ROYAL COMMISSION ON WATER SUPPLY.

REPORT

OF

THE COMMISSIONERS.

Presented to both Houses of Parliament by Command of Her Majesty.

LONDON:
PRINTED BY GEORGE EDWARD EYRE AND WILLIAM SPOTTISWOODE,
PRINTERS TO THE QUEEN'S MOST EXCELLENT MAJESTY.
FOR HER MAJESTY'S STATIONERY OFFICE.

1869.

[*Price* 1*s*. 6*d*.]

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ORIGINAL COMMISSION.

VICTORIA R.

Victoria, by the grace of God of the United Kingdom of Great Britain and Ireland Queen, Defender of the Faith.

To Our right trusty and right entirely-beloved Cousin and Councillor Charles Henry Duke of Richmond; Our trusty and well-beloved Sir John Thwaites, Knight; Henry Drury Harness, Esquire, Companion of Our most Honourable Order of the Bath, Colonel in Our Corps of Royal Engineers; Benjamin Samuel Phillips, Esquire, one of the Aldermen of Our City of London; Thomas Elliot Harrison, Esquire; and Joseph Prestwich, Esquire; greeting.

Whereas We, taking into Our Royal consideration that an ample supply of wholesome water at all times is of essential importance to the health of the population, especially in large towns:

And whereas the present supply delivered in the Metropolis, as well as in many other large towns, has been found insufficient, and is likely to become more so as the population increases, unless some additional sources of supply can be permanently provided:

And whereas a large portion of the water now supplied to the Metropolis and other large towns is drawn from rivers and open streams which pass through populous districts, and are therefore continually exposed to pollution from various causes:

Now know ye, that We have deemed it expedient that a Commission should forthwith issue for the purpose of ascertaining what supply of unpolluted and wholesome water can be obtained by collecting and storing water in the high grounds of England and Wales, either by the aid of natural lakes or by artificial reservoirs at a sufficient elevation for the supply of the large towns, and to report, firstly, which of such sources are best suited for the supply of the Metropolis and its suburbs; and, secondly, how the supply from the remaining sources may be most beneficially distributed among the principal towns.

And further know ye, that We, reposing great confidence in your zeal and ability, have authorized and appointed, and do by these Presents authorize and appoint, you the said Charles Henry Duke of Richmond, Sir John Thwaites, Henry Drury Harness, Benjamin Samuel Phillips, Thomas Elliot Harrison, and Joseph Prestwich, to be Our Commissioners for the purposes aforesaid.

And for the better enabling you to form a sound judgment on the premises We do hereby authorize and empower you, or any three or more of you, to call before you, or any three or more of you, all such persons as you may judge most competent by reason of their situation, knowledge, and experience, to afford you correct information on the subject of this Inquiry.

And it is Our further will and pleasure that you, or any three or more of you, do, with as little delay as possible, report to Us in writing under your hands and seals your several proceedings by virtue of this Our Commission, together with your opinion on the several matters herein submitted for your consideration.

And We will and command that this Our Commission shall continue in full force and virtue, and that you, Our Commissioners, or any three or more of you, may from time to time proceed in the execution thereof, although the same be not continued from time to time by adjournment.

And for your assistance in the execution of this Our Commission, We do hereby authorize and empower you to appoint a Secretary to the said Commission, whose services and assistance We require you to use from time to time as occasion may require.

Given at Our Court at St. James's, the twenty-fourth day of December 1866, in the thirtieth year of Our Reign.

By Her Majesty's command.

S. H. WALPOLE.

NEW COMMISSION.

VICTORIA R.

Victoria, by the grace of God of the United Kingdom of Great Britain and Ireland Queen, Defender of the Faith.

To Our right trusty and right entirely-beloved Cousin and Councillor Charles Henry Duke of Richmond, Knight of Our Most Noble Order of the Garter; Our trusty and well-beloved Sir John Thwaites, Knight; Henry Drury Harness, Esquire, Companion of Our most Honourable Order of the Bath, Colonel in Our Corps of Royal Engineers; Sir Benjamin Samuel Phillips, Knight, one of the Aldermen of Our City of London; Thomas Elliot Harrison, Esquire; and Joseph Prestwich, Esquire; greeting.

Whereas We, taking into Our Royal consideration that an ample supply of wholesome water at all times is of essential importance to the health of the population, especially in large towns:

And whereas the present supply delivered in the Metropolis, as well as in many other large towns, has been found insufficient, and is likely to become more so as the population increases, unless some additional sources of supply can be permanently provided:

And whereas a large portion of the water now supplied to the Metropolis and other large towns is drawn from rivers and open streams which pass through populous districts, and are therefore continually exposed to pollution from various causes:

And whereas We did, by Warrant under Our Royal Sign Manual bearing date the Twenty-fourth day of December last, appoint you to be Our Commissioners for the purpose of ascertaining what supply of unpolluted and wholesome water can be obtained by collecting and storing water in the high grounds of England and Wales, either by the aid of natural lakes or by artificial reservoirs at a sufficient elevation for the supply of the large towns, and to report, firstly, which of such sources are best suited for the supply of the Metropolis and its suburbs; and, secondly, how the supply from the remaining sources may be most beneficially distributed among the principal towns.

Now know ye, that We have revoked and determined, and do by these Presents revoke and determine, the said Warrant bearing date the Twenty-fourth day of December last, and every matter and thing therein contained.

And further know ye, that We, reposing great confidence in your zeal and ability, have authorized and appointed, and do by these Presents authorize and appoint, you the said Charles Henry Duke of Richmond, Sir John Thwaites, Henry Drury Harness, Sir Benjamin Samuel Phillips, Thomas Elliot Harrison, and Joseph Prestwich, to be Our Commissioners for the purpose of ascertaining what supply of unpolluted and wholesome water can be obtained by collecting and storing water in the high grounds of England and Wales, either by the aid of natural lakes or by artificial reservoirs at a sufficient elevation for the supply of the large towns, and to inquire into the present Water Supply to the Metropolis, and whether there are other districts in addition to the high districts of England and Wales from which a good supply of unpolluted and wholesome water can be obtained; and to report, firstly, which of such sources are best suited for the supply of the Metropolis and its suburbs; and, secondly, how the supply from the remaining sources may be most beneficially distributed among the principal towns.

And for the better enabling you to form a sound judgment on the premises We do hereby authorize and empower you, or any three or more of you, to call before you, or any three or more of you, all such persons as you may judge most competent by reason of their situation, knowledge, or experience, to afford you correct information on the subject of this Inquiry.

And Our further will and pleasure is that you, or any three or more of you, do, with as little delay as possible, report to Us in writing under your hands and seals your several proceedings by virtue of this Our Commission, together with your opinion on the several matters herein submitted for your consideration.

And We will and command that this Our Commission shall continue in full force and virtue, and that you, Our said Commissioners, or any three or more of you, may from time to time proceed in the execution thereof, although the same be not continued from time to time by adjournment.

And for your assistance in the execution of this Our Commission, We do hereby authorize and empower you to appoint a Secretary to the said Commission, whose services and assistance We require you to use from time to time as occasion may require.

Given at Our Court at St. James's the Fourth day of April 1867, in the thirtieth year of Our Reign.

By Her Majesty's command.

(Signed) S. H. WALPOLE.

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REPORT.

TO THE QUEEN'S MOST EXCELLENT MAJESTY.

MAY IT PLEASE YOUR MAJESTY,

WE, the Commissioners appointed by Your Majesty for the purpose of inquiring into the means of obtaining additional supplies of unpolluted and wholesome water for the Metropolis and other large towns, humbly report to Your Majesty as follows.

1. The Commission issued by Your Majesty, and dated the 24th of December 1866, commanded us to ascertain "what supply of unpolluted and wholesome water can be "obtained by collecting and storing water in the high grounds of England and Wales, "either by the aid of natural lakes or by artificial reservoirs at a sufficient elevation "for the supply of the large towns, and to report, firstly, which of such sources are "best suited for the supply of the Metropolis and its suburbs; and, secondly, how the "supply from the remaining sources may be most beneficially distributed among the "principal towns."

A second Commission, dated the 4th April 1867, commanded us also "to inquire "into the present water supply to the Metropolis, and whether there are other "districts, in addition to the high districts of England and Wales, from which a good "supply of unpolluted and wholesome water can be obtained."

2. It will be convenient to divide our Report into six parts.

I. On the practicability of obtaining large supplies of water from the mountainous districts of England and Wales.

II. On other available sources of supply.

III. On the present Water Supply of the Metropolis.

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PART I.

ON THE PRACTICABILITY OF OBTAINING LARGE SUPPLIES OF WATER FROM THE MOUNTAINOUS DISTRICTS OF ENGLAND AND WALES.

3. Our attention was first directed to the question of obtaining large supplies of water from the mountainous districts of England and Wales; and five engineering projects, having this object in view, have been laid before us.

Four of these plans have for their object the supply of the Metropolis, viz.:—

Mr. J. F. Bateman's plan, from the sources of the Severn.

Messrs. Hemans and Hassard's plan, from the lakes of Cumberland and Westmoreland.

Mr. Hamilton Fulton's plan, from the sources of the Wye.

Mr. Remington's plan, from the hills of Derbyshire.

The fifth plan, that of Mr. Dale, proposes to supply various towns in Lancashire and Yorkshire.

It will be our duty to describe these plans, and to remark on some of them at considerable length. We have caused the more important of them to be traced on the map of the rivers of England appended to this Report (Appendix B N.) which has been prepared for our use, under the direction of Colonel Sir Henry James, R.E., by the Ordnance Survey Department. From this map, on which the basins drained by the several rivers are distinguished, and many important levels given, a tolerable conception of the general form of the surface of the country can be obtained.

MR. BATEMAN'S PLAN.

4. The first on the list is that of Mr. John Frederick Bateman, F.R.S., civil engineer, who has constructed some of the largest works for Water Supply in the kingdom.

The plan proposed by this gentleman for supplying the metropolis was first published by him in a pamphlet bearing date November 1865, (which we have reprinted in App. E. Appendix E. to this Report,) and it has been more fully developed in evidence given by him before us.

General Description of the Scheme.

5. Mr. Bateman proposes to collect water by reservoirs to be formed in the mountainous districts of North Wales, and to convey it by an artificial conduit to London.

He urges that the supply for London ought to be sought where the water is purest, softest, and most abundant, and most secure from injury by any operations of manufacture or agriculture. To obtain these conditions he has considered it necessary to go to mountains of hard and impermeable rock, where little cultivation goes on, where only a scanty population is likely to collect, and where reservoirs for storage could be easily provided. He assumes also, as a further condition, that the necessary quantity should be delivered to London at an elevation from which nearly the whole metropolis could be supplied without pumping.

He considers that the nearest high land fulfilling all these conditions is to be found in North Wales, and that the quantity of gathering ground there available is more than sufficient. He has selected, as the best, certain high drainage grounds lying to the south of Snowdon and to the east of Plynlimmon and Cader Idris, and supplying the head waters of the River Severn.

6. The map marked E (2) shows the districts referred to. The Severn rises on the east slope of Plynlimmon, and a few miles down its course it is joined by five other streams, namely, the Tylwch or Dulas, the Clywedog, the Carno, the CerySt, and the Tarannon. Mr. Bateman proposes to combine the drainage grounds of these various streams into one district, which is tinted green on the map, and which may be distinguished as the *Southern District.* The waters from this district being collected by intercepting conduits, are to be poured into a main reservoir at Trefeglwys, subsidiary reservoirs being added in other parts of the area.

Mr. Bateman also proposes to appropriate the upper drainage grounds of two other rivers lying more to the north, namely, the Vyrnwy and Banw, whose combined waters flow into the Severn between Welshpool and Shrewsbury. This drainage ground is tinted pink on the map, and may be called the *Northern District.* Its waters are proposed to be stored in several reservoirs constructed on the various streams, and to be collected at a point above Rhyd y Gro.

Both these districts are stated to be generally favourable for water collection. The ground lies high, the rainfall is large, and the conformation of the country admits of the construction of large reservoirs. The geological structure is favourable for the quality of the water, and Mr. Bateman gives an analysis to show that these waters are, in fact, very pure and remarkably free from mineral matter.

7. Mr. Bateman proposes to convey the water from the two districts by separate conduits, converging to a point of junction at Marten Mere, near Montgomery: from this point the joint volume of water would be conducted southwards by a common aqueduct, which, crossing the Severn near Bridgnorth, and passing near the towns of Stourbridge, Bromsgrove, Henley-in-Arden, Warwick, Banbury, Buckingham, Aylesbury, Tring, Berkhampstead, and Watford, would discharge into large reservoirs proposed to be constructed on the high land near Stanmore, about ten miles north-west of London. The total distance the water would have to be brought to London from the delivering point of either of the districts, would be a little above 180 miles. The aqueduct is designed to be capable of conveying 230,000,000 gallons per day.

The direction of the conduit is shown on the plan marked Appendix E (1), and sections of it in various places are given in the Appendices A Q and A R. It would be chiefly an open canal, lined with masonry, but it would be tunnelled where necessary through the hills, and formed by syphon pipes across the deep valleys.

The heads of the conduit, in the Welsh hills, would be at a height of about 450 feet above the mean sea level, and allowing one foot of fall per mile, the water would be delivered into the reservoirs at Stanmore at about 270 feet above the sea.

8. These reservoirs are shown on the plans marked Appendices A N (1 and 2). 6568–70.
They are designed to contain 2,000 millions of gallons, equal to twenty days' supply at the present rate of consumption.

