municipal.
				Domestic.	Trade.	Municipal.					
Great Berkhamsted W. W. Co.	1902	8·7	65·7	—	—	—	—	20·62	—	—	—
	'06	9·0	109·5	—	—	—	—	33·33	—	—	—
Great Grimsby W. W. Co.	'02	77·0	1,021·0	—	—	—	—	36·33	—	—	—
	'06	90·0	1,231·0	—	—	—	—	33·73	—	—	—
Guildford T.C.	'00	20·0	173·8	—	—	—	—	27·00	—	—	—
	'06	21·0	232·4	148·3	12·7	23·0	48·3	30·32	18·98	1·66	3·00
Halifax Corp.	1897	217·0	1,577·0	—	—	—	—	19·91	—	—	—
	1906	228·0	1,760·2	—	—	—	—	21·15	—	—	—
Harpenden W. W. Co.	'02	4·7	18·0	—	—	—	—	10·49	—	—	—
	'06	5·1	38·5	—	—	—	—	20·68	—	—	—
Harrogate Corp.	'01	31·1	451·0	361·0	90·0	†	*	39·73	31·80	7·93	†
	'06	49·2	569·8	—	—	—	—	31·70	23·40	8·30	†
Hartlepool G. and W. Co.	1875	44·0	554·0	256·0	298 0	—	—	34·49	15·94	18·55	—
	'99	89·0	1,247·0	722·0	525·0	—	—	38·38	22·23	16·15	—
	1904	92·5	1,359·0	740·0	619·0	—	—	40·25	21·92	18·33	—
Hastings Corp.	'02	75·0	440·0	—	—	—	—	16·07	—	—	—
	'06	85·0	560·0	—	—	—	—	18·05	—	—	—
Henley - on - Thames W. Co.	'01	6·0	78·6	74·6	1·6	2·4	—	35·89	34·06	0·74	1·09
	'06	6·5	91·7	85·4	3·0	3·3	—	38·65	36·00	1·26	1·39
Hinckley U.D.C.	'01	11·5	56·1	40·4	14·3	1·4	—	13·35	9·61	3·41	0·33
	'06	12·0	72·9	50·8	20·6	1·5	—	16·63	11·59	4·70	0·34

* In domestic. † In trade.

TABLE V.—*Showing the increase in the consumption of water in England and Wales—Contd.*

Water supply authority.	Year.	Population, in thousands, in area of supply.	Annual supply, in millions of gallons.					Daily supply, in gallons, per head of population.			
			Total.	In area of supply.			In bulk to other authorities.	Total.	Domestic.	Trade.	Municipal.
				Domestic.	Trade.	Municipal.					
Hucknall Huthwaite U.D.C.	1901	4·0	11·5	11·3	0·2	—	—	7·78	7·60	0·18	—
	'07	4·5	13·5	13·3	0·2	—	—	8·22	8·10	0·12	—
Hull Corp.	1893	196·0	3,110·7	—	369·2	—	0·4	43·48	—	5·16	—
	'96	223·7	3,211·6	—	481·5	—	1·3	39·20	—	5·90	—
	1901	246·0	3,377·3	2,557·3	752·5	55·0	12·5	37·61	28·48	8·38	0·61
	'03	254·0	3,330·8	—	771·3	—	16·1	35·75	—	8·32	—
	'06	267·5	3,490·1	2,593·2	818·5	55·0	23·4	35·50	26·56	8·38	0·56
Ipswich Corp.	1891	51·8	426·8	364·3	50·3	12·2	—	22·57	19·27	2·66	0·64
	'96	57·8	386·0	271·7	79·3	15·1	—	18·30	12·88	3·76	1·66
	1901	65·6	524·1	397·1	109·3	17·7	—	21·89	16·59	4·56	0·74
	'07	73·4	544·3	411·1	116·4	16·9	—	20·32	15·34	4·34	0·64
King's Lynn Corp.	'02	20·3	237·2	—	—	—	—	32·04	—	—	—
	'06	21·3	250·0	—	—	—	—	32·17	—	—	—
Knaresborough U.D.C.	'02	5·0	45·6	—	—	—	—	25·00	—	—	—
	'06	5·5	54·1	—	—	—	—	26·92	25·80	1·12	—
Leamington Corp.	'02	28·0	214·0	—	—	—	—	20·94	—	—	—
	'06	29·0	246·4	—	—	—	—	23·27	—	—	—
Leeds Corp.	1896	420·0	5,473·2	—	—	—	—	35·70	—	—	—
	1902	430·0	5,691·2	—	—	—	—	36·26	24·50	11·00	0·76
	'06	463·4	5,870·1	—	—	—	—	34·70	21·80	12·10	0·80
Leicester Corp.	1878	100·2	1,012·1	—	—	—	—	27·68	—	—	—
	'96	220·0	1,445·4	—	—	—	—	18·00	—	—	—
	1901	243·9	1,858·2	1,311·0	469·7	77·6	—	20·87	14·72	5·27	0·87
	'06	270·5	1,582·5	1,074·5	450·3	57·7	—	16·03	10·89	4·56	0·58

TABLE V.—*Showing the increase in the consumption of water in England and Wales—Contd.*

Water supply authority.	Year.	Population, in thousands, in area of supply.	Annual supply, in millions of gallons.					Daily supply, in gallons, per head of population.			
			Total.	In area of supply.			In bulk to other authorities.	Total.	Domestic.	Trade.	Municipal.
				Domestic.	Trade.	Municipal.					
Lewes W. W. Co.	1901	11·3	136·8	96·5	36·4	3·9	—	33·03	23·30	8·78	0·95
	'06	12·6	150·0	109·4	34·7	5·9	—	32·68	23·84	7·55	1·29
Lincoln Corp.	1897	52·0	445·8	—	—	—	—	23·51	—	—	—
	1901	53·6	542·1	405·8	111·2	25·1	—	27·71	20·74	5·68	1·29
	'07	58·0	623·5	497·2	101·1	25·1	—	29·45	23·49	4·77	1·19
Liverpool Corp.	1800*	77·5	36·5	—	—	—	—	1·30	—	—	—
	'46	339·1	1,020·0	—	—	—	—	8·24	—	—	—
	'51	420·1	1,648·5	—	—	—	—	10·75	—	—	—
	'61	504·1	5,281·7	—	—	—	—	28·70	—	1·60	—
	'71	594·1	6,366·6	—	—	—	—	29·36	—	—	—
	'81	704·3	6,387·6	—	—	—	—	24·84	—	5·07	—
	'91	748·7	6,901·4	—	—	—	—	25·25	—	—	—
	'99	818·7	9,315·5	—	—	—	—	31·17	17·89	10·00	3·28
	1902	850·0	9,731·6	—	—	—	—	31·37	—	—	—
	'06	906·8	10,801·0	—	—	—	—	32·63	—	—	—
London Companies†	1820	966·0	8,589·5	—	—	—	—	24·36	—	—	—
	'50	2,174·0	16,753·5	—	—	—	—	21·11	—	—	—
	'57	2,605·0	27,192·5	—	—	—	—	28·60	23·50	3·10	—
	'81	3,815·0	41,792·0	—	—	—	—	30·01	26·01	4·00	—
	'84	4,272·0	48,727·5	—	—	—	—	31·25	—	—	—
	'96	5,607·2	72,265·6	—	—	—	—	35·31	—	—	—
	'98	5,814·2	74,479·7	—	—	—	—	35·10	—	—	—
	1900	5,953·5	76,650·0	—	—	—	—	35·27	28·22	7·05	—
	'02	6,379·4	77,200·1	—	—	—	—	33·15	26·52	6·63	—

* Supplies hawked from about 60 water carts. Companies formed 1799 and 1822. Purchased by Corporation 1847.
† Companies formed at various times between 1619 and 1845, and transferred to the Metropolitan Water Board in 1904.

TABLE V.—*Showing the increase in the consumption of water in England and Wales—Contd.*

Water supply authority.	Year.	Population, in thousands, in area of supply.	Annual supply, in millions of gallons.					Daily supply, in gallons, per head of population.			
			Total.	In area of supply.			In bulk to other authorities.	Total.	Domestic.	Trade.	Municipal.
				Domestic.	Trade.	Municipal.					
London (*contd.*) Metropolitan W.B.	1904	6,490·3	80,201·6	—	—	—	—	33·54	26·83	6·71	—
	'05	6,747·2	79,572·6	—	—	—	—	32·31	25·85	6·46	—
	'06	6,851·0	82,125·2	—	—	—	—	32·84	26·27	6·57	—
Luton W. Co.	'02	36·4	304·0	—	—	—	—	22·88	—	—	—
	'06	42·4	411·4	—	—	—	—	26·58	—	—	—
Malton U.D.C.	'02	4·8	60·6	—	—	—	—	34·90	—	—	—
	'06	4·9	67·8	—	—	—	—	38·00	35·00	3·00	—
Manchester Corp.‡	1845	—	1,095·0	—	—	—	—	—	—	—	—
	'55	—	2,948·5	—	—	—	—	—	—	—	—
	'61	—	3,911·4	—	—	—	—	—	—	—	—
	'71	—	5,508·2	—	—	—	—	—	—	—	—
	'81	—	6,909·3	—	—	—	—	—	—	—	—
	'85	—	7,172·5	—	—	—	—	—	—	—	—
	'90	—	8,216·2	—	—	—	—	—	—	—	—
	'91	—	8,632·0	—	—	—	—	—	—	—	—
	1901	1,100·0	11,050·6	—	—	—	—	27·52	—	—	—
	'04	—	12,043·0	—	—	—	—	—	—	—	—
	'08	1,250·0	14,615·2	—	—	—	—	32·03	—	—	—
Margate Corp.	'02	26·5	278·7	—	—	—	—	28·81	—	—	—
	'06	36·0	382·5	—	—	—	—	29·11	—	—	—
Newhaven and Seaford W. Co.	'02	11·0	64·6	—	—	—	—	16·09	—	—	—
	'06	12·0	84·0	—	—	—	—	19·18	—	—	—

‡ Works of the Manchester and Salford Water Works Co. purchased by the Corporation in 1847.

TABLE V.—*Showing the increase in the consumption of water in England and Wales—Contd.*

Water supply authority.	Year.	Population, in thousands, in area of supply.	Annual supply, in millions of gallons.					Daily supply, in gallons, per head of population.			
			Total.	In area of supply.			In bulk to other authorities.	Total.	Domestic.	Trade.	Municipal.
				Domestic.	Trade.	Municipal.					
Newport Corp.	1888	—	428·7	—	—	—	—	—	—	—	—
	'91	61·0	459·8	—	—	—	—	20·65	—	—	—
	'95	69·0	638·2	—	—	—	—	25·34	—	—	—
	1901	73·6	661·8	—	—	—	—	24·62	—	—	—
	'05	81·4	767·7	453·9	313·8	—	—	25·85	15·28	10·57	—
	'08	87·8	898·7	556·3	342·4	—	—	28·03	17·35	10·68	—
Nottingham Corp.	1897	272·8	1,979·0	—	—	—	—	19·88	—	—	—
	1902	301·0	2,223·0	—	—	—	—	19·65	—	—	—
	'07	340·0	2,744·9	—	—	—	—	22·10	11·48	10·62	—
Nuneaton Corp.	'02	25·0	110·0	—	—	—	—	10·96	—	—	—
	'06	28·8	181·3	—	—	—	—	17·27	12·52	4·75	—
Oswestry Corp.	'02	9·7	76·0	46·0	30·0	†	—	21·47	12·99	8·48	—
	'06	9·9	102·0	58·0	44·0	†	—	28·23	16·06	12·17	—
Peterborough Corp.	'01	34·0	479·0	315·5	*	150·0	13·5	38·60	25·42	*	12·09
	'06	34·8	546·0	365·5	*	150·0	30·5	42·98	28·78	*	11·89
Plymouth Corp.	1897	98·6	1,770·2	—	—	—	—	49·20	—	—	—
	1901	132·3	2,225·0	1,555·6	315·4	72·3	310·4	46·07	32·21	6·53	1·50
	'06	145·2	2,034·5	—	—	—	368·7	38·39	25·64	10·56	†
Poole Corp.	'02	27·0	119·7	—	—	—	—	12·15	—	—	—
	'06	29·4	170·5	141·2	17·9	11·4	—	15·91	13·18	1·67	1·06
Ramsgate Corp.	'02	35·0	434·1	364·5	43·9	25·7	—	33·97	28·53	3·43	2·01
	'06	38·3	424·8	364·9	33·1	26·8	—	30·41	26·12	2·37	1·92

* In domestic. † In trade.