9. The plan proposed by Mr. Bateman for the distribution of the water in the metropolis is shown on the map, Appendix A N. He would make use, as much as possible, of the existing store reservoirs of the various companies, to which he would convey the water by large main pipes from the great Stanmore reservoirs. He would, 6570–88.
however, re-arrange the distribution, dividing the metropolis into four districts, as shown on the map, conveniently arranged so as to suit the levels of the smaller reservoirs. He would further make such alterations in the service mains as would be necessary to provide for a constant service to all the houses, thus doing away with the present intermittent system.

10. Mr. Bateman states that his aqueduct, in traversing the midland counties, would 269–75.
pass within ten miles of the centre of a very populous country which is probably the most difficult to supply with water of any large manufacturing district in England—namely, Birmingham, Wolverhampton, Dudley, Walsall, and the Staffordshire coal district. He therefore thinks it would be expedient to make provision for supplying these places.

There are many important points to be considered in reference to Mr. Bateman's scheme, and on which we have received a considerable amount of evidence.

Evidence as to the Scheme.

11. With regard to the *quantity* of water which can be procured, Mr. Bateman is of opinion that no distant and expensive plan ought to be entertained which would supply less than 200,000,000 gallons a day; and he thinks such a scheme ought to be capable of further extension, so as to provide ultimately for a still larger supply.

The quantity which can be obtained depends on three elements, namely, the area of gathering ground, the rainfall, and the proportion of the latter which can be collected and stored.

12. The *area* of drainage ground marked out by Mr. Bateman is as follows:— 6561.

	Square miles.
Northern District about - - - - -	104
Southern " " - - - - -	100
Total - -	204

22–5. 6701. He, however, points out that this area is capable of great extension in the same basin, and that, moreover, it would be easy to add other adjacent districts of a similar character included in the basin of the Wye. The map E (2) shows the additions that may thus be made, and which comprise about 183 square miles.

13. The *rainfall* appears to be open to some doubt, no complete system of rain gauges having been kept in the district for a sufficient length of time. Mr. Bateman, therefore, in making his calculations on this point, relies to a great extent on the physical conformation of the country, and on the facts observed in nearly analogous cases.

App. E. He considers the conformation of the country favourable to a large rainfall. Taking into account the partial results noted by himself, and those obtained in places where like conditions prevail, Mr. Bateman considers that the rainfall here should be as great as in the highlands of Scotland, and as great as in the lake districts of England, with the
23–6. exception possibly of a particular locality subject, from peculiar local circumstances, to an excessive amount of rain.

App. E. 103–8. 119–22. He considers he is justified in estimating the probable *average* rainfall in his district at about 75 inches. But as it does not do to lay out waterworks on an average, he prefers to take the two or three driest consecutive years he can find, and estimates 60 inches for them.

He then comes to the question what proportion of this is available. From long general experience and numerous observations he finds the loss, in such districts, from evaporation and absorption, vary from 9 inches to 16 inches, the smaller loss being where the rocks are the hardest and the declivities the greatest. He takes, as a safe estimate for this district, a mean of 12 inches, which, deducted from 60 inches, leaves 48 inches as the net available produce. But for greater security, he diminishes again this last result by 25 per cent., taking only 36 inches as the estimated available proportion of the rainfall on which to base his calculations. He states that this is only three inches more than he is actually collecting and storing in the Manchester Waterworks, where he supposes the rainfall is probably little more than half what it is on the Welsh hills.

From the amount of available rainfall is deducted the quantity necessary for affording
36. 109–14. compensation to the rivers. Mr. Bateman states that the compensation given in the manufacturing districts, (where frequently, in dry weather, every drop of water is impounded in the night and given out in the day,) has usually been about *one-third* of that which can be collected. But for this district he has allowed only *one-fourth*, because it is not a manufacturing district; there are comparatively no mills, and one-fourth would very materially increase the workable volume of the stream.

He remarks that the floods in these districts are enormous, being from 500 to 1,000 times greater than the dry weather flow, and it is from these that the water would be stored for the use of London, and for compensation. By impounding the water the destructive floods would be diminished and the useful volume in dry weather increased, and he adds that this has been the universal result wherever this principle has been applied.

34. On these grounds, Mr. Bateman arrives at the following quantities:

———	Northern District.	Southern District.
Amount estimated at a rainfall of 36 inches, about	148,000,000	144,000,000
Deduct one quarter for compensation for rivers -	37,000,000	36,000,000
Leaving for the available supply - - -	111,000,000	108,000,000

giving about 219,000,000 gallons per day as the gross produce of the two districts, having the areas above stated. But from the facility of increase of area, he has not hesitated, in his subsequent calculations, to assume an available quantity of 300 millions of gallons.

14. Other authorities, whom we have examined, think Mr. Bateman's estimate of quantity and rainfall too high.

2465–86. Mr. Hawksley, also a civil engineer of great experience in water supply, judging by analogous districts, considers that the average rainfall would not exceed 45 inches over the whole surface. But he remarks it is known to be impossible, by any system of reservoirs that can be constructed, even with large capital, to deal with more than the average of three consecutive years of minimum fall; the minimum year has about one-third less than the general average, and in the three consecutive driest years the average fall is almost precisely one-sixth less. Hence, deducting one-sixth from 45 inches, there remains 37½ inches, which Mr. Hawksley considers the quantity due to the three minimum years. Then, secondly, the loss by evaporation, &c. over a district like that, part of which is lowland and part highland, he estimates at about 13½ inches, which leaves 24 inches as the quantity of rainfall available, instead of 36 inches as estimated by Mr. Bateman.

Mr. G. J. Symons, who has for several years recorded annually (in a work published by him entitled "British Rainfall") the fall of rain in various parts of the kingdom, and who has given us elaborate evidence bearing on this and other plans, infers from the facts at his disposal, that the mean fall in three successive dry years would be 44 or 45 inches. 467–506. 526–45. 2729–30.

The Rev. J. C. Clutterbuck doubts Mr. Bateman's estimate of rainfall, and considers the gaugings of the rivers form the only safe criterion of the amount of water obtainable. 1848–66.

Mr. Rawlinson, civil engineer, believes averages in this respect delusive, and considers that a deduction of one-third should be made from the average, to give the minimum fall. 1427–40.

Mr. Hassard, civil engineer, considers that the conclusions which Mr. Bateman has arrived at from the result of gauges kept during the three wettest months of an exceptionally wet year, are not in accordance with the results of gauges in the immediate locality relative to the fall of three dry years. He is of opinion that a greater rainfall than 42 inches could not be reckoned upon over that drainage area in three successive dry years. 965–78.

Mr. Bateman's answers to these objections may be seen in his evidence. 6485. 6524–39.

15. The *storage* is a matter of much importance, as affecting the quantity of water which can be made available to send off the ground. This storage must be sufficient in capacity to collect and impound the flood waters during heavy rains, so as not only to provide sufficient supplies in the dry portions of the year, but also, to a certain extent, to equalize the product of wet and dry years. The storage room must further be calculated not only for the quantity of water intended to be conveyed away, but also for the additional quantity to be sent down the rivers as compensation. 6615.

There being no natural lakes in the district, Mr. Bateman is obliged to have recourse to the formation of reservoirs on a large scale. App. E. 6513–5.

For reasons given by him he considers that a provision for 120 to 140 days' supply would be sufficient, and on this assumption he proposes to make the following reservoirs:— 6560–63. App. E. 37–52. 109–15.

Northern District.

	Cubic feet.
Four reservoirs, total capacity about - -	3,494,000,000.

Southern District.

Three reservoirs - - - - -	3,215,000,000.

The sites of these will be seen on the map E (2), and further particulars will be found in Appendix E., and in Mr. Bateman's evidence. He states that none of the embankments would be more than 80 feet in height, and they would be placed in situations where either hard impervious clay or the solid rock of the Silurian formation would afford the means of making them perfectly safe and water-tight. Two of these reservoirs would be some miles in length, and one, with an embankment of 75 feet high, would hold 50 per cent. more than the available water of Loch Katrine.

16. Some objections have been brought against this portion of Mr. Bateman's plan. Mr. Hawksley considers the proposed storage insufficient, and that the reservoirs, to provide for the three driest years, ought to store about 170 days' supply. 2483. 2489.

Objections have also been made to the amount of property which must be sacrificed to form the reservoirs, and to the danger which might be apprehended in the valley of the Severn from any accident happening to artificial reservoirs, at such an elevation, and containing such an immense storage of water.

17. Another point of great importance in Mr. Bateman's scheme is the *quality* of the water which it will afford.

He has laid before us some analyses procured by him of samples collected in the district; but as we felt that this was a matter on which it was desirable to have the most positive and unexceptionable data, we determined, with the sanction of the Lords of Your Majesty's Treasury, to carry out an independent investigation, by having the district examined, and samples collected and analysed, by competent persons under our own direction.

It was important, in the first place, that the district should be examined, and the samples collected, by a person accustomed to such matters, and this duty we intrusted to Mr. W. Pole, F.R.S., a civil engineer of experience in water supply. He was instructed to go over the ground and select points where samples might be taken, so as to give a fair idea of the waters of the district; to take such samples and forward them to the chemists for analysis; and to note any observations as to the district generally which might appear worthy of our attention. Mr. Pole's report will be found in Appendix B.

Fourteen samples of water were taken, in different parts of the district, and were submitted for analysis to two chemists of eminence, Dr. Frankland, F.R.S., who is employed by the Registrar General to analyse the metropolitan waters, and Dr. Odling, F.R.S., Professor of Chemistry at St. Bartholomew's Hospital. Their report will be found in Appendix D.

18. The quality of water afforded by any particular gathering ground will depend, in the first place, on the geological structure and mineralogical composition of the rocks; in the second place, on the nature of the surface; and thirdly, on the population, cultivation, and on any accidental circumstances that may affect its purity.

To illustrate the geological and physical features of Mr. Bateman's gathering ground we have caused to be prepared the two maps marked Appendices B A, 1 and 2, the former showing the geology of the district, the latter the elevations of the ground expressed by contour lines. The geological and mineralogical features are favourable; the rocks (almost entirely slates of the Silurian series) are such as are best adapted to preserve the purity of the water falling on them, being practically insoluble, and very little liable to disintegration.

The nature of the surface varies in different parts. In the higher portions it is hilly and steep, the slopes are covered with grass used for cattle and sheep pasture, and the population is very scanty. In descending the valleys cultivation begins, trees appear, and the population increases; while in the lower and flatter parts of the district the land is fertile and well tilled. The latter, however, forms only a small portion of the district, and there is no population beyond that of small villages included in the drainage area.

App. D. 6200-6432. 6433-6484.

19. The analysis of the Welsh waters bears out the anticipation of their quality that might be formed *à priori*, and gives the following results: The quantity of solid contents is very small, varying over the district generally from about $2\frac{1}{4}$ to $4\frac{1}{2}$ grains in the gallon. The waters are extremely soft, their hardness, according to Dr. Clark's test, being generally only 1 or 2 degrees. The organic matter is also small, and there are no traces of any noxious pollution; and so far as could be judged by the samples collected, they were of fair appearance, taste, and aëration.

Mr. Bateman asserts that the water will require no filtration, as the storage in such large reservoirs will sufficiently clear it. He bases this opinion on the general clearness of water in natural lakes.

20. We may briefly allude to five objections which have been made to the Welsh waters on the ground of quality.

The first is to the amount of cultivated land in the lower portions of the district, the manuring of which must, it is said, pollute the water flowing over it. But the analyses do not detect any noxious pollution.

App. B.

21. The second objection is the existence of certain manufactories, the refuse of which is calculated to defile the water. This objection has been examined by Mr. Pole on the ground, and shown to be quite insignificant.

App. B. App. D. 8213-4.

22. The third objection is that the district contains metalliferous veins and mineral workings, principally lead, which, it is urged, must contaminate the streams. This is, at first sight, a formidable objection, on account of the well-known powerful effect of many metallic salts upon the human system. On this account we directed Mr. Pole carefully to examine the facts upon the ground, and his full report on the subject, conjoined with the analysis of the samples he brought away for the purpose, disposes we think effectually of this objection. It is true that there are lead workings in the southern district, and that from many of them suspicious-looking refuse is turned into the streams; but it is found that this refuse contains as a rule no metallic salts soluble in water, and consists only of a detritus formed from the earthy matrix of the ore, generally finely divided quartz or slate, which has been separated by the grinding and washing processes, and is held in

mechanical suspension by the water passing away. This, if admitted into the reservoirs, would soon deposit and leave no pollution in the water; Dr. Frankland even suggests that its presence might be useful, by carrying down organic matter in the process of deposit. Mr. Pole points out that it might be easily prevented from fouling the streams.

23. The fourth objection is in regard to the existence of peat, and its influence on the water. There is a tendency for peat mosses to form and accumulate in mountainous districts, and the brown colour they impart, under certain conditions, to the water issuing from them, is well known. Mr. Pole remarks that in the higher parts of this district patches of peat moss were of frequent occurrence, and that beds of peat of considerable extent were cut and used generally in the neighbourhood for fuel. We believe it is found that in dry weather the streams of such districts, being the produce of springs, remain clear, not taking the peaty tinge; but that in rainy weather, and flood times, when the water permeates and drains through the mosses, an objectionable colouring effect occurs. The majority of the samples collected for the Commission were App. D.
taken in fine weather, and are reported as clear; but one or two exceptional samples 6203.
procured during partial floods were highly coloured, being reported as "deep yellow" after standing two days, and leaving a very brown residue on evaporation.

Mr. Bateman, from his experience of Loch Katrine, believes that the brown colour of 134–6.
peaty water is lost by exposure to the atmosphere, and argues that the effect of the 6657–62.
storage in large reservoirs, and the passage through the long conduit, would have the effect of delivering the water in London perfectly colourless. He has also described to us an ingenious arrangement in the Manchester Waterworks, by which the colourless dry weather discharge of certain streams is separated from the peaty water of floods; but the 2510.
applicability of this system on so extensive a scale as that necessary for the London supply has been questioned by other witnesses.

Dr. Angus Smith thinks it might be necessary to remove the colour by filtration, but 7264.
is in doubt how to apply the process. He thinks it cannot always be drunk with 7214–55.
impunity, but the only points requiring much attention are the bitter taste and the appearance.

Dr. Frankland says that the ordinary sand filtration will not remove the colour, and 6203–12.
suggests the use of animal charcoal; but he agrees with Mr. Bateman, that by storage in large reservoirs much of the peaty matter would, in all probability, be precipitated.

Dr. Miller thinks peaty water would not be injurious to health, but describes it as at 7059–7124.
times very disagreeable for drinking purposes.

Mr. Hawksley is of opinion that in the metropolis it is very necessary that the water 2504–9.
should be white water, perfectly clear and colourless, because coloured water would be disagreeable and contrary to the taste of the people. He says soft water is almost necessarily tinted, as it generally comes from moors and from elevated mountain districts, on which there is a large quantity of peat growing, and it is almost impossible to prevent that water acquiring a stain more or less deep. In dry seasons water from these districts may be a good colour, but it is coloured during floods, and these form the great bulk of the supply.

Being asked, If he could choose between the present and soft water for the London supply, which he would prefer? he says, if he could get the water tolerably free from stain he would use the soft water, but if not he would most certainly prefer the white water. He says that peaty water would not be tolerated in London, and instances that its introduction into Liverpool has given rise to much dissatisfaction. Manufacturing towns choose soft water, even if brown, on account of its importance to their trade; but generally, for drinking purposes, the clear, bright, sparkling water is preferred.

Dr. Letheby also states the water from peaty districts would be so frequently tainted 3870–2.
and coloured that it would be objectionable, and that Londoners would not drink it. They would prefer a clear, pure, chalk water.

Mr. Simpson objects to the peaty tinge of water brought from certain hilly districts. 4685.
He says:—"The Severn water at certain seasons is brown as coffee, and it is not a pleasant "water to drink," and he alludes to the colour of the water at Manchester and Liverpool, corroborating Mr. Hawksley, that at the latter place there was a great complaint on this ground.

24. The fifth objection is one often brought against soft waters, namely, the facility with which they often act on lead.

Drs. Frankland and Odling consider that soft waters do not necessarily act on even App. D.
bright lead, and that on tarnished lead they seldom act at all.

1491–8. Professor Way considers that if soft water were used, it would be prudent to guard against its action on lead, by substituting iron for lead pipes.

2671. Dr. Lyon Playfair states that on the intermittent system of supply, with the pipes alternately full and empty, soft water may act upon the lead of the pipes; but if the pipes were always full, as on the constant supply system, there would be very little or almost no risk.

3140–2. Dr. Parkes considers that it would be hazardous if means were not taken to secure the pipes against the action of soft water.

The evidence does not show any instance of injurious effects having resulted from the introduction of soft water into Manchester, Whitehaven, and other towns.

6616. 25. On the important question of cost Mr. Bateman has given us estimates prepared in great detail, having reference to a supply of 230,000,000 gallons per day; but in order to make the outlay gradual, he proposes to divide the execution into four progressive stages, giving—

	Galls. per day.
For the first stage - - - - -	130,000,000
„ second „ - - - - -	170,000,000
„ third „ - - - - -	200,000,000
„ fourth „ - - - - -	230,000,000

The estimates of outlay on the new works for these several stages, including interest on capital expended during the construction of the works, are as follows:—

For the first stage - - - - -	£8,685,006
„ second „ - - - - -	10,571,615
„ third „ - - - - -	10,822,474
„ whole ultimate supply of 230,000,000 gallons per day	11,400,023

These sums include the necessary arrangements for conveying the new supplies to the existing reservoirs, with a view to their distribution by the existing mains, but do not include the purchase of existing works or interests. Mr. Bateman, however, estimates that certain property of the companies, to the value of 1,000,000*l*., may be disposed of as soon as the supply by gravitation is introduced; and he therefore deducts this, reducing each of the above amounts by that sum.

App. E. 6738–44. 26. Mr. Bateman uses arguments to justify the expediency of such a large outlay for the water supply of London as his scheme would involve. He says, "The amount of "the estimate need not startle the public, for it is not more in proportion, either to the "quantity of water to be obtained, or the ability of the inhabitants to pay for it, than "has been expended in Glasgow, Manchester, Liverpool, and many other towns, while "it is far below the cost incurred by many other towns which could be mentioned."

He gives the following comparative statement of the outlay actually incurred in several large towns for bringing improved supplies of water, including compensation to old companies:—

	Cost for each million of gallons per day.
Liverpool - - - - - - -	£120,606
Glasgow, for limited supply - - - -	59,200
Do., for full supply - - - - -	33,645
Manchester - - - - - - -	60,000
London, estimated outlay for limited supply of 130,000,000 gallons -	£165,416
Do., for full supply of 230,000,000 gallons - - -	100,454

But Mr. Bateman considers a fairer test of the ability to pay for water is found in the *assessable value* of respective places, and he gives the following data, calculated in 1865, since which time, however, the rateable value in London has much increased:—

	Total assessable Value.	Assessable Value for Dwelling Houses.
	£	£
Glasgow - - - - -	1,200,000	600,000
Manchester - - - - -	1,200,000	600,000
London - - - - -	15,000,000	10,000,000

From this he reasons that London could bear an outlay for waterworks twelve times as great as Manchester and Glasgow, if measured by the total assessable value, or sixteen times as great if measured by the assessment on dwelling houses alone. And as the outlay in each of the two smaller cities has been something more than 1,500,000*l.*, the proportionate outlay for London would be 19,000,000*l.* on the first principle, and 25,000,000*l.* on the second.

27. Mr. Hawksley doubts the sufficiency of Mr. Bateman's estimate, believing that his reservoirs must be increased in capacity, as before stated.

28. Mr. Bateman developes a financial plan by which he conceives the scheme could be economically carried out, namely, by following the example of the two towns mentioned. App. E.

In each of these towns the waterworks are the property of the corporation, who have the power to levy two rates on account of the water supply, viz.:—

1. A *public rate*, levied in consideration of the protection against fire which "constant supply" and "high pressure" necessarily confer, and in consideration also of the great advantage which all property is supposed to derive from a full supply of water.
2. A *domestic rate*, in respect of the water supplied for domestic purposes.

Both these rates are compulsory rates, levied on all parties, whether they take the water or not. The amounts actually levied at present are:—

———	Public Rate.	Domestic Rate.
	In the Pound.	In the Pound.
In Glasgow - - - - -	1*d.*	1*s.* 0*d.*
In Manchester - - - - -	3*d.*	9*d.*
In Liverpool - - - - -	6*d.*	4½*d.*

Mr. Bateman proposes that the water supply of the metropolis should be vested in a public body, who should have power to levy rates of this kind, and who would then proceed to purchase the interests of the several existing water companies, and to introduce the new supply.

29. Mr. Bateman explains that he has been led to the projection of his gigantic scheme by the analogy of the works he has carried out for supplying Glasgow with water from Loch Katrine. For many years the inhabitants of that city, who had previously drawn their supplies from the Clyde, had become uneasy as to the quality of the water, and had anxiously sought for purer sources. In 1853 Mr. Bateman proposed to supply the city by water collected in Loch Katrine, and brought to Glasgow by a conduit 35 miles long. The proposal was at first startling by its magnitude, but after much discussion it was sanctioned and carried out, and the water was delivered from the new source in 1859. Various particulars will be found in the drawing, Appendix A O. 146–58. 176–86.

Emboldened by the success of this work, and acting on the assumption that the metropolis is, or soon will be, in a similar difficulty to Glasgow as regards the supply from its natural river, Mr. Bateman has now brought forward this still bolder scheme. He has sought about, he says, in all directions for a suitable source of supply, and believes that the district he has chosen possesses greater advantages than any other. We may conclude our description with his own words on this point. He says:—

"I may say that I selected this district with a perfect knowledge of what every other part of the country could do. I was aware of the vast quantity of water, and about which there can be no kind of question, in the Lake district, and the elevation of the Lakes; and I knew that those lakes from which water could be obtained were not higher than the sites of reservoirs, which could be formed just as large as lakes, and better than lakes, because you could make them hold more water in the same area in the Welsh hills. Therefore, not only with reference to distance, but with reference to inclination, it was most important to get the water which you wanted at the nearest point. The backbone of England is not only now largely drawn upon by a great many large towns on both sides, in Yorkshire and Lancashire, but it neither possesses the facility for constructing reservoirs, nor the vast amount of rainfall, nor the large area of drainage which for the metropolis is necessary, nor ought it to be tapped, because it is, in fact, the natural resource of all the manufacturing towns in Lancashire and Yorkshire and Cheshire, and therefore the Derbyshire hills and Yorkshire hills were out of the question. The only two districts from which water could be derived were the English lakes and the Welsh hills, without interfering with what might be considered in a national point of view the property 158.

of other districts. But the English lakes, at no greater elevation than the Welsh hills, were at twice the distance, or nearly so.

* * * * * * * * * *

A consideration of all these circumstances (and I gave the whole subject full consideration) determined me in going to the Welsh hills. I saw that there you could get everything nearer, and at an elevation which would enable you to make the works cheaper than in any other part of the kingdom."

Remarks by the Commission on Mr. Bateman's Plan.

30. Having now described the main features of Mr. Bateman's scheme, as presented to us, we proceed to offer some remarks upon it.

31. We are of opinion that Mr. Bateman's plan is practicable in an engineering point of view. The construction of large reservoirs, and the formation of a long conduit, present no problems beyond the ordinary resources of engineering skill, and there are no local or other difficulties to be contended with but such as must be expected to attend works on such a large scale, and such as may with ordinary prudence be surmounted.

32. With reference to the estimates of the cost of these works, as laid before us by Mr. Bateman, we must remark that although he has taken great pains to ascertain the main features of the scheme, sufficiently to establish its practicability, and in some cases by actual survey, yet that detailed surveys and sections of the greater part of the works (the cost of which surveys would probably be not less than 10,000*l.*) have not yet been made. In the absence of such detailed surveys of a scheme involving works of great magnitude, and to some extent novel, and subject to large contingencies and elements of uncertainty, we do not consider that it is possible to arrive at any reliable estimate of the cost which could safely be taken as the basis for recommendation of the scheme.

33. Mr. Bateman, in answer to question No. 6740, has given a calculation of the expected annual income and expenditure, but we are satisfied that there are many points in this calculation which are open to objection or doubt, and we are not able to adopt it.

34. He has also, in answer to question No. 6632, given, in a tabular form, "comparative "estimates of obtaining additional supplies of water from the existing sources and North "Wales," but on examination of the details of these calculations we are of opinion that these estimates are equally open to objections, and Mr. Bateman has not convinced us of the superior economy of the Welsh scheme. He contemplates considerable saving from the consolidation of the management, and from the levying of compulsory rates; but these measures would be equally applicable, and the benefits arising from them equally available, if the present sources of supply were retained.

35. It must be recollected that Mr. Bateman, if his gravitation scheme were introduced, could not entirely dispense with pumping. The high-water level of his Stanmore reservoirs, though 270 feet above ordnance datum, would be less than 200 feet above the ground level of many populous parts of London. And considering the depths to which both the Stanmore and the district reservoirs must of necessity occasionally be drawn down, and the large pressure necessary to force the water through the main and distributory pipes, we doubt whether the head would be sufficient to supply the upper stories of the houses in many parts of London, particularly under the unequal drafts resulting from the system of constant supply. In all these places, therefore, pumping would be required, and this would diminish the advantage assumed for the gravitation scheme.

36. The quality of the water, which appears very similar to that supplied to Glasgow from Loch Katrine, is satisfactory as regards its softness and purity. On other points we consider there are objections.

In the first place it is liable to be coloured by peat. The evidence shows the large presence of peaty matter in the flood samples, and as the great body of the water collected would be in floods and rainy seasons, there seems reason to believe that the coloured condition would be a common one. We agree with the witnesses that coloured water would not be acceptable to the inhabitants of London, for a taint in the water which is visible to every drinker is more likely to be objected to than one which might perhaps be less harmless but less easily seen. We think the question of how far the colour would be lost by storage and in the conduit requires determination by more extended experience;

and it is obvious that the adoption of any system of filtration, if applicable in such a case, would add largely to the original outlay, as well as to the annual cost of the supply.

There is another point requiring serious consideration, namely, the action of soft water on lead, which is often energetic. Of the sixteen samples of Welsh waters collected for the Commission by Mr. Pole, nine were found to act more or less on bright lead, and five to have no action; while on tarnished lead two had considerable action and fourteen had no action. It is true that the introduction of soft water into towns has in this respect often been effected with apparent impunity. The pipes and cisterns soon become coated in a way that, if they are kept full, is thought to preserve them from chemical action. We are, however, told by a very competent witness, that in Manchester "there have been 7268.
" several instances where medical men have believed injurious effects to have been caused " by the lead, and in several cases where there have been lead cisterns the effect has been " very decided indeed; but there have been also several where it has been believed that " the lead poisoning had its origin from the pipes alone,—enough at least to render great " caution necessary." We have had it also stated "that soft waters do not *necessarily* " act on lead." Although, therefore, under a perfectly efficient system of management, or by the substitution of iron for lead, there may be little danger to be apprehended from the use of soft water, still, under the innumerable accidental conditions which must occur in the distribution of a large town supply, arising from repairs of pipes, leakages, carelessness, peculiar states of the water resulting from local causes, and so on, there is no doubt that whilst in hard water the risk of danger is reduced to a minimum, in soft water, on the contrary, the risk must be a maximum one, and one which must always exist.