TABLE V.—*Showing the increase in the consumption of water in England and Wales—Contd.*

Water supply authority.	Year.	Population, in thousands, in area of supply.	Annual supply, in millions of gallons.					Daily supply, in gallons, per head of population.			
			Total.	In area of supply.			In bulk to other authorities.	Total.	Domestic.	Trade.	Municipal.
				Domestic.	Trade.	Municipal.					
Reading Corp.	1897	71·6	914·9	—	—	—	—	35·03	—	—	—
	1902	85·0	1,280·5	—	—	—	—	41·27	20·00	21·27	—
	'06	91·1	1,347·8	—	—	—	—	40·53	20·00	20·53	—
Rhyl U.D.C.	'02	16·5	143·0	—	—	—	—	23·75	20·50	3·25	—
	'06	17·0	175·5	145·0	30·5	†	—	28·28	23·37	4·91	—
Richmond (Surrey) Corp.	'02	27·5	316·0	—	—	—	—	31·48	—	—	—
	'06	34·4	395·0	—	—	—	—	31·50	—	—	—
Ripon Corp.	'02	8·2	74·8	—	—	—	—	25·00	—	—	—
	'06	9·0	86·4	—	—	—	—	26·30	—	—	—
Rotherham Corp.	'02	80·0	510·0	—	—	—	—	17·47	—	—	—
	'06	91·0	650·0	—	—	—	—	19·57	15·00	4·57	—
Rugby U.D.C.	'02	20·0	160·0	—	—	—	—	21·90	—	—	—
	'06	23·0	226·0	—	—	—	—	26·92	20·00	6·92	—
Saffron Walden Corp.	'02	5·9	39·0	—	—	—	—	18·11	—	—	—
	'06	6·0	43·0	—	—	—	—	19·63	—	—	—
St. Albans W. W. Co.	'02	—	193·3	—	—	—	—	—	—	—	—
	'06	22·0	236·5	—	—	—	—	29·45	25·00	4·45	—
St. Helens Corp.	1879	—	—	—	—	—	—	33·89	18·36	15·53	*
	'81	56·0	663·0	318·2	344·8	*	—	32·44	15·57	16·87	*
	'86	65·0	807·6	426·8	380·8	*	—	34·04	17·99	16·05	*
	'91	74·0	1,028·0	547·2	480·8	*	—	38·06	20·26	17·80	*
	'96	82·0	1,125·3	661·4	463·9	*	—	37·60	22·10	15·50	*
	1901	89·0	1,244·1	698·4	545·7	*	—	38·30	21·50	16·80	*
	'07	98·0	1,523·8	912·1	611·7	*	—	42·60	25·50	17·10	*
	'08	—	—	—	—	—	—	—	20·00	—	—

* In domestic. † In trade.

TABLE V.—*Showing the increase in the consumption of water in England and Wales—Contd.*

Water supply authority.	Year.	Population, in thousands, in area of supply.	Annual supply, in millions of gallons.					Daily supply, in gallons, per head of population.			
			Total.	In area of supply.			In bulk to other authorities.	Total.	Domestic.	Trade.	Municipal.
				Domestic.	Trade.	Municipal.					
Scarborough Corp.	1866	—	164·4	—	—	—	—	—	—	—	—
	'71	—	209·7	—	—	—	—	—	—	—	—
	'76	27·4	263·1	—	—	—	—	26·35	—	—	—
	'81	30·6	318·6	—	—	—	—	28·54	—	—	—
	'86	32·2	340·5	—	—	—	—	28·99	—	—	—
	'91	33·9	403·0	—	—	—	—	32·60	—	—	—
	'96	36·0	407·9	—	—	—	—	31·04	—	—	—
	1901	38·3	505·1	—	—	—	—	36·15	—	—	—
	'06	40·7	474·9	378·4	96·5	†	—	32·00	25·49	6·51	†
	'08	41·2	477·1	386·3	90·7	†	—	31·76	25·71	6·05	†
Selby U.D.C.	'02	8·5	67·9	—	—	—	—	21·88	—	—	—
	'06	9·5	71·0	—	—	—	—	20·48	—	—	—
Sheffield Corp.....	1897	415·0	2,718·9	—	—	—	—	17·95	—	—	—
	1902	429·5	4,158·5	2,211·0	1,305·7	132·0	509·9	23·27	14·10	8·33	0·84
	'06	477·4	4,710·2	1,945·9	1,478·8	193·3	1,092·2	20·76	11·16	8·49	1·11
Sleaford W. C.....	'01	5·5	26·0	—	—	—	—	12·95	—	—	—
	'06	6·0	46·0	—	—	—	—	21·00	—	—	—
Slough W. W. Co.	'02	11·5	79·0	—	—	—	—	18·82	—	—	—
	'06	15·0	121·3	—	—	—	—	22·15	—	—	—
Southampton Corp.....	1897	76·4	1,049·8	—	—	—	—	37·63	—	—	—
	1901	76·8	1,373·9	852·4	370·0	151·5	—	49·01	30·41	13·20	5·40
	'06	80·0	1,164·6	751·1	329·6	83·9	—	39·88	25·72	11·29	2·87

† In trade.

TABLE V.—*Showing the increase in the consumption of water in England and Wales—Contd.*

Water supply authority.	Year.	Population, in thousands, in area of supply.	Annual supply, in millions of gallons.					Daily supply, in gallons, per head of population.			
			Total.	In area of supply.			In bulk to other authorities.	Total.	Domestic.	Trade.	Municipal.
				Domestic.	Trade.	Municipal.					
South Hants W. Co.	1902	70·1	558·5	—	—	—	—	21·82	—	—	—
	'06	83·2	620·0	—	—	—	—	20·41	—	—	—
South Staffordshire W. W. Co.	'02	585·2	4,190·4	—	—	—	—	19·62	—	—	—
	'06	655·3	4,900·7	—	—	—	—	20·49	—	—	—
Stafford Corp.	1895	22·0	120·1	100·2	18·7	1·2	—	14·96	12·47	2·33	0·16
	1901	25·0	156·4	118·3	16·8	7·4	—	17·14	12·97	1·84	2·33
	'08	25·5	221·6	173·8	23·6	1·9	—	23·81	18·68	2·42	2·71
Staffordshire Potteries W. W. Co.	'02	280·0	2,000·0	—	—	—	—	19·57	—	—	—
	'06	310·0	2,810·0	—	—	—	—	24·83	20·00	4·83	—
Stamford W. W.	'02	8·4	42·9	—	—	—	—	13·99	—	—	—
	'07	8·5	47·5	—	—	—	—	15·31	—	—	—
Stourbridge W. W. Co.	'01	30·0	304·3	279·8	24·5	—	—	27·79	25·55	2·24	—
	'06	35·0	559·5	522·2	37·3	—	—	43·80	40·88	2·92	—
Sutton District W. Co.	'02	45·7	460·5	422·0	25·1	13·4	—	27·58	25·28	1·50	0·80
	'06	60·0	641·2	—	—	—	—	29·28	—	—	—
Swansea Corp.	1897	100·0	1,058·5	—	—	—	—	29·00	—	—	—
	1902	110·0	1,169·7	—	—	—	—	29·13	—	—	—
	'06	120·0	1,825·0	—	—	—	—	41·61	—	—	—
Tees Valley W. B.	1896	187·3	3,463·9	—	—	—	—	50·66	—	—	—
	1906	245·0	5,360·4	—	—	—	—	59·94	—	—	—
Tonbridge W. W. Co.	'01	17·6	123·5	109·0	3·0	2·5	9·0	19·22	16·97	0·47	0·39
	'07	21·3	171·0	165·0	4·5	1·5	—	22·00	21·23	0·58	0·19