The circumstance that generally no ill effects have been found to result from the introduction of soft water, is inconclusive against the instance in which it has been affirmed; and unless a very clear and serious case were to occur, many minor cases of slight injury might take place without the cause being suspected.

We shall make some further remarks on the comparative advantages and disadvantages of hard and soft water in a subsequent part of our Report.

37. There is at present an insufficiency of data as to the amount of rainfall in the district, but we are of opinion that the evidence before us tends to show that Mr. Bateman's estimate of it is too high. The rainfall in all districts varies very much in different years, as well as in different parts of the same district, and hence it is only by a long continued and widely extended series of observations on the ground itself that any exact results can be obtained.

Although Mr. Bateman's anticipations on this point may not be fully realized, it must 6701-2.
be borne in mind that he states such a deficiency may be met by taking in a larger area of gathering ground. This appears feasible, the drawback being that it would increase the outlay necessary to be expended.

38. There is every reason to believe that if Mr. Bateman's scheme were ever brought forward in Parliament, it would be subject to a most powerful and determined opposition from interests of various kinds connected with the river and estuary of the Severn.

The Commission has received little or no evidence on this head; for the reason, no doubt, that until the scheme assumes a more practical shape, there is not sufficient inducement to the various parties to come forward.

Mr. Hawksley alludes to some of the points that would be likely to come into dispute, 2460-4.
stating that there are very large interests down the River Severn, from its head to the foot of the estuary, which will be interfered with.

Mr. Simpson corroborates this, and adds that the abstraction of water would be a serious evil, and that considering the great trade and the sums of money that have been spent on the river, it is questionable whether it ought to be interfered with.

It has also been objected that the appropriation of the streams and the loss of the floods would destroy or injure valuable fisheries, particularly of salmon; but on this point we have had no evidence, no one interested in these fisheries having appeared before us.

39. A serious objection has been raised to this as well as to other large schemes for supplying the metropolis from a distance, namely, the danger of having so large a population as that of London and the suburbs dependent solely on one supply of water, which might so easily be stopped by any one of several causes, such as wilful damage, frost, or the failure of any work along the line.

In regard to the first of these causes, we believe anxiety has been felt in other analogous
2527–8. cases. Mr. Hawksley says that this objection has been practically raised by foreign Governments to schemes of his own under similar circumstances.

2422–8. Mr. Duncan testifies to the anxiety lately felt on this point at Liverpool, and the precautions taken there to prevent interference with the works.

2527–43. Mr. Hawksley also attaches much importance to the difficulties likely to arise in long-
3990–8. continued cold weather, from frost and snow impeding the current through the long open conduits; and Mr. Muir, the engineer to the New River Company, states that it requires labour and considerable expense in severe frost to keep the New River in efficient flow.

6570. Mr. Bateman, in reply to these objections, says he has provided for ordinary cases of
6643–4. interruption by reservoirs of so large a size near London, that within 10 miles there would
240–43. be three weeks' storage to cover any interruption from accident or repair. He admits that no provision could be made against the possibility of the water being cut off during hostile occupation or by wilful damage; but this objection is, Mr. Bateman considers, applicable to many large cities; and is a contingency so remote as not to weigh against the many advantages of the plan.

6669–79. His experience of Loch Katrine aqueduct leads him to attach no great weight to the objection as to freezing, as in a very severe winter, when the temperature fell to 12 and 14 degrees below zero in the open air in the district along which the conduit was carried, the temperature of the Loch Katrine water never fell lower than 39 degrees, and there was not a particle of ice in any shallow or bay in Loch Katrine.

We do not, however, consider the two cases analogous. The great depth of Loch Katrine may maintain a minimum temperature of 39°, but in smaller reservoirs the temperature would necessarily be liable to fall lower. Further, the water after leaving Loch Katrine, having to pass through a tunnel 2,325 yards in length and in places 523 feet below the surface of the ground, and again just before reaching Glasgow passing through another tunnel of 2,640 yards long and 246 feet below the surface, would necessarily have its temperature raised in winter in consequence of the permanent greater heat of the ground at those depths. In the Welsh scheme, on the contrary, there are no deep tunnels; and whereas in the Glasgow works the whole distance of 26 miles was tunnelling or "cut and cover," here there would be nearly 100 miles of open cutting In a river like the Thames the temperature in winter is kept up by the springs which feed it, an advantage an aqueduct does not possess.

The freezing of canals and rivers, even of considerable capacity, in this climate, is a matter of frequent occurrence; and it must be borne in mind that, although the channel may not actually be stopped, the presence of ice and congealed snow in it would seriously diminish the velocity of flow and consequently reduce the quantity of water conveyed.

Then in a conduit of such vast length, and involving engineering works of such great variety and magnitude, it is only reasonable to contemplate the possibility that by some unavoidable mischance, such as a landslip or otherwise, failure or accident might happen to some of the works, which might have the result of stopping the flow for perhaps a considerable time; and in case of repairs being necessary it must be remembered that a large river 180 miles long, with a considerable fall and velocity, would be a difficult thing to deal with.

40. The objection as to the danger of the collection of such vast bodies of water in artificial reservoirs at the head of so important and populous a valley as that of the Severn, derives its principal force from the accidents that have been known to arise, and the destruction of life and property that has ensued from the rupture of reservoirs. And, considering that several large towns and populous and flourishing districts, would all be at the mercy of a flood from one of these gigantic stores of water, and that any failure would be most likely to happen when the store was at the largest, there is no doubt that an accident of the kind would be a great national disaster. In the hands of competent engineers and contractors, with ample funds and time at their disposal, the works may be so substantially constructed as to reduce the risk of such accidents to a remote chance, but we think that, although such an objection ought not to weigh against the plan if it were necessary, it may form an element in the choice between this and other sources of supply.

THE CUMBERLAND LAKE SCHEME.

41. Another plan, somewhat similar to that last described, is brought forward by Messrs. Hemans and Hassard, who propose to supply the metropolis with water from the lakes of Cumberland and Westmoreland.

This plan is described in a pamphlet published by the promoters in July 1866, which we have reprinted in Appendix F., and we have had explanations given by both these gentlemen in their examinations before us.

42. They remark, "It is felt that these suggestions appear somewhat at a disadvantage, "particularly as the sources of water supply recommended would seem at first sight to "demand works in length and extent of greater and more startling magnitude than even "the already sufficiently bold project of Mr. Bateman, for bringing water to London from "the Welsh hills at a distance of 183 miles. The sources herein recommended lie at a "distance of 240 miles from London, but, notwithstanding this increase of distance, we "believe that when the subject is fully investigated it will appear that our project—"although involving an apparently larger outlay in the first instance—will, from the "absolute certainty of the rainfall, the extraordinary purity of the water, the facilities "afforded by the existing lakes for the construction of the immense reservoirs, and from "the revenue which may fairly be expected from the sale of water in the districts "traversed by the aqueduct, be found the best and cheapest which has yet been proposed, "and that ultimate economy will arise from its selection." App. F.

43. The scheme is somewhat complicated in its arrangement, but it will be easily understood from the map, Appendix F (1).

It will be seen that to the north of the great dividing range of hills running east and west between Scaw and Shap fells lie three large lakes, Thirlmere, Ullswater, and Haweswater. These are at a considerable altitude, the level of the water above the sea in each lake being as follows:—

	Feet.
Thirlmere - - - - - -	533
Ullswater - - - - - -	480
Haweswater - - - - - -	694

It is proposed to dam up the outlets of the two higher lakes, so as to raise their levels still further, namely, Thirlmere by 64 feet, and Haweswater by 42 feet.

It is also intended to increase the quantity of water running into them by adding the drainage from the sides of neighbouring hills, to be collected and brought into the lakes by intercepting conduits at proper levels.

The waters from these two lakes would then be conducted by conduits and tunnels into the centre or lower lake, Ullswater, which would be treated as a great distributing reservoir from which the supply would be drawn off as required. This lake has a large drainage of its own, and it is proposed to increase it by a small additional district in the same way as the others.

The natural outlet of the Ullswater lake is at the north end, by the River Eamont, flowing into the Eden, and so by Carlisle into the sea. It is proposed, however, in the present scheme, to tap the lake at its southern end, and to run the water off from it by a tunnel to be formed under Kirkstone Pass, opening out on the slopes of the hills above Windermere, from whence the water would flow by gravitation through a conduit to London.

44. *Area of the Districts.*—The area of the district proposed to be made available as collecting ground is as follows:— App. F. 1.

	Square Miles.
Thirlmere drainage - - - - -	44
Haweswater ,, - - - - -	38
Ullswater ,, - - - - -	95
Total	177

To this may be hereafter added—

Drainage on the southern slopes of the main range -	53

App. F. 45. *Rainfall and Quantity of Water.*—The lake district having been long noted for its large rainfall, the promoters consider that on this point no difference of opinion can arise.

In the pamphlet (Appendix F.) the promoters state that the observations of the late Dr. Miller, from 1847 to 1853 inclusive, give an average annual fall of 100·56 inches, but 1864 and 1865 being dry years gave only 80·38 inches. They therefore, to avoid question, took the smaller figure 80 inches as the rainfall to be depended on.

606-23. Mr. Hassard, however, in his evidence gives a revised estimate. He says that the three years 1853, 1854, and 1855 were consecutive years of very great drought, the quantity being only about 83 per cent. of the average. These three years give a mean of 64 inches, which therefore he takes as his standard of estimation.

App. F. From the rainfall has to be deducted the loss by evaporation and absorption, which, in a precipitous and rocky district, the promoters assume will be not more than 12 inches. They, however, take it as 14 inches.

The following therefore appears to be their estimate of the quantity to be yielded by the district:—

	Area of collecting ground - - - - - -	177 sq. miles.
612.	Mean rainfall of three consecutive dry years - - -	64 inches.
	Deduct loss by evaporation and absorption - - -	14 „
	Available - - -	50 „
706.	This from a drainage area of 177 square miles will give per day about - - - - - - -	350,000,000 gallons.
	Deduct for compensation to rivers a quantity equal to 9 inches of rain over the collecting area - - - -	63,000,000 „
	Available for supply to metropolis and other towns - -	287,000,000 „

Mr. G. J. Symons has given us an elaborate report on the rainfall. He considers the evidence in regard to the lake district unusually complete; and he infers from the whole that the true mean rainfall for it may be taken at 77 inches, and the mean of three dry years at 80 per cent. of this, or 61·6 inches. In the driest years he would take something like 66 or 68 per cent. of the average, which would give about 53 inches. During the ten years ending 1859 there was only one drought of more than 40 days' duration, and more than one inch of rain fell during its continuance.

46. *Storage.*—The storage would be obtained principally in Ullswater, Thirlmere, and Haweswater lakes, but partly also from auxiliary reservoirs formed in other places; the raising of Thirlmere and Haweswater, as already described, would allow of a large amount of storage room in them. It is also proposed to raise Ullswater 5 feet, and to draw it down 20 feet when absolutely necessary. It is explained, however, that this would only be required when the maximum quantity was taken, and even then only in very rare cases of extreme drought.

The whole available storage would be about 5,563,000,000 cubic feet, which is equal to 120 days' supply at 250 millions of gallons, or to 157 days' supply at 200,000,000 gallons per day, after giving credit for the average minimum summer yield, and allowing for compensation.

App. F. 47. *Conduit.*—The water would be conveyed from Ullswater to London over a length of 270 miles by conduits, tunnels, and iron pipes.

The work of greatest magnitude connected with the scheme would be the tunnel under Kirkstone Pass, to bring the water southwards from Ullswater. It would be $7\frac{1}{4}$ miles in length. From the south end of this tunnel the conduit would pass by Ambleside and Kendal, and down the eastern side of Lancashire (avoiding the Wigan coalfield), to the east of Manchester and of the Potteries district, and to the east of the Stafford-
301-2. shire coalfield and of Birmingham, and onwards towards London, following a route nearly parallel with that of the London and North-western Railway. The conduit would be in effect equivalent to a river 30 feet wide and 10 feet deep. The inclination taken has
428. been small, viz., 6 inches, and in some cases 4 inches per mile, and for pipes 20 to 24 inches per mile. Probably in some part wrought-iron pipes of 8 feet diameter, lined with cement,

might be used with advantage. Detailed descriptions of these works, and of the nature of
the districts over which they are taken, will be found in Mr. Hassard's evidence. The 733.
conduit would terminate in a large regulating reservoir to be constructed near Edgeware, 743.
at a distance of about 12 miles from Cumberland Gate, Hyde Park. The height of 730–57.
this would be $232\frac{1}{2}$ feet above Ordnance datum, which the promoters consider would 765–7. 778–817.
ensure an ample pressure for ordinary domestic supply and in case of fire, and would allow 823–38.
of the use of the existing appliances of distribution, which they assume would be destroyed 818–22.
by the use of a much higher pressure and by the adoption of a different system of service. Elevated districts must still be supplied by pumping. The reservoirs are proposed to be in duplicate, containing in the aggregate 15 days' supply at 250,000,000 gallons per day.

48. *Other Towns on the Way.*—The promoters state that the conduit, in passing through the heart of England, Lancashire, the Potteries, and the midland counties, would be capable of affording *in transitû* a practically unlimited supply of water to the large manufacturing districts and population on the line of its route. They estimate that more than 50,000,000 gallons per day might thus be disposed of.

49. *Additional Supply from Bala Lake.*—The promoters contemplate taking in 589–604.
water from Bala lake, in order to replace water which might be sold to manufacturing 884–98.
towns in the north. This would require an additional aqueduct 70 miles in length, which would join the main conduit at Stoke; and at the point of junction they propose to form an additional reservoir capable of holding about 21 days' supply; they estimate the cost of this addition at 1,500,000*l.*, and the extra quantity obtained at from 50,000,000 to 60,000,000 gallons.

50. *Estimate.*—The promoters estimated in their pamphlet that the cost of the project App. F.
complete, for 250,000,000 gallons a day, would be 12,200,000*l.* But in Mr. Hassard's 1060.
evidence he gives an amended estimate as follows:—

Reservoirs, conduits, and works of collection -	£1,013,000
Tunnel under Kirkstone Pass - - -	360,000
Aqueduct to London - - - -	9,806,260
Regulating reservoirs near London - - -	500,000
	£11,679,260
Interest during construction, and other expenses -	1,820,740
	£13,500,000

Mr. Hassard compares this estimate with that for Mr. Bateman's plan, and also with 681.
the cost expended for a like purpose in Liverpool, Manchester, and Glasgow, and gives 693–9.
the result as follows, being the cost for each million gallons per day:— 718–28. 839–51.

In Liverpool - - - - - -	£115,115	1059.
In Manchester - - - - - -	60,000	1060
In Glasgow, present - - - - -	59,260	
„ ultimate - - - - -	33,645	
In London, from Wales - - - - -	95,454	
„ from lakes - - - - -	88,000	

Formidable objections have been raised to these estimates, as will be seen in the 6703–36.
evidence.

51. *Financial Scheme.*—Messrs. Hemans and Hassard agree with Mr. Bateman that App. E.
the water consumers should be the proprietors of the new works; that a compulsory 910–12.
rate should be levied for water supply on all property within the area benefited; and that the existing waterworks should be purchased and incorporated with the new project, and the companies secured in their present incomes.

They give in their pamphlet a statement of estimated income and expenditure, and Mr. Hassard gives amended figures in his evidence.

52. *Quality of the Water.*—The topographical and geological character of the gathering ground is generally similar to that of the Welsh hills, but is in some respects more

favourable, inasmuch as the hills are higher and steeper and less covered with vegetation, and the area contains less population and less cultivated land. Some portions of the district are less favourable than others, but they might, if it were necessary, be excluded.

The two maps, marked Appendices AZ, 1 and 2, have been prepared to show the geological features of the ground, and its elevation at various points above the mean sea level.

There are extensive lead workings in some parts of the district, but the evidence shows that they need not form any objection to the scheme.

We have made an independent investigation of the quality of the water from this district, in the same manner as that from North Wales; the samples were, as in the former case, collected by Mr. Pole and analysed by Drs. Frankland and Odling, and the reports of these gentlemen will be found in Appendices A and D.

The results of the analyses are very similar to those of the Welsh waters as regards softness and purity, and freedom from mineral contents and organic contamination. But the waters are open to the objection mentioned in the former case as regards the probability of their being coloured by peat. The samples generally were taken in fine weather, but many of these were slightly coloured, and two samples that were taken when the streams were in flood were reported to be "yellowish brown, leaving a nearly black residue on evaporation." It is suggested that these waters might be excluded from the collection and used for compensation, but it is probable that they only represent the state that the streams generally would assume in heavy rains, when the water storage would principally take place. The water taken from the lakes was "clear and colourless, leaving a "slightly brown residue on evaporation."

Remarks by the Commission on Messrs. Hemans and Hassard's Plan.

53. This plan has so many points of resemblance to that of Mr. Bateman, that many of the remarks we have made on the Welsh project will be applicable to this also.

The plan is practicable, and has the advantage of the existence of the natural lakes at a high level, but the estimates of cost are more uncertain than in the former case, on account of the less detail in which the promoters have prepared their plans, the greater length of the conduit, (about 90 miles longer than Mr. Bateman's,) and the greater uncertainty as to its exact route and nature.

The quantity of water obtainable is abundant, as the rainfall, whatever may be its exact amount, is admitted on all hands to be very large.

The quality of the water is satisfactory, subject to the same objections that we have mentioned in the Welsh case.

6916–78. 7149–82. There would probably be less formidable opposition to this scheme than to Mr. Bateman's, on account of the less magnitude and importance of the rivers flowing from the district. But the objections from the possible stoppage of the flow in the conduit would be increased in proportion to its greater length.

The remark we have made as to the necessity for pumping to some extent in the Welsh scheme applies with much greater force to this plan, as the promoters propose to deliver the water into the store reservoirs near London at a level 37½ feet lower than Mr. Bateman. This level we believe would be insufficient to supply any but the lower districts, so that pumping would be required over a large portion of the metropolitan area.

There is no doubt that the lake district is a very fine gathering ground for soft water; but it is deserving of consideration that this district is not unlikely to be claimed as the most natural source of supply for large and increasing manufacturing populations in the north of England, for whom soft water would be particularly valuable; and we hold it to be erroneous in principle that any one town or district should take possession of a gathering ground geographically belonging to another, unless it can be clearly shown that circumstances render such a step justifiable.

MR. HAMILTON FULTON'S PLAN.

3446–3571. 4078–4171. 54. The plan proposed by Mr. Fulton is explained in his evidence, and in the two plans in the Appendix marked A A (1 and 2).

He proposes to take water from the upper sources of the River Wye in Mid-Wales. The reasons alleged for the selection of this district are—

3450. "That it is very thinly inhabited, the water at present is scarcely used at all, either for manufacturing, domestic, or navigation purposes; the fisheries which exist can be protected from injury; there are no manufacturing towns in the watershed; and the only application of water for mechanical purposes is for flour mills, of which there are very few."

He also adds—

"The reason why I have chosen the Wye district in preference to any other is, that the importance of the navigation of the Wye is very small, and consequently the abstraction of its water would be no injury as far as the navigation is concerned. Indeed from the sea up to Hereford, which is the largest town in the district, and which has a population of between 15,000 and 16,000 inhabitants only, I believe the trade is nearly extinguished on the river, that is to say, it is nearly superseded by the railway; and the only trade by navigation which exists now is by the canal from the Severn, which runs up to Hereford." 3174.

Mr. Fulton has selected four districts on the Wye and its head tributaries : App. AA.

	Square miles.
No. 1 containing - - - -	146
2 " - - - -	125
3 " - - - -	102
4 " - - - -	67
Total area	440

Reasoning by analogy with the lake district he assumes a rainfall of 60 inches per annum, and that the net quantity after deducting for evaporation and absorption will be 30 inches. 3454–67.

Taking then the highest district, No. 1, with which he proposes to commence, this would give a yield of 175,000,000 gallons. From this he deducts 44,000,000 gallons for compensation to the rivers, which leaves a net quantity of 130,000,000 gallons fro m this district alone. The four districts together are estimated to yield a net average daily supply of 393,000,000 gallons. Six reservoirs are proposed in the first district as shown in the map, the lowest of them being near Rhyader and at a height of 590 feet above the sea. 3500.

From this point there would be a conduit to London 180 miles long. It would be laid first along the valley of the Wye, so as to take in the water of the other and lower districts when required, and passing Glasbury and Hay; and thence it would pass near Kington, Ludlow, Tenbury, Bewdley, Stourport, Bromsgrove, Henley-in-Arden, Warwick, Banbury, Tring, and Watford, to a point near Barnet, eight miles from Hyde Park, where it is proposed to construct a service reservoir at 276 feet above mean sea level. The aqueduct would be 15 feet wide and 14 ft. 6 in. deep with a fall of from 6 to 24 inches per mile, and it is estimated to deliver 230,000,000 gallons per day. 3519–25.

Mr. Fulton has made an approximate estimate of the cost of the first portion of the scheme, viz., to bring 130,000,000 gallons, which amounts to 7,000,000*l*. For 100,000,000 gallons more the cost would be 2,000,000*l*. in addition. 3531–46. 4093–4102.

55. We have had no evidence on this scheme, except from the promoter himself. We consider, however, that from its general similarity to Mr. Bateman's plan it might be further investigated, if any scheme of the kind for the supply of the metropolis should be deemed necessary.

MR. REMINGTON'S PLAN.

56. Mr. George Remington proposes to bring water from the hills of Derbyshire, collecting it at a point above Mill Dale on the River Dove, 586 feet above the sea, and bringing it by a conduit 135 miles long to a reservoir on Barnet Hill, 300 feet above Ordnance datum. 4321–4442.

He proposes to appropriate an area of 262 square miles, and the following extract from his evidence will show his estimate of the quantity of water obtainable—

4335. What quantity of water do you propose to supply per day at Barnet Hill?—About 100,000,000 gallons. I have put it down in the paper which I sent in to the Commission as 83,000,000 gallons, or one-sixth of the rainfall on the 262 square miles, but in round numbers I would take it at 100,000,000 gallons per day.

The rainfall has been gauged at Uttoxeter, which is on the Dove, but Uttoxeter is very low, and there the rainfall is about 30 inches, and I have assumed the quantity falling on the high district to be 48 inches. 4337.

He estimates that his scheme would cost 5,000,000*l*.

In the absence of more complete data we cannot regard this scheme further than in the light of a suggestion, and we need not remark on it more particularly, except to say that this in any case could only form an auxiliary source; while from the proximity of a number of important manufacturing towns we consider such a source should be reserved for their supply, for which it seems well fitted.

MR. DALE'S PLAN.

1061 *et seq.* 57. The last plan for obtaining water from mountainous districts is that of Mr. Thomas Dale, engineer to the Corporation Waterworks of Hull. This plan is described in his evidence before us, and in a pamphlet published by him in 1866.

He proposes to take water from the same sources as Messrs. Hemans and Hassard, namely, from the Cumberland and Westmoreland lakes; but instead of bringing it by an aqueduct to London, he contemplates conveying it by pipes to supply various towns in Yorkshire and Lancashire.

The plans, Appendices Q (1) and Q (2), will give an idea of Mr. Dale's project. It will be seen that he would convey water from Ullswater and Haweswater first to Leeds and various towns in Yorkshire, and then, by a continuation of the conduit, to Liverpool and other towns in Lancashire.

The following is a list of these towns, and the quantities which Mr. Dale's scheme proposes to supply:—

	Gallons per day.
Lancaster	2 millions.
Preston	8 „
Wigan	4 „
Dewsbury	3 „
Wakefield	3 „
Liverpool	40 „
Leeds	15 „
Bingley	1 „
Kendal	2 „
Bolton	8 „
Blackburn	6 „
Keighley	2 „
Bradford	10 „
Huddersfield	4 „
Burnley	4 „
Rochdale	4 „
Halifax	4 „
Colne	1 „
Bury	8 „
St. Helen's	2 „
	131 „

We have already stated, in speaking of Messrs. Hemans and Hassard's scheme, that this is a favourable district for affording water supply to manufacturing districts in the north; but we believe Mr. Dale's proposal to take the water across the backbone of England to the Yorkshire towns a mistake, as they can be well supplied from districts nearer to them. It would, we conceive, be more advantageous to confine the supply from the lakes to the towns and districts lying to the west of the main chain of hills, and to carry the water more directly to them.

REMARKS ON GRAVITATION SCHEMES GENERALLY.

58. The experience with plans for supplying large towns with water by gravitation, from catchment reservoirs formed in hilly districts, has not yet been so extensive as to enable engineers to make accurate calculations, in all cases, as to their sufficiency.

App. BB. Liverpool, for example, was originally supplied by pumping from the red sandstone strata under the town; but some years ago, this source proving insufficient, large works were established for bringing water by gravitation from the Rivington Hills. The supply however proved much less than was expected, the sandstone had again to be resorted to, and now additional sources are required. It was anticipated, on good authority, that a supply of 12 or 13 million gallons per day from the new works might be reckoned on; but our evidence says—

> The Rivington Works are practically a failure as gravitation works; three dry years in succession reduce the available water to six millions of gallons per day, and four successive years of drought, which may very probably occur in future, would reduce it still further; and unless enormous reservoirs or lakes could be made, capable of storing the surplus waters of three or four years; these works must prove insufficient.

At Newcastle-on-Tyne gravitation works were constructed in 1848, but in 1850 the supply failed, and the former establishments for pumping from the Tyne had to be again resorted to. Enlargements of the gravitation works were carried out, but still with insufficient results, and a permanent pumping establishment is now in course of erection.

Bristol was supplied in 1851 by gravitation from the Mendip Hills; in 1864 the supply failed, and after enlarging the works, recourse was had to permanent pumping works from springs nearer the town.

59. During the sittings of this Commission the gravitation plans throughout the country have been subjected to a severe test by the occurrence of an unusually long drought in 1868. Although the rainfall of the whole year was above the average, yet it was very unequally distributed, as from the end of April to the end of September, a period of five months, there was scarcely any rain. Hence the capacities of the catchment reservoirs were severely tested, the towns having to depend entirely on the stores in them, without any feeding supply except that of perennial springs.

We have had evidence on this point from Mr. Bateman, Mr. Hawkesley, and Mr. John Taylor, chief assistant to the late Mr. James Simpson, who has given us, in Appendix B C., the result of inquiries made as to the effects of the drought in several towns.

60. In Manchester it appears that after official notices had been published cautioning the inhabitants against waste, and urging them to economize their supplies, the corporation, on the 3rd of August, limited the supply to the city to 12 hours of the day, stopped the street watering, and diminished the trade supplies by one half. They also made an arrangement with the millowners for reducing by one half the quantity given to the mills on the line of the river, and made compensation in money for the deficiency. In the middle of September the general supply to the town was further limited to eight hours per day, and the quantity for trades also diminished. Many persons were prosecuted for waste or undue use of water. The eight hours' supply lasted seven days, and the 12 hours' supply 76 days.