TABLE V.—*Showing the increase in the consumption of water in England and Wales—Contd.*

Water supply authority.	Year.	Population, in thousands, in area of supply.	Annual supply, in millions of gallons.					Daily supply, in gallons, per head of population.			
			Total.	In area of supply.			In bulk to other authorities.	Total.	Domestic.	Trade.	Municipal.
				Domestic.	Trade.	Municipal.					
Torquay Corp.	1901	51·0	596·0	461·7	94·0	37·9	2·4	32·02	24·80	5·05	2·03
	'06	52·0	532·2	492·2	**	39·9	—	28·04	25·93	**	2·11
	'08	53·0	653·2	613·3	12·7	27·1	—	33·76	31·70	0·66	1·40
Tunbridge Wells Corp.	'01	34·8	260·0	—	—	—	—	20·47	—	—	—
	'06	36·7	366·9	—	—	—	—	27·39	—	—	—
Tynemouth Corp.	'01	59·0	413·5	—	—	—	—	19·20	—	—	—
	'06	64·0	462·0	—	—	—	—	19·78	—	—	—
Uppingham W. W. Co.	'02	2·5	10·9	—	—	—	—	12·00	—	—	—
	'06	3·0	20·0	—	—	—	—	18·26	—	—	—
Wakefield Corp.	'02	138·0	885·5	284·7‡	213·9‡	†*	386·9	17·58	18·83‡	14·15‡	†*
	'06	148·7	948·6	262·3‡	225·6‡	†*	460·7	17·48	16·80‡	14·45‡	†*
Wallasey U.D.C.	1891	33·1	365·2	318·2	40·2	6·8	—	30·23	26·34	3·33	0·56
	'96	40·0	563·1	469·8	77·2	16·1	—	38·57	32·18	5·29	1·10
	1901	54·6	620·8	517·8	89·5	13·5	—	31·15	25·98	4·49	0·68
	'06	61·0	746·8	577·6	150·7	18·5	—	33·54	25·94	6·77	0·83
	'08	70·0	866·4	667·9	181·7	16·8	—	33·91	26·14	7·11	0·66
Warminster U.D.C.	'02	5·8	36·0	—	—	—	—	17·00	—	—	—
	'06	5·8	44·2	—	—	—	—	20·90	—	—	—
Warrington Corp.	'01	81·5	667·0	425·0	205·7	36·3	—	22·42	14·29	6·92	1·22
	'06	97·4	787·2	501·3	241·9	43·9	—	22·14	14·10	6·81	1·23
Weardale and Consett W. Co.	'02	292·3	2,240·4	—	—	—	—	21·00	11·00	10·00	—
	'06	320·3	2,317·1	—	—	—	—	19·82	10·45	9·37	—

** In municipal. ‡ City of Wakefield only. †* In trade and domestic.

TABLE V.—*Showing the increase in the consumption of water in England and Wales—Contd.*

Water supply authority.	Year.	Population, in thousands, in area of supply.	Annual supply, in millions of gallons.					Daily supply, in gallons, per head of population.			
			Total.	In area of supply.			In bulk to other authorities.	Total.	Domestic.	Trade.	Municipal.
				Domestic.	Trade.	Municipal.					
Whitehaven Corp.	1902	27·5	365·0	—	—	—	—	36·36	20·00	16·36	—
	'06	24·0	547·5	—	—	—	—	62·50	34·00	28·50	—
Winchester W. and G. Co.	'02	20·9	219·0	—	—	—	—	28·71	—	—	—
	'06	21·0	253·7	—	—	—	—	32·22	—	—	—
Wirral W. W. Co.	1885	5·3	171·1	170·5	0·6	—	—	88·14	87·83	0·31	—
	'91	5·8	233·8	233·4	0·4	—	—	109·89	109·70	0·19	—
	'96	6·4	335·8	335·5	0·3	—	—	143·98	143·85	0·13	—
	1901	6·6	301·8	272·7	29·1	—	—	124·53	112·51	12·02	—
	'08	8·1	266·5	260·0	6·5	—	—	89·92	87·72	2·19	—
Woking G. and W. Co.....	'02	21·2	166·0	—	—	—	—	21·45	—	—	—
	'06	35·0	261·5	—	—	—	—	20·47	—	—	—
Wolverhampton Corp.	'02	136·0	1,087·0	—	—	—	—	21·90	—	—	—
	'06	152·0	1,200·0	—	—	—	—	21·63	—	—	—

TABLE VI.—*Showing the rate of increase in the annual water supply in various periods.*

Water supply authority.	Annual supply.		Storage capacity of reservoirs		Increase in the annual supply in millions of gallons in the periods					Where the increase is starred the period is
	In the year.	In millions of gallons.	In millions of gallons.	In terms of the annual supply.	1861-71.	1871-81.	1881-91.	1891-1901.	1901-06.	
Birmingham Corporation	1907	7,810	12,309	1·58	—	—	—	722*	586	1895-1901
Bradford ,, ...	'08	4,745	2,802 *c* 1,816	0·38	—	730	365	365	365*	1901-1908
Cardiff ,, ...	'06	2,061	1,079	0·52	—	—	—	—	309	—
Derby ,, and Co.*	'08	1,147	5 *s*	—	156	208	33	216	111	—
Halifax ,, ...	'06	1,760	1,346	0·76	—	—	—	—	183*	1897-1906
Hull ,, ...	'06	3,490	10 *s*	—	—	—	—	267*	113	1893-1901
Leeds ,, ...	'06	5,870	3,986	0·68	—	—	—	218*	179*	1896-1902-1906
Liverpool ,, ...	'06	10,801	16,107	1·49	1,085	21	514	2,830*	1,070*	1891-1902-1906
London—Metropolitan Water Board and Companies†	'06	82,125	9,157 *a*	0·11	—	25,039*	25,733	9,125*	5,475*	1850-1881, 1891-1900-1906
Manchester Corporation.....	'08	14,615	11,135 *b*	0·76	1,597	1,401	1,723	2,419	3,565*	1901-1908
Newport ,, ...	'08	899	930	1·04	—	—	—	202	237*	1901-1908
St. Helens ,, ...	'07	1,524	19 *s*	—	—	—	365	216	280*	1901-1907
Sheffield ,, ...	'06	4,710	4,252	0·90	—	—	—	1,440*	552*	1897-1902-1906
Tees Valley Water Board	'06	5,360	1,597	0·30	—	—	—	—	1,896*	1896-1906