The following are extracts from Mr. Bateman's evidence in regard to this case:—

With regard to the quantity of water supplied to Manchester during the drought of 1868, you stated that the balance left in store on the 25th of September, after 150 days drought, was 435,000,000 gallons, but that during 45 days there was a diminished quantity supplied to the mills, and further that during 52 days the water was shut off at night. Supposing the supplies to the mills and to the town to have been continued to their full amount during this period, have you calculated what would have been the quantity in store?—We should have exhausted our store, and we should have been, perhaps, something like 200,000,000 or 300,000,000 gallons deficient. 7427.

You are preparing larger storage, are you not?—Yes. Our works are now very far from being complete, but we are constructing two new large reservoirs; and we have a third reservoir which we have never been able to fill owing to the bad foundation, which, as soon as the two others are completed, we shall restore, and that will nearly double our storage at once. It is a mere question of storage in Manchester. We have abundance of water, but we are two years behindhand in our works, and we are two years beforehand in the calculated supply. We have been extending the supplies to the outlying districts so much that, while we have been falling behind in our engineering operations, we have been going too fast in the supply of water to the district, and therefore the two causes together put us into this position this year. 7428.

In our Manchester Waterworks we are at present incomplete. We are behindhand in several of our reservoirs which we are now constructing, and we are beforehand with the quantity of water which we are supplying, so that we are not quite equal to what we should be in storage, and therefore we were not able to give the full supply of water which we could have desired during the last drought. Our available storage in Manchester is equal at present to only 24,000 cubic feet of water per acre of collecting ground. In Liverpool the storage is equal to 48,500; in Dublin it is equal to 25,500; at Loch Katrine it is equal to 30,000; and at Gorbals it is equal to 52,000.

At Rochdale, as early as the 25th June, the supply was limited to four hours per day for 15 weeks; but with this precaution, during the second week in October the store became entirely exhausted, and the town would have been almost without water but that recourse was had to pumping from a colliery in the neighbourhood.

At Bury the store ran so low towards the end of August that it was reserved entirely for compensation to the mills, and the company obtained a supply of seven gallons per head from neighbouring works; for baths and for the numerous manufacturing and trade uses in the town there was none. This continued for five weeks.

At Preston the reservoir became practically dry at the end of August, and costly pumping works were hastily established, which were required for 58 days.

At Kendal the reservoirs were exhausted earlier, and measures of the same kind were adopted.

At Newcastle the gravitation works would have failed for many weeks had they not been supplemented by the pumping from the Tyne.

At Bradford 60,000 of the inhabitants were limited to one day's supply per week for 16 weeks, and 90,000 had their supply gradually reduced during five or six weeks to six hours per day. The want of water for manufactures was here seriously felt.

At Halifax the reduction began on the 11th of May; the domestic supply was limited to 14 hours per day for 66 days, to 10 hours for 10 days, and to six hours per day for 86 days; the supply to large consumers being gradually reduced from 30,000 to 1,000 gallons per day.

At Sheffield the supplies were first reduced in June, and further in July, August, and September, the last reduction being to four hours per day.

The towns of Stockport, Bolton, Ashton, Stalybridge, Oldham, Dewsbury, Warrington, Blackburn, and others suffered more or less, and Mr. Taylor concludes his report with the following remark:—

> The general result has been that nearly all gravitation supplies of water, obtained from drainage grounds, have failed in a manner hitherto unprecedented within the known experience of such works, proving that the data on which they have been based have been fallacious, and that the storage reservoirs and gathering grounds of such works must be greatly increased to meet the demands of years like the present.

61. The causes of this difficulty may lie either in an over-estimate of the available rainfall or in an insufficient provision of storage. The sufficiency of water-collecting plans in these respects must be tested both by the concurrence of several consecutive dry years and by occasional droughts of long duration; and to obtain the necessary data on these points, for any particular district, must require special observations on that district extended over a considerable time.

62. In so variable a climate, and with a rainfall in different parts of the kingdom ranging in round numbers from 20 to 100 inches, it is of primary importance to have the most complete information as to the rainfall, and, as the annual variation is also great, the average fall for a term of years cannot be determined without observations extended over a long period. Less than 20 years would probably not suffice. But the question, with reference to a water supply, has to deal not with the average rainfall of a long term of years, but with a short term depending on the capacity of the storage. In no case yet contemplated would it be prudent to rely on more than the average of three years, and under certain conditions it is doubtful whether two years would not be a safer term.

The Rev. W. Jenyns, in his "Observations on Meteorology," gives an instance in which, even with a term of 10 years, the average varied 7½ inches, the mean quantity in one case being 18½ and in the other 26 inches. In two other terms of 10 years the difference was 2·331 inches.

The experience, however, of half a century would seem necessary to determine the minimum fall for a short term of years. We may take the annual rainfall recorded at the Greenwich Observatory from 1815 to 1868, to average 24 inches. From these observations it appears that during this period of 54 years there were three years in which the rainfall was under 17 inches, or only about two-thirds of the average, viz., in 1832, 1840, and 1864; that during the same period there was one term, and one term only, of three years, 1832–4, in which the average amount of rainfall was a quarter short of the average annual fall; that there were four terms of that length in which the annual rainfall was from a quarter to a sixth short; while once in the 54 years there was a term of five years, the rainfall of which averaged nearly a sixth short. These variations are shown in the following table:

Length of Term.		Average annual Rainfall.	Quantity short of general Average of 24 Inches.
		Inches.	
year	1832 - - - (doubtful)	16·1	−7·9
	1840 - - - - -	16·6	−7·4
	1864 - - - - -	16·4	−7·6
2 years -	1832–3 - - - - -	18·5	−5·5
	1834–5 - - - - -	20·2	−3·8
	1857–8 - - - - -	19·6	−4·4
	1863–4 - - - - -	18·05	−5·95
3 years -	1832–4 - - - - -	18·3	−5·2
	1856–8 - - - - -	20·4	−3·5
5 years -	1854–8 - - - - -	20·8	−3·2

The short three-years terms occurred at intervals of 22 years; for the short five years the limits of recurrence are not yet reached.

In the mountainous districts of England the irregularity of the rainfall is still greater. Mr. Symons has given evidence showing that in a period of 22 years at Windermere it has reached as high as 116·26, and fallen as low as 47·54 (1861 and 1855), whilst once in that time the mean of three years (1855–57) did not exceed 52·71. The mean of the 22 years was 79·85.

It is evident, therefore, that a very long series of observations is necessary to be made before any authoritative opinion can be expressed, not only as what may be the true average annual rainfall, but what (for this inquiry is still more important) may be the mean of the three driest years, and at what interval they may occur. In the case of a large city like London, when such a source of supply is proposed, an exact determination seems to us imperative. Of course it will be understood that not only should the observations extend over a long term of years, but also that they should be made in many places so as to get at the average rainfall of the district, which Mr. Symons has well shown to have very different values in immediately adjacent places; as it varied in the same year in fourteen areas in the Lake district, from 45 to 100 inches. When the rainfall has been determined with exactness, the proportion which can be delivered in a hard rock district may be estimated with considerable accuracy.

The system of collecting grounds utilizes, no doubt, the rainfall to the greatest extent. But the great disadvantage is, that the springs to fall back upon in time of drought are insignificant in comparison with the great quantities stored in permeable strata; the very circumstance of a large immediate delivery of the rainfall precludes the possibility of that subterranean storage of a large portion of it, which forms so valuable a resource during severe and long-continued droughts.

63. The question of storage room involves complicated considerations, which have been especially dwelt upon by Mr. Hawkesley. On account of the irregularity of the rainfall, particularly in mountainous districts, it is impracticable to construct reservoirs large enough to store the entire quantity received, so that all large floods occurring when the reservoirs are full must pass away and be lost. Hence the available average obtainable from reservoirs must fall much short of that deduced simply from the fall of rain. We cannot here enter further into this question; but the experience we have above mentioned suffices to show the difficulty of making reliable calculations on this head, even when tolerably complete data are at hand.

64. It is worthy of remark that during the exceptionally long drought of 1868 the Thames and the Lee seem not to have been diminished in volume below the ordinary flow of dry years, a result entirely due to the equalizing effect of the great subterranean stores contributing to their flow.

We shall hereafter go more fully into the advantages of these rivers as sources of supply, which cause them to contrast so favourably with gravitation schemes.

PART II.

ON SOURCES OF SUPPLY OTHER THAN THE MOUNTAINOUS DISTRICTS OF ENGLAND AND WALES.

65. Your Majesty's Second Commission commanded us to inquire "whether there are " other districts, in addition to the high districts of England and Wales, from which a good " supply of unpolluted and wholesome water can be obtained."

Several plans or proposals, of various degrees of magnitude, having for their object to supply the metropolis, wholly or partially, from sources of this character, have been mentioned to us by the parties named in the following list. It will be convenient to divide these into classes, as follows:—

Class I.

From the River Thames or its Tributary Streams.

1. Mr. McClean, from the Thames near Henley.
2. Mr. Bailey Denton, from the higher parts of theThames basin.
3. Mr. Brown, from the same.
4. Mr. Bravender, from the same.

Class II.

From the Lee.

5. Mr. Mylne, from the upper part of the Lee basin.

Class III.

From the Chalk and Oolite Formations in the Basin of the Thames.

6. The Rev. J. C. Clutterbuck, from the chalk and oolitic area of the Thames basin.
7. Mr. Homersham, from wells in the chalk around London.
8. Mr. P. W. Barlow, from certain chalk springs in North Kent.
9. Mr. Meeson, from chalk springs at Grays in Essex.

Class IV.

Miscellaneous.

10. Mr. Thos. Hennell, from the chalk and Bagshot sands of the neighbourhood of Basingstoke and Farnham.
11. Mr. G. W. Ewens, from certain chalk springs near Havant.
12. Mr. Telford McNeil, from the Bagshot Heath district.

A plan proposed by Mr. A. S. Ormsby, to collect water from artificial drainage surfaces, does not appear to come within the scope of our inquiry.

Some of these projects are merely suggestions, and none of them have been prepared with the completeness and detail of the larger plans. It will, therefore, not be necessary to notice them at the same length.

CLASS I.

From the River Thames or its Tributary Streams.

66. Several projectors, considering that the Thames when it reaches Hampton has become polluted by the drainage of the land and towns above, have proposed to take the water at higher points, generally combining with their propositions other suggested arrangements for the improvement of the supply.

Mr. McClean's Plan.

5498 et seq. 67. Mr. McClean, M.P., Civil Engineer, gives a description of a plan which he brought forward in 1849 and 1850, in conjunction with the late Mr. Blackwell, who was for many years engineer of the Kennet and Avon Canal. It is illustrated by a plan and section which are printed in Appendices T (1) and T (2) to our report.

Mr. McClean's proposition is to embank and canalize the Thames above Medmenham (between Henley and Great Marlow), so as to form, in the present channel of the river, a long series of impounding reservoirs, which would be advantageous not only for storing water but also for improving the navigation. He would then take the water from the lowest of these pounds, 105 feet above low water in London, and proposes thus to obtain a supply of 200,000,000 gallons a day.

The drainage area included is 2,500 square miles, and the mean annual rainfall is estimated at 26 inches.

The aqueduct would be a canal 36 miles in length, the last five miles to be covered. It would be 40 feet wide by 12 feet deep, and is intended to deliver the water in London at about the level of the Paddington Canal, or the New River head, from which level Mr. McClean assumes all the low part of London might be supplied by gravitation, that necessary for the higher parts being pumped to elevated reservoirs at Hampstead and Clapham.

Mr. McClean believes that the quality of the water taken at Medmenham would be very satisfactory.

The estimate for the plan when brought forward was 1,500,000*l*., excluding the pumping parts of the scheme.

Mr. McClean gives further details, and says he has no doubt that by storing the flood 5637.
waters in the upper reaches of the Thames more water may be obtained than can ever be
required; and that by embanking the river in the way he proposes he would increase the 5718-21.
quantity by preventing the water going out on the lands and inundating them, whereby a great deal is lost and the quality much deteriorated.

Mr. Bailey Denton's Plan.

68. Mr. Bailey Denton's plan, which is illustrated by a map, Appendix V., is thus generally described by him :—

"I am prepared to show that the upper streams of the Thames basin, the tributaries of the Thames, are 1532.
capable of supplying the metropolis if supplemented by storage, and that that storage would partly consist of the water of under-drainage and the water of drainage by arterial improvements from the upper lands which form the margin of the Thames basin. I should state, however, that my proposal is to take from the Thames and its tributaries, at points above which water may be obtained in positive purity by the proper exercise of conservancy, all that may be required for the supply of London, having stored in winter the surplus waters of that period of the year in order to repay the river system in summer what may be required to maintain it at a fixed standard height."

With respect to the quantity of water available he makes the following remarks :

"To give some proof that there is water sufficient, I would just mention these facts to the Commission. 1547
The area of the watershed of the Thames is 3,300,000 acres, the population we may take at 4,500,000, the average rainfall is 26 inches, the minimum is between 19 and 20 inches, and that minimum is disposed of in this way—3 inches support the perennial supply of the river, that is to say, maintain the river in summer at the ordinary height; taking 3 inches from 20 there remains 17, and of that 17 we find by information of various sorts that a very large share runs off to the sea in winter; but, beyond the fact that this accretion occurs when the rivers are full, there is another fact, that whatever water is taken by under-drainage from the atmosphere it is so much positive increase to the river supply, and as under-drainage proceeds so will the supply be increased."

"I propose to collect the water from the higher portions of the basin, that is, from the oolitic sources on the 1557.
north of the Thames, say from Cricklade to Oxford, and from the various streams rising in the chalk throughout the whole of the area of 3,300,000 acres. It is not possible to state the quantity of water discharged by springs from the water-bearing strata of the Thames basin, but it is pretty accurately known that, while $1\frac{1}{2}$ inches of rain maintains the ordinary summer flow in the river from April to September inclusive, at least 4 inches runs off during the remaining six months from October to March inclusive, without taking into consideration excessive floods. The ordinary winter flow, in fact, compared with the ordinary summer flow is as $2\frac{1}{2}$ to 1. No dogmas as to loss by evaporation and other causes touch this fact, which manifestly proves, when the discharge drainage water is taken into account, the capability of storing in winter all that can possibly be required for compensation in summer."