Note.—*c* denotes compensation reservoirs.

s denotes service reservoirs as auxiliaries to pumping installation.

a denotes that, in addition to storage, the pumping from wells yields 51·4 million gallons a day. Works authorised or in course of construction will increase the storage capacity to 14,952·6 million gallons.

b denotes that when Thirlmere is raised to the full extent, its storage capacity will be 8,135,000,000 gallons, and the total storage of Thirlmere and Longendale reservoirs will be 14,141,000,000 gallons.

* Works purchased by Corporation in 1880. † Works transferred to Metropolitan Water Board in 1904.

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Discussion *on* Mr. W. R. Baldwin-Wiseman's Paper.

Dr. H. R. Mill said his special knowledge of this subject was confined to that part of it which had to do with the amount of water available to meet the demands upon it, but he was in hearty agreement with the author as to the great importance of having some central authority charged with taking account of the natural resources of the supply. So far, their knowledge had grown up almost by chance, for many of the older records were of little value, being made at a time before the methods were properly understood. With regard to rainfall especially, some of the older records in the most important areas for the supply of water were almost useless, owing to the fact that improper instruments and methods of exposure had been adopted. The result was that in some cases as much as 50 per cent. too much rain was recorded, with a disastrous effect on water authorities who had to give compensation based on rainfall; and in other cases scarcely more than 50 per cent. of the actual rainfall was recorded, with an unfortunate effect on the possessors of water rights which ought to be adequately paid for when appropriated. The voluntary observations of rainfall had now been carried on under proper conditions for nearly fifty years, for it was in 1860 that Mr. Symons commenced his systematic collection of data; and the number of observers had grown from 500 to 4,500. But many of those areas where it was most important to get observations in order to measure the supply of available water were still left without observers. On the high moorlands and mountain summits it was exceedingly difficult to get records, and such as existed were generally obtained by engineers immediately before or after laying out waterworks on those sites. In a short time it was impossible, on account of the variations in climatic conditions from year to year, to get a trustworthy estimate of the rainfall. He had again and again been struck with the great importance of some large and impartial body being appointed to adjust the various claims for water supply. Of course, contending boroughs considered their own interests; and County Councils could only look after the areas of their own county, which they sometimes desired to supply with water brought from another county over their boundary. Absolute impartiality could only be secured by a national authority to which all boroughs and districts would be equally important, and which could advise without bias how the available water supply should be divided amongst rival claimants. It should, in his opinion, be made compulsory in all existing waterworks to record the rainfall in suitable places, so as to ascertain the actual quantity which falls, and it should also be compulsory to keep accurate records of the flow off, both of the water that went into the reservoir and that which passed outside. In that way they would be able to ascertain how much of the water that fell as rain was available for supply, which was not the case at present. Work of that sort should be extended to areas of potential supply, and

should be done by some national authority, not left to the efforts of individuals. The responsibility of being the owner of all the rainfall observations made in this country since 1677 was really too great to be placed on any private individual; and he should be pleased to think that such an authority as was outlined in that Paper might be the ultimate heir of the British Rainfall Records. The value of those records was mainly practical, since for meteorological purposes a very much smaller number would probably be sufficient. They had not yet been thoroughly worked up from the point of view of their great value to the country (which would increase with each subsequent year), but they contained the means of determining the resources of the country in water, and its value both for power and consumption. At present the system was very incomplete, especially in areas where the highest rainfall occurred. There was no fear, however large the population might become, that there would not be enough water precipitated on the high lands to satisfy all requirements, if only it were properly collected and distributed. A rainfall of only 30 inches over one-tenth of the land surface of the British Isles would yield, could it all be utilised, a supply of 350 gallons per head per day for the whole present population of the country. The rainfall on the higher land averaged much more than 30 inches, and if it were distributed where it was wanted the whole country could be supplied for all time.

Mr. E. J. HARPER said what struck him during Dr. Mill's remarks was the enormous difference between the supply of water and the comparatively small use made of it. He did not think the author intended to indicate in anything he said that they used too much water. No doubt there was plenty of room for development even now, although the British "bath" was known all the world over; and he should not be frightened even at the figures quoted for the particular industrial school—although he doubted whether the swimming-bath in those figures stood for its full proportion. He should like to point out the way in which the water was actually wasted—he did not mean merely that the water which could not be used was allowed to run away, but it was carried away in a wasteful form. For instance, they saw that the intercepting sewers of London were constructed of a size five times as great as was required to carry away the normal daily flow. They had to be made of that size because on three or four days in every year they were liable to particularly heavy rain-storms, in the course of which a very large amount of rain fell in a short time. At those times the sewers were charged to their utmost capacity, and sometimes overcharged, so that a certain quantity had to be allowed to run direct into the river, instead of being carried out to Barking and Crossness. Therefore, there was a large expenditure in the construction of sewers to carry away water which they did not want and which, if it could be saved, might be made available for the water supply and thus reduce the cost of any future scheme for bringing water to the Metropolis from the Welsh

hills, a result which many competent authorities thought they would have to come to, notwithstanding the efforts now made by the Metropolitan Water Board in the Thames Valley and elsewhere to meet the needs of the population for the immediate future.

Miss B. L. HUTCHINS asked whether any attempt had been made to correlate the statistics of water supply with the death rate.

Dr. R. DUDFIELD said he had read this Paper with great interest, but he regarded the contribution as historical rather than strictly statistical. He desired to offer one or two criticisms only. In the first place, the author seemed to him to have confused to a certain extent "consumption" or "demand" with "supply." "Supply" of water was referred to several times when "consumption" was really meant. Possibly the use of the word "supply" was due to the view taken of the question by his profession. From the point of view of medical officers of health, it looked like a very wrong use of the term.