"My proposal embraces three sources of supply with a means of future augmentation, viz., the upper sources 1651.
of the Thames giving 100,000,000 daily, the Lee giving 60,000,000, the Wey and the Mole giving 40,000,000, making 200,000,000 daily, exclusive of the Colne and the Wandle, which with storage may provide a share at some future time."

"I have already observed that there is almost a total absence of any reliable gauging of the Thames and its 1662.
tributaries. but we do know this from the evidence of Mr. Stacey before the Rivers Commission, and a remarkable fact it is, that the general summer average volume at Wolvercot, which is just above Oxford, is 73,000,000 gallons *per diem;* but in the dry summer, 1865, it was reduced to 62,000,000 gallons. But the winter flow is represented by very different figures. On the 2nd of January 1863 the quantity flowing down was 321,000,000 gallons, which is represented as the ordinary winter flow; it increased gradually in five days to 350,000,000, 430,000,000, 588,000,000, 636,000,000, 702,000,000, and 742,000,000, which was the highest it arrived at. I submit that that must go some way to prove the capacity of the Thames basin to supply water if the surplus be stored in winter, to compensate the rivers for what may be taken out of them in summer. It will be observed that Mr. Stacey represents the ordinary winter flow at Wolvercot as about $4\frac{1}{2}$ the ordinary summer flow, instead of $2\frac{1}{2}$ times as I prefer to take it."

At Lechlade the Thames and Severn Canal joins the Thames, and higher up the North Wiltshire Canal joins the Thames and Severn Canal. Mr. Denton proposes to purchase those canals and utilize them for the collection of the waters of the Thames above, and then to bring the water from Lechlade to London by a conduit, 127 miles in length. This conduit would collect the waters from the various tributaries, the Coln, the Leash, the Windrush, the Evenlode, the Cherwell, and the Ray, into a concentrating reservoir just below Oxford; then, passing down from Oxford to London, the Ock would be in the same way brought under contribution, as well as the Thame, the Loddon, and the Hertfordshire Coln. The main conduit would start from Lechlade at a height of about 220 feet above ordnance datum, and would bring the water to Hampton, where Mr. Denton proposes to deliver it to the present water companies, for them to raise to high-service reservoirs for distribution by gravitation.

He proposes to have compensating reservoirs on the impervious bed of the Oxford clay.

The Wey and the Mole would have a separate system, and be added, when the demand increased. The water from the upper portions of each stream would be brought down by a channel above the surface of the ground of the main valley, so that no flood water or polluted water could enter.

1603. He proposes to intercept the sewage in two ways; for a certain distance up each contributing stream it would be by open drains, but above that (and in fact wherever it would be more economical), there should be compulsory power to raise and apply it to the hills, so as to favour a complete absorption of the sewage into the soil. Mr. Denton says—

1620. "Such a plan must be preferable to irrigation on low meadow ground, where the effluent water, passing *over* instead of *through* soil, must always be charged with a certain proportion of sewage in solution, if not also in suspension. A study of the geological character of the upper portions of the Thames basin—the chalk and the oolite—will satisfy you that, maintaining as they do the river system of the Thames, they are capable of absorbing sewage to any amount, with benefit rather than injury to the springs themselves."

The cost of the works is estimated by Mr. Denton at about 5,320,000*l*. He does not propose that the cost of the interception of the sewage should form any part of his scheme, as in two years the towns will be bound to carry it out themselves.

6838 et seq. 69. *Mr. T. C. Brown* of Cirencester has given valuable data as to the rainfall in the upper part of the basin of the Thames, from 1845 to 1868; it varied from 19·9 inches in 1854 to 48·8 inches in 1852, and the mean of the 23 years gave 30 inches. He gives information as to the sources of water in the Upper Thames district, and suggests that London might be supplied with pure water, for drinking purposes only, to the extent of say six to nine millions of gallons per day from these sources, conveying it to London by pipes along the Great Western Railway.

App. H. 6888 et seq. 70. *Mr. Bravender*, land agent and surveyor at Cirencester, who has also devoted careful attention for a long period to the upper part of the basin of the Thames, gives important geological and hydrological information on the subject, which will be found in his evidence and in Appendix H.

Regarding the springs in the oolites, we may make the following extracts:—

6906. What is the sum total of those various springs which you have described; you have described Boxwell spring which gives a yield of above 1,000,000 gallons a day, and you say that the pump at the Thames head delivers 3,000,000 gallons a day; can you enumerate the other springs?—There is a spring at Ewen which gives the same as Boxwell spring, or a little more than 1,000,000 gallons. There is Ampney spring at Ampney Crucis, two miles east of Cirencester, which is thrown out from the fuller's earth by a fault, and which gives out an enormous quantity. I find in April /66 I measured the entire flow near the mill and found it to be considerably more than 20,000,000 gallons in the day; and yesterday I visited this spring and carefully measured the flow of water, and find that upwards of 30,000,000 gallons were passing the bridge near the mill. I also visited Bibury spring and found it discharging rather more than the one at Ampney Crucis. There is a spring about a mile above that at Ablington which I have also gauged, and that gives out quite enough to turn a mill; the discharge is more than 2,000,000 gallons. Then there is a spring above Winson from the same source which gives out about a million and a half. The Bibury, Ablington, and Winson springs are on the Coln, the Ampney spring is between the Churn and the Coln, the Ewen spring falls into the Thames at Ashton Keynes and does not get into the Churn.

6907. What are the limits of height above the sea within which those springs occur?—They are all about the same level as Cirencester, or a little higher, from 300 to 380 feet above the sea.

He proposes to add about one-third to the present supply of the water companies, by collecting water in the valleys of the Churn, the Coln (Gloucestershire), the Windrush, and the Ock, and conveying it by a conduit or pipes to London.

Mr. Bravender estimates that about 9 to 11 inches of the mean annual rainfall is available over the whole district.

CLASS II.

From the Lee.

71. The possibility of increasing the supply from the basin of the River Lee, by storage reservoirs or otherwise, has been alluded to by several witnesses, but the only definite plan laid before us for this purpose is the following:—

Mr. Mylne's Plan.

72. Mr. R. W. Mylne, son and formerly assistant of the late Mr. Mylne, who was for 50 years engineer of the New River, has proposed a plan for increasing the supply of water from the basin of the River Lee, which is described at great length in his 4972 et seq.
evidence, and is illustrated by the map, Appendix Z.

He proposes to make the drainage area better available by collecting the streams and chalk springs into impounding reservoirs to be formed at various places, but principally at Enfield Chase, which, being on the London clay, is, he conceives, more favourable for the purpose than any sites that can be found on the Lee proper.

This plan would, he states, bring 70,000,000 gallons daily into London, in substitution for the present supplies of the New River and East London companies, adding therefore about 28,000,000 gallons. This would be, he says, a minimum on the driest years.

The cost of these works, excluding compensation, is estimated by Mr. Mylne at 1,250,000*l.*

The following extracts from Mr. Mylne's evidence will illustrate the nature of his plan:—

"In contradistinction to the view recently put forward, that no means of storage could profitably be carried out without descending as low in the valley as Broxbourn or Waltham, it is herein suggested that a considerable quantity from the upper tributaries mostly of pure spring water might be diverted and transferred by gravitation from a point above Hertford direct to convenient sites for reservoirs at Enfield Chase on the 4995
London clay beyond and altogether outside of the watershed of the upper portion of the Lee basin, and a further quantity might be impounded within the basin in the valley of the Rib. It is proposed to make diversion cuts on the before-named four tributaries, viz., the Lee proper, the Mimram, the Beane, and the Rib, and convey the collected quantities along an artificial channel to a point in the valley 2½ miles above Hertford; the total contributing area would be 246 square miles, giving an average daily yield of 43,000,000 gallons, but it is only proposed to take 40,000,000 gallons, and to convey that volume in a direct line to London through a tunnel and covered channel 5½ miles in length into reservoirs proposed to be made on Enfield Chase. The two proposed reservoirs to be made, into which the waters would gravitate, will cover an area of 70 acres, and will contain, including the tunnel, 1,391,000,000 gallons with a top-water level of 130 feet above Trinity high-water mark and a maximum depth of 37 feet of water. . . . . . . In order to increase the extent of reservoirs on Enfield Chase, and to bring a higher water level into use for distribution, it is proposed to construct four further reservoirs at the additional height of 36 feet, and to lift into them by steam power a considerable portion of the collectable quantity entering into the two gravitation reservoirs previously described. These will cover an area of 340 acres and will contain 1,249,000,000 gallons, with a top-water level of 166 feet and a maximum depth of about 38 feet of water. The total storage capacity of the six reservoirs on Enfield Chase would therefore amount to 2,640,000,000 gallons or 423,552,000 cubic feet. The execution of the tunnelled part would be throughout its length entirely in chalk and being near to the upper surface of the chalk and overlaid with tertiary sands and intersecting the local disturbance already alluded to, as well as across the general dip of the chalk, no doubt a considerable quantity of water may be expected. It is assumed that from the tunnel works, with the additional seven square miles of gathering ground at its southern end, together with the Lee tributaries, it will secure a total daily yield of at least 47,000,000 gallons. The storage capacity necessary for securing a uniform daily flow has been ascertained at Feilde's weir to be for 118 days 66,000,000 gallons a day, and inasmuch as the volume is proportionably much larger and more constant from the upper tributaries, it is estimated that a provision of 90 days' storage would be quite sufficient for the extended gathering ground. On the Rib it is proposed to adopt the plans designed by the late Mr. Rendel for the reservoir below Standon, which exceeds 200 acres, and would hold above 500,000,000 gallons, with a maximum depth of 20 feet of water. . . . . . . Besides the works contemplated for the diversion of the upper tributaries of the Lee, it is intended to retain the New River channel for the flow of the Chadwell spring, and to collect all the springs issuing from the west bank of the valley between Amwell and Rye House, and lift them by steam power about 10 to 15 feet into the New River; also to purchase the water rights of the copious springs which now work Hoddesdon Mill and to collect those and others in the locality, and lift them also from 15 to 20 feet into the New River. Those sources, it has already been stated, may be calculated upon to yield the respective quantities of 4,500,000, 6,000,000 and 8,000,000 gallons per day, and out of the gravels and sands near Hoddesdon, where the water is assumed to absorb and soak away into the sands under the London clay, a quantity of at least 4,500,000 may be estimated, and could be lifted into the New River at a height of not more than 20 feet. A very much larger quantity from this source might possibly be obtained, but perhaps only effectively by longitudinal adits or driftways up the sides of the valley, works which are not contemplated in the present scheme. The collective quantity of all these strictly spring waters could be secured at a very small cost, and would amount in quantity in dry seasons to about 23,000,000 gallons per

day, a volume equal to the present flow in the New River, and therefore, notwithstanding the proposed abandonment of all further abstraction of water out of the Lee at Ware, the New River would remain in its present condition as to volume as far down as Enfield, where further works are suggested. . . . . . With regard to the manner of distributing the total daily yield of 47,000,000 from the store reservoirs and 23,000,000 gallons from the New River, in all 70,000,000, there are various modes of division that might be made, but considering that two companies have to be provided for, it is suggested that the East London Company should have 30,000,000 delivered over 24 hours, from filter-beds placed at the foot of the high-level reservoirs, and pipes from thence to Stamford Hill, delivering at the level of 112 feet into a service reservoir. The East London Company have a small reservoir at Stamford Hill, and I propose by means of a large main to deliver there at the level of 112 feet, and from thence the distribution over the whole of the East London district would be by gravitation, except perhaps a small area immediately in the vicinity of Stamford Hill itself."

5000. "The advantages to the East London Company are, that the water would be drawn from a purer source than at their present intake, being freed from the valley drainage and future cost of diverting it, and obtaining a gravitation supply in lieu of pumping, and the New River Company would have an increase and improved supply, freeing them from the necessity for many years to come of looking to the river Thames or other distant sources, but confining their endeavours to within the legitimate and as yet unutilized valley waters of the river Lee."

5024. "That would be 63 days' storage on Enfield Chase, with a further storage on the river Rib."

CLASS III.

From the Chalk Formations in the Basin of the Thames.

73. Many witnesses have alluded to the great natural storage of water in the porous strata, chiefly the chalk, which form so large a portion of the drainage area of the Thames basin. By reference to the geological map (Appendix Y.), and to the evidence of
3041. Mr. J. T. Harrison, it will be seen that out of 3,676 square miles of surface no less than 1,047, or two-sevenths of the whole, consist of the chalk downs so well known, and extending so widely over this part of England. These strata absorb and store a large portion of the rainfall; and although much of this store finds its way by springs into the streams, and so already contributes to the supplies drawn from them, there has always been a desire on the part of those interested in water collection to go in preference directly to the stores themselves.

The water in the chalk round London has repeatedly been proposed as a source of supply, either wholly or partially, for the metropolis. The New River was constructed to take advantage of chalk springs, and a large portion of the water it at present conveys comes from this source.

It is on record that in 1827, Martin, the artist, proposed to bring the water of the Colne (the principal chalk river to the north of London) to the metropolis, and Mr. Telford, in 1834, proposed to supply London from the Verulam and the Wandle, both effluents directly from the chalk. A few years later, in 1840, a company was started called the London and Westminster Water Company, who chose Watford as their source, backed by a strong approving report from the late Robert Stephenson; and some years later this was revived under the name of the London (Watford) Spring Water Company.