The author had pointed out that between the years 1377-1801 the population of the country quadrupled itself, that ratio being, of course, based on the assumption that the population for 1377, given in Table I, could be taken as reliable. In other words (approximately) five centuries were required for the population to quadruple itself. On the other hand, in the course of one century (1801-1901) the population again quadrupled itself (see Table II). Although comparing five centuries with one, the author said he did not think the growth of the population during the nineteenth century was abnormal, and had expressed the view that a similar increase might be expected throughout the twentieth century. It appeared to him (the speaker) that such a change in the rate of increase could hardly be regarded as normal. Moreover, the evidence which was now accumulating did not point to a corresponding increase during the twentieth century. It was very doubtful whether the rate of increase would be anything like that observed in the nineteenth century. With regard to the question of the consumption of water on the railways, he desired to point out that although the economy in water consumption resulting from the improvements in manufacturing machinery had been duly set out, yet in dealing with the railway service, the author recognised no corresponding economy, assuming for the whole period a fixed average of 30 gallons per train-mile. If engineers had been able to effect such economies in stationary engines, he could not, as a layman, see why they should not assume that similar economies had been effected in the railway service—in fact, he thought very similar economies had been effected. It appeared to him, therefore, probable that the statistics of railway consumption need revision.

He thought they were all agreed that there was great need for a central authority to control the allocation of the visible supplies of water in this country. They had the peculiar spectacle of various

independent municipal authorities playing a game of "grab" in Parliament for the supplies available in different parts of the country; and it was generally the case of "first come first served." It was now being recognised that the abstraction of water in large quantities from certain parts of the country to supply distant municipalities was prejudicing the growth and development of the areas from which those supplies were drawn. It was quite time steps were taken to regulate the appropriation of the catchment grounds and to safeguard the requirements of the districts in the immediate vicinity thereof. To a certain extent, the Local Government Board did exercise some control, for he understood that when a Water Bill came before Parliament the Local Government Board's officers were consulted. With what Dr. Mill said about the rainfall they must all agree. It was quite time that such observations were taken on a national basis. It was a characteristic peculiarity of the British nation that large undertakings, such as the record of the rainfall, were left to private enterprise for a long time. The Government generally took the work over when it had been thoroughly organised and credit was to be obtained with a minimum expenditure of energy.

Dr. W. N. SHAW welcomed a Paper like this, which suggested further investigation into the extent of our knowledge or, perhaps he should say, our ignorance, on the different aspects of the question of water supply. With regard to the rainfall, one must recognise that this country was exceptionally fortunate in having so large a body of observers organised so efficiently as the system had been under Dr. Mill and his predecessor, Mr. Symons. But, what occurred to him as very curious was, how little they knew about the rivers and their heights from day to day, month to month, year to year, and so forth. It might be that his ignorance on the subject was personal only, and that information about the rivers in the British Islands was to be found in books of reference if anyone cared to look the matter up. But, for his own part, except for some particulars about the Thames, he believed there was very little collected information about the amount of water flowing in rivers. Going about the country, one saw marks on bridges showing where floods came to in such and such years, and so on. But none of these data were collected in any way, so far as he knew, to give information for economic purposes, if required. It was rather astonishing that these matters were not within the cognizance of some central body. Another important aspect of the matter was the way in which they were accustomed to pollute the streams, large or small; and then, if they wanted water for domestic purposes, they had to fetch it from a great distance, from some stream not already polluted. The alternative of making a special channel to carry away pollution and using the natural water supply for domestic purposes was worth consideration. A central body having such matters in hand might well turn its attention to the conservancy of the rivers, and take up the whole matter of the hydrography of the country. The hydrographer of this country

was a distinguished naval officer who dealt, not with the water in the country, but with the water outside the country—not with the rivers, but with the seas and the oceans. He thought there was room for a hydrographer in the other sense; and he trusted that this discussion might lead to provision being made for the adequate supervision of the water supply of the country.

Mr. R. H. HOOKER said the author had given a number of very interesting statistics of the quantity of water supplied in many towns, but he would have been glad if he had gone a little further and summarised them, so as to give if only an approximate notion of the total quantity consumed. He thought that the author might have been bold enough to add together the quantities used in all the chief towns as shown in the tables, and therefrom arrive at an estimate of the consumption in urban districts generally; and then, if they had the author's opinion as to the amount used by the rural population, some rough idea of the total consumption in the country could be formed, and also some notion of the rate of increase in recent times. Another point that the author had scarcely touched upon was the diminution of the amount of water available. Practically all the water used was drawn from underground supplies, although it had, of course, come originally from above ground. The question of the depletion of the underground supplies was a very much more serious problem than would appear from the paper. There had been numerous complaints in recent years that water companies were tapping the underground supplies to such an extent as to cause serious scarcity in many parts of the country, particularly around London, while elsewhere many small streams had ceased to run entirely. London, again, now made such heavy demands upon the river Thames that many persons considered that the quantity left to flow in its natural channel was barely sufficient for purposes of health. He fully agreed with Dr. Mill that ample rain fell from the skies to give enough water for all possible requirements in the future; but it had to be remembered that practically all that fell in the summer (apart from heavy thunderstorms) was absorbed by vegetation, while the winter rains, as soon as the ground was saturated, flowed off. The moral to be drawn was that which the author had drawn, namely, that this water should be stored, and more especially he would emphasise the necessity of storing the winter rains.

Mr. G. A. H. SAMUEL said there was one point which he should be glad if the author would clear up. He noticed in Table V, with regard to the Corporation of Leicester, that in the year 1901 the population was 243,000, and in 1906, 270,000; yet the annual water supply during those years had actually decreased in quantity. That was a most unusual circumstance, and he should like to know the explanation.

The CHAIRMAN, in proposing a vote of thanks to the author, said that the Paper was not only useful on account of the information

it contained, but, as was often the case with Papers read before the Society, was almost equally valuable for the indications it afforded of the want of adequate information upon the subject. Impressive arrays of figures were sometimes paraded in public as statistics, to which Fellows of this Society would hardly vouchsafe that title. The discussion had brought together authorities well known for their treatment of some of the issues involved. Dr. Mill, for instance, had recently made some valuable observations at the Geographical Society on the extent of the rainfall records in the Welsh mountain tracts, and though the Doctor considered the number of observers inadequate, the speaker rather agreed with Dr. Shaw that the number of volunteer co-operators was highly creditable to this country. Official observations were not to be got without considerable expense and their popularity or importance was not yet sufficiently recognised to gain them support enough to unloose the public purse-string. It had been remarked that whereas the title of the Paper related to the consumption of water, the subject was the supply. In his experience in India, however, the latter to a great extent regulated the former and in towns, an increase in the supply usually led to a much greater consumption, not to say waste and he had himself had to mitigate unruly competition at newly erected stand-pipes similar to that mentioned in the Paper as having taken place in London in 1594. Mr. Harper's opinion on the waste of water in London was entitled to all respect, but the speaker was inclined to think that irrespective of the inevitable waste entailed by the sewer system, there was a very regrettable waste in household use and in smaller places still more, perhaps, than in the metropolis, more effective and stringent supervision of domestic consumption was needed.

Mr. BALDWIN-WISEMAN, in reply, said he was glad to hear such a concurrence of opinion in favour of the formation of the central authority which he had suggested, for he felt that only through the agency of such a body could the various returns be collected and correlated, which were so urgently needed for a thorough study of the hydrological problem.

It was of little or no use studying the problem from the point of view of water supply or of rainfall alone. Floods and the means of providing against them, sewage disposal, water supply and eventually, if the canals were resuscitated, the canal system of the country, would all have to be taken into account as a connected entity.

Dr. Mill quoted a figure giving the quantity of water available if the rain falling on a certain fraction of the total area was used for purposes of supply, but throughout the Paper he had endeavoured to guard against saying that there was an insufficiency of water. That was not the point; it was a question of cost and quality, rather than one of quantity. There would always be sufficient water in the country as a whole, if not in certain districts, but if water supplies were drawn from the lowland areas, with a large resident population thereon, a considerable amount of money would have to

be expended in purifying and filtering it, so that practically they had to depend on the upland areas[1] for anything like pure water, and much of that area, small as it is, is not available for purposes of water supply; but if the best disposition was made of the resources, and if a central authority was authorised to determine how and where any particular town should obtain its supply, the rainfall would be used judiciously, satisfactorily and to the best advantage; whereas, at present, everyone struggled for what they could get, with less satisfactory results to all parties.

By way of illustration, the town of Chorley, which lies at the foot of Anglezarke Moor, and only a mile to the west of the existing Rivington reservoirs, was naturally entitled to the drainage from the Rivington watershed, in which they had a reservoir; but mighty Liverpool, 21 miles away from the area in question, came along and by putting down some reservoirs deprived Chorley of any opportunity of enlarging or extending their own scheme. In this case, however, Liverpool settled the matter, in a generous way, by agreeing to supply Chorley with what they required. But that might not always be the case; other big brothers might not always be so magnanimous as Liverpool had been and smaller authorities might be sent to the wall.

In reply to Mr. Harper's observations as to waste, while he would not quarrel with any industrial school using 75 gallons per head per day, if it were necessary, he should doubt, judging by the normal English standard, if anything like that quantity was really economically or judiciously used, but there was every probability that some of this rather large supply was wasted.

He had not any figures correlating the water supply with the death-rate. The death-rates in various towns and districts were published and one could, no doubt, tabulate the annual or daily water supply per head against these. But the water supply figures would not be available over a sufficiently lengthy period to be of much use, the figures of water supply in several towns are only approximate before 1900 and insufficiently classified under the three heads—domestic, trade and municipal—to be directly comparable.

In many cases the recorded annual water supply is merely based on the observed flow for a period of a few days, or on measurements of the inflow and outflow of a reservoir, but as everyone handling the water question knows, there is an hourly, daily, weekly, monthly

[1] TABLE *showing the disposition of land in England and Wales.*

Disposition of land.	Area in thousands of square miles.	Area as a percentage of the total area.
Between sea level and 250 ft. contour	26·5	45·4
„ 250 ft. and 500 ft. contour	16·3	28·0
„ 500 „ „ 1,000 „ „	10·5	18·0
Above 1,000 ft. contour	5·0	8·6
Land under crops and grass	38·2	65·5
Towns, hamlets &c.	5·8	10·0
Moorland, heath &c.	14·3	24·5

and yearly variation[2] in the rate of supply, so that such observations over short periods are almost valueless for purposes of estimating the real annual supply.

Dr. Dudfield had differed from him on the question of population and the use of the word "abnormal" in reference to the increases in the population during the nineteenth century. He would point out that he had given a rather lengthy explanation of his intention, which qualified the sentence in which the word was used and he had hoped that it would have been interpreted in the sense of the qualifying context. He had explained, at some length, the conditions which had conduced to the apparent stagnation of the population in former times, as he did not believe that there was actual stagnation, but that the deaths wiped out the benefits gained by the births.

In the special period which Dr. Dudfield had chosen for criticism —1377—the population had been but a few years previously almost halved by the "Black Death," which from 1349 and with other plagues right down to the end of the Stuart period, ravaged the country at frequent intervals and considerably reduced the population on the occasion of each visitation. For instance, Liverpool, in common with most other towns, frequently suffered from attacks of the "Plague" and "Sweating Sickness"; in 1361 the attack was so severe that there was no one to carry the corpses to Walton for interment, and the townsmen obtained the permission of their diocesan—the Bishop of Lichfield—to bury their dead in St. Nicholas' churchyard, and in 1558 the visitation was such, that the weekly market was not held for three months and the annual November fair was abandoned; medieval opportunities for earning much money which no townsman would lightly forego. In the nineteenth century there was the additional advantage of having medical officers of health and hospitals and the progress made in medical and other sciences, the

[2] TABLE *showing the average daily supply during each month of the year in terms of the average daily supply throughout the year as unity.*

Towns or districts	London.	Manchester.	Liverpool.	Bilston.
Period	1906.	1905-08.	1899.	1897-1902.
Average daily supply in thousands of gallons	222,376	37,654	25,306	754
January	0·922	0·967	0·885	1·011
February	0·904	0·968	0·976	0·989
March	0·914	0·957	0·921	1·005
April	0·951	0·961	0·933	1·000
May	0·986	0·999	1·01	0·995
June	1·082	1·015	1·04	1·029
July	1·129	1·055	1·06	1·052
August	1·114	1·028	1·09	1·037
September	1·089	1·037	1 04	1·027
October	1·003	1·027	0·996	0·961
November	0·964	1·002	0·972	0·936
December	0·942	0·987	1·06	0·946

provision of good water supplies and of efficient urban and domestic sanitation, all tended to revolutionise the conditions of existence and differentiate them from those of all previous centuries. In former times, all sorts of filth were thrown or drifted into the wells; punishments being frequently inflicted, at the Court Leets of various towns, for the fouling of the wells or the streets near by.