The Chemical Commission of 1851 devoted considerable attention to the examination of the chalk water, and recommended it strongly as the best supply for the metropolis, on the ground that the quantity was large, and the quality superior to that of any other water that could be obtained. The following extracts from their Report will illustrate their views on the subject :—

"The water which it is proposed to bring from the neighbourhood of Watford, for the supply of the metropolis, claims consideration as being entirely spring water, and has a peculiar scientific interest as representing the pure primitive basis of the river water which is at present consumed. A supply of water of the same description is also offered from the south side of the river, to be derived from the chalk strata upon the line of the South-eastern Railway, and the quantity attainable on either side is said to be so considerable as to exceed the actual requirements of the metropolis. Of the chalk district, which surrounds London on all sides, and covers an area of not less than 3,000 square miles, the upper strata appear to be charged with water to a height of several hundred feet above the level of the sea. This water issues again in numerous natural springs, or may be reached by moderate boring. The daily yield of single springs or of artificial wells in some parts of this district is remarkable for its quantity, often amounting to 300,000 gallons, and occasionally rising to 1,000,000 gallons and upwards; a copiousness of flow, which is referred to the chalk rock being highly pervious to water, from its fractured and cavernous state. This chalk spring water is not to be confounded with the water of the deep wells of London, although the latter are carried into the chalk strata below the clay, but differs as completely in composition from the latter as any two waters can well do. Nor does any evidence exist of a relation or dependence of the London deep wells upon the water of the chalk districts; nor reason to infer that the yield of the latter would be restricted within the narrow limits of the former. Indeed, all grounds for comparison of the two waters will disappear if it is true, as many well-informed persons believe, that the deep wells of London draw their supplies chiefly from the sands under the blue clay and above the chalk, the water of which sands appears to flood the upper beds of the chalk. The superposition of the thick mass of strata which form the London clay, certainly alters considerably the condition of the chalk below it, and renders it no longer comparable with the water-bearing strata of chalk in Hertfordshire and Kent, which are not so covered, and are situated above the level of the sea. The whole original supply of the New River Company, from the Chadwell and Amwell springs, was water of the kind under consideration, and a very sensible proportion of the present large supply of that company is still spring or well water of the same nature."

"On comparing the Watford spring water with the New River water and Thames water as supplied by the water companies, a considerable similarity is observed in the character of their saline constituents. The lime is in larger quantity in the spring water, but then it is nearly if not entirely in the state of carbonate. The earthy sulphates, which give rise to permanent hardness, are almost entirely absent from the spring water. The general character of this supply may be further described as follows :—

"1. The spring water contains no matter in suspension to cause turbidity or colour; its clearness and brilliancy are unexceptionable.

"2. It possesses a desirable coolness, having at all seasons a temperature between 50° and 52°.

"3. The amount of organic matter it contains is inconsiderable, and of a kind which appears to be incapable of undergoing putrefactive decomposition, so that it may be safely disregarded.

"4. The salts which it contains would not interfere with its use as a beverage. It is indeed a choice water for drinking."

We have received the four following propositions for utilizing this source.

74. The *Rev. J. C. Clutterbuck*, who has paid much attention to this subject, gives his views upon it at considerable length. 1782 et seq.

He believes that considering the large chalk springs issuing at high levels in various places round London, it would be possible to find in such springs a considerable quantity of water, of good quality. The most reliable sources are springs in the chalk, and speaking of their abundance he says :—

"Along all valleys in which rivers run, the Kennet, for instance, the chalk streams are fed from their sources down to the place where they deliver themselves into the river, because they run just on the springs, and are fed as they go. You may not see very large springs, but you will see an immense gathering of water in the course of the river by the discharge of the water from the springs." 1836.

He disapproves, however, of obtaining the water from the chalk by pumping, in regard to which he says :—

"You would obtain a certain quantity, but it would be at the expense of the rivers; the rivers would cease to flow. When my advice has been asked I have invariably said, Take the water as it flows above ground, and do not tamper with it below; that is what I have invariably said, and I believe it is sound advice." 1837.

By taking the water as it flows down the rivers, and by an arrangement of reservoirs, he considers there might be an immense storage of water in the upper districts.

The springs in the chalk under London have, he considers, been over-taxed, and the consequence has been an unnatural depression of the water. Any hope of obtaining a supply for the metropolis from this source would in his opinion be a failure.

75. *Mr. Homersham*, civil engineer, who has supplied Caterham and other districts with water drawn from the chalk areas round London, proposes to supply the metropolis entirely with spring water from the chalk, and to do away with the present supply taken from the Thames. He believes that there would be no difficulty in getting from this source a very large quantity. The cost would be small, by reason of the readiness and cheapness with which water can be obtained from the chalk in well-selected situations. He considers that any objection to the hardness of chalk water may be obviated by the use of Dr. Clark's softening process, in which he has had considerable experience. 6762 et seq.

The water at Caterham appears by Dr. Frankland's analysis to be remarkably free from organic matter. App. AX (2.)

76. *Mr. P. W. Barlow*, civil engineer, believes that the ultimate solution of the difficulty of supplying London will be found in the chalk. He has found several powerful springs issuing from the chalk on the south side of the Thames; in one small district near Gravesend they amount to 10,000,000 gallons per day. He believes that by driving a tunnel parallel with the river, 20 miles long, from Lewisham to Gravesend, or a little beyond, 60,000,000 gallons per day might be obtained. 5959 et seq.

77. *Mr. R. Meeson* has given us an account of large springs issuing from the chalk pits at Grays, in Essex, and which furnish an abundant supply. The water is of good quality, limpid and of uniform temperature, very similar to that of the Amwell springs, but rather harder, being 16·6° of Clark's test. About 450,000 gallons per day are at present used to supply Brentwood and Romford and parts adjacent. About 6863 et seq.

7,000,000 gallons per day have, however, been raised, and Mr. Meeson believes the springs would supply 10,000,000 at least.

We add some extracts from Mr. Meeson's evidence:—

"The water springs are situate in the chalk pits at Grays in Essex, about a mile distant from the Thames. When undisturbed they rise to a height varying from about four feet to eight feet below Trinity high-water mark. . . . . . . The depth of water which passed over the gauge, which was 3 feet 8 inches wide there, was 5¼ inches, so that the quantity then obtained every 24 hours exceeded 2,100,000 gallons, besides that used on the works. This quantity was delivered daily, the engines being worked day and night, ceasing for only a few hours between Saturday evening and Sunday morning. During the week the water was lowered about 12 feet, and it then became possible to excavate the chalk to that additional depth over a small space; but when the engines ceased working the water speedily rose to its former height, and it occupied an entire day and night so to reduce the water as that work might be resumed; and throughout the entire remainder of the week the springs yielded the supply I have mentioned, which was all that the pumps then in use were capable of delivering. . . . . . . These operations have been carried on now for many years, yet notwithstanding so large a quantity has been pumped daily into the Thames, no perceptible alteration has taken place in either the quantity or quality of the water."

CLASS IV.

Miscellaneous Schemes.

Mr. Hennell's Plan.

1913 et seq. 78. Mr. Thomas Hennell proposes to bring 14,000,000 gallons of water per day to London, in extension of the present supply, from the Basingstoke Canal, and from sources adjacent to it, aided by storage reservoirs to hold 840 millions of gallons. He would purchase the canal from the company and use it as a conduit, forming a paved brick channel throughout its length.

He calculates that six-sevenths of the water would come from the chalk at the Basingstoke end of the canal, where it is 252 feet above ordnance datum, and the remainder from the district of the Bagshot sands between Farnborough and Woking. The quantity might, however, be largely increased.

In answer to questions respecting the springs intersected by the canal in passing through the chalk below Basingstoke, Mr. Hennell states:

2013. "To take first the Whitewater; that I found in October contained, in round numbers, 10,500,000 gallons. I propose to take one-third of that, and that is rather the largest of the three principal sources."

2014. "I measured the stream again last week, and I found 14,500,000 gallons daily. Then, in addition to that, there are the Mapledurwell and the Newram springs within a mile of Basingstoke."

2015. "The Mapledurwell springs contain 1,980,000 gallons. There are springs east and west of the village; those which are on the east side of the village I cannot conveniently take, because they are at a low level, but they unite afterwards, and therefore I take two-thirds of the western springs only, which would be equal to one-third of the whole. They unite before they come into any stream where they would be required, and therefore I take two-thirds of 1,980,000, that is 1,320,000. Then the Newram springs contain, in round numbers, 4,500,000, of which I take two-thirds; that is 3,000,000."

2016. "The entire total is 28,296,000."

The water would be conveyed by the canal to a point near Weybridge, from whence a conduit eight miles long would have to be made to Thames Ditton, where the water would be received by the companies and pumped for the supply of the town.

The estimated cost, including the purchase of the canal, is set down by Mr. Hennell at 280,000*l*.

Mr. Ewens' Plan.

3685 et seq. 79. Mr. G. W. Ewens points out the existence of certain springs in the chalk from Emsworth to Bedhampton near Chichester, from which he believes a large quantity of pure water might be obtained of a quality very similar to New River water. He mentions springs of this kind at Emsworth, Havant, Bedhampton, Brockhampton, and Langbourne, and adds:

3699. "There are six streams formed by nine separate series of springs; each of these streams flow into the sea at an average distance of half a mile from the spot from whence they take their rise. There are eight flour mills driven by these six streams."

The water might be pumped into large reservoirs on Portsdown Hill and near Petersfield, and conveyed by a conduit to London.

Mr. Telford McNeil's Plan.

5815 et seq. 80. Mr. Telford McNeil proposes to give a supply of 200,000,000 gallons daily by intercepting water from the Thames at Teddington, raising it 200 to 380 feet, and conveying it in an open channel to the Bagshot sands, through which it is to be made to filter, and from which it is to be conveyed back in a closed conduit to London, and again pumped into reservoirs at Norwood and Hampstead. The estimate is something above 6,000,000*l*.

Remarks on the above-mentioned Plans.

81. The chief feature of Mr. McClean's plan is the mode by which he proposes to effect the storage in the Thames, and this may deserve consideration whenever it may be found necessary largely to increase the quantity of water drawn from the river. The plan for taking the water from Medmenham would be very expensive, and, probably, of doubtful utility as regards quality (for reasons that will hereafter be shown), while it would be open to the objection of depriving the 37 miles of river between Medmenham and Hampton of a large proportion of its dry weather volume.

The plan of Mr. Bailey Denton, a gentleman of very large experience in drainage matters, is remarkable on account of the manner in which he proposes to deal with the sewage. His opinions also as to the mode of increased storage are valuable.

Mr. Brown and Mr. Bravender point to the value of the springs in the oolites as subsidiary sources of supply.

The plan of Mr. Mylne for increasing the supply from the Lee presents some ingenious and novel features. By the proposed mode of collection he would obtain the water in a state of greater purity than at present, while the mode of storage also claims advantages over former plans. We question whether the quantity Mr. Mylne estimates could be rendered available in the driest seasons, but if any measures should be considered desirable for enlarging and improving the supply from the Lee, his plan would deserve consideration.

With respect to the water sources in the chalk formations we shall speak more at length hereafter. Mr. Meeson's springs at Grays deserve special mention on account of the practical use already made of them by him.

Mr. Hennell's plan has some novelty, but the water might probably be more advantageously utilized for other towns nearer the line of canal.

Mr. Ewens calls attention to some fine springs; they are too far away to be of use for London, but might probably be of value to towns in the neighbourhood.

GENERAL REMARKS ON THE SOURCES AND SPRINGS IN THE THAMES BASIN.

82. It may now be well to review all the resources of the Thames basin before we proceed to consider the important question of the future supply of the metropolis.

83. In order to explain the geological and physical features of this tract of country we have had prepared the large map of the Thames basin marked Appendix Y (1). It is drawn on the scale of six miles to an inch; it shows by colours the various geological formations; and it has contour lines marked upon it at every 100 feet difference of altitude, by which the levels of the ground at the various parts of the basin may be seen. Another corresponding map, Appendix Y (2), has the contours shaded, by which the varying elevations of the ground are made more distinct.

84. The drainage of the Thames valley above Kingston extends over 3,676 square miles; this area receives an average annual rainfall of about 27·2 inches, and one-third of the quantity due to this rainfall flows down the Thames at Hampton.

This delivery is the result of very complex conditions. One third of the area consists of impermeable clays, and two-thirds (or about 2,450 square miles) of permeable oolitic limestones, sands, and chalk. From the former, the rainfall, after allowing for evaporation and for vegetation, flows off at once, and whenever in excess gives rise to floods, whereas the rainfall on the latter is at once stored up, and its ultimate delivery through springs to the streams and rivers is spread over weeks or months. To this cause is owing the permanence of flow of a river draining a permeable rock district, compared with the irregular delivery of a river draining an impermeable district, and it is a consideration of great importance in a question of water supply.

85. In order to indicate the extent of the underground reservoirs formed by the permeable strata, and the sources on which the springs depend for their supplies, we have constructed a series of sections, shown in Appendix Y (3). A complete and elaborate survey would be necessary in order to give the exact lines, whether of the surface of the ground or of the levels of the underground water, but these sections will serve to give an

idea, sufficiently approximate for our object, of the extent and capacity of the underground reservoirs on which the streams depend for their supplies during periods of drought.

86. All permeable formations tend necessarily, by the absorption of rain, to become charged with water up to the level generally of the streams and rivers of the district; and further, owing to the resistance experienced by the rain water in passing through the strata, the water, wherever the ground rises above the level of the rivers, accumulates therein in proportion to the length, breadth, and height of the range of hills, so that instead of the line of underground water level presenting a flat surface between two valleys, it presents a curved surface varying according to certain conditions. Taking the lowest point of escape as determining the permanent level above which all the water tends to run off in springs, the height of the curve above this level gives the head of water on which the springs