In Lymington wells were sunk in the High Street and apparently by way of insuring the contamination of the sixteenth century water supply of this medieval town, the butchers' shambles were grouped all round the area. Again, in restriction of the population, there were the limitations imposed by the trade guilds, by civil wars, and by famine.

As to the further point raised, he admitted that railway engines had improved as much and probably more than stationary steam engines, but, the figure which he used in his table to multiply the train-mileage by, was the best and most recent figure and not the worst figure; if any corrections were made for the earlier years, he would have to increase the figures of water consumption in those years by two, three or four times that stated; but what it was, nobody knew, as records are not available for the earlier years.

With regard to the Local Government Board reporting on Bills before Parliament, they certainly did report at present on the financial and engineering aspects of any schemes before them, but he hoped it would one day be possible, not only to report on these aspects, but also on the hydrological aspect and the suitability of a scheme, not only for the wants of a particular district, but also for its co-ordination in the greater scheme of the most economical development of the water resources of the whole country.

There were efficient fishery and conservancy boards, such as the Thames Conservancy Board, who kept records of the stream flow and of the take of the water companies, if there were any, on the stream; but such records were few in number and not general in application, so that engineers had, not infrequently, to form an opinion on a paucity of recently acquired or discontinuous data and were thus liable to arrive at incomplete and inaccurate conclusions.

What one wanted to know was the amount of the rainfall on and run off from, the various geological formations. The rainfall returns, excellent as they were, were not infrequently inadequate to supply this data; as frequently, in upland areas, where records were most wanted, no meteorological station had been established. One also needed to know the variations in the levels of the springs, the rate of rise of the floods on the several streams, the highest flood levels and the frequency and duration of the floods; data which would vary for each river and for the different geological formations along the same river course.

Much of the present information as to floods is very uncertain, as one realised, if it was one's misfortune to work up a flood case, some months after the flood had subsided. The oldest inhabitant would gladly indicate, with much assurance and a wealth of detail, the several points to which he could recall the flood had risen, but

when one came to level these, if the error had not already been detected by ordinary observation, one felt that there must be some flaw in his memory or in his powers of observation, as there would be differences of level of 5, 10, or even more, feet between reputed flood levels not very far apart and one wanted more reliable data than that.

He was pleased to hear Dr. Shaw make the suggestion that there should be a hydrographer, who should be a landsman, in addition to the present holder of the title, who was a navy man.

Mr. Hooker wished that he had summarised his results and given the increase over the whole country for a period of years, but he wanted his Paper to be certain on the points upon which it touched and he felt that to have attempted such a table would have been almost worse than useless; in such a Paper as this, it was more a question of what one left out, rather than what one put in and when he looked into the various published records, many of those he had at first thought of using had to be eliminated, owing to various causes, some of which he had already mentioned.

Again, records over a lengthy period are not directly comparable, as the area of supply, the extent, nature and administration of the works, varied from time to time. A water supply might be administered by a company, then taken over by a township and finally perhaps transferred to a water board, the conditions of supply and waste prevention varying during the period covering these several transfers. In the earlier part of the period the annual supply might be estimated, in the latter part it might be accurately metered, new works might be added, old works improved and enlarged and a variety of other causes might give rise to a variation in the supply in no wise comparable with those of earlier years.

A question had been asked about the Leicester figures recorded in Table V, and whilst it would be answered by the replies to other queries, the question itself would serve as an illustration of this point.

When meters are introduced and officers are appointed to supervise the fittings, the waste immediately begins to decrease, for the users, knowing they are being watched, are more careful and knowing the inspectors are liable to call and complain of the defective taps and cisterns, take care to repair them when defects are developed, whereas in all probability they would not do so if no inspector called.

If a general figure were required for the total national consumption, he would say he made an estimate, some years ago, that about 80·5 per cent. of the total population of England and Wales was supplied with water. Using this figure and allowing 25 gallons per head per day, the annual consumption works out at about 259,600,000,000 gallons of water. This might be a fair figure, but he would only put it forward as an approximation, for there were many supplies of which no measurement was taken at all, particularly in the cases of villages and small country districts.

Reverting to the criticism on the use of the word "supply" or

"consumption," he would say that an engineer always used the word "supply," meaning not only the works forming the system of supply, but also the delivery of water to the consumer. To an engineer "supply" meant "consumption," the latter word being hardly ever used in engineering literature, and never in professional conversation.

As to the percolation through the soil, they did not know the total available amount of water which could be withdrawn from underground sources for a variety of causes. First of all, the formations varied in thickness, in porosity, in extent and in the condition and inclination of the outcrop. One formation might be bare, horizontal and more or less open and a considerable portion of the rainfall would find its way into it; another might be steep, or the greater portion of its area might be covered with clay and but little rainfall would get into it. But even if this could be accurately estimated, one could not estimate the amount stored in any strata without knowing the thickness or the porosity of the strata.

In a paper which he read before the Geological Society[3] about three years ago he did work out an estimate for the amount of percolation over the whole of the Thames basin, and that figure came out at about 3·4 inches out of a total average annual rainfall of 26·1 inches. But when one had determined the amount of rainfall which got into a formation, one could not then determine the amount which could be got out, as that was limited by the disposition, depth and dimensions of the wells, the power of the pumps and the dimensions of the cone of depletion, which varied with the frictional resistance of the strata.[4]

An excellent case presented itself in the East Riding. A large amount of water is drawn from the chalk for the supply of Hull and Beverley, yet near by are certain villages, such as those of Holderness, which would be glad to have a supply of almost any kind of good water, but cannot obtain it; yet, bubbling up in the muddy waters of the river Humber is a large volume of fresh clear water, known as the Hessle whelps, running to waste from the chalk, from which Beverley and Hull obtain their supplies.

The following were elected Fellows of the Society:—

William Henry Beveridge.	Viscount Ridley.
James Henry Duffell, A.I.A.	Charles Vincent Sale.
James Kerr, M.A., M.D., &c.	

[3] W. R. Baldwin-Wiseman. *The Influence of Pressure and Porosity on the Motion of Subsurface Water. Quart. Journ. Geol. Soc.*, vol. lxiii, 1907, p. 100.

[4] W. R. Baldwin-Wiseman. *The Flow of Underground Water. Min. Proc. Inst. C.E.*, vol. clxv, 1905-06, part 3, p. 327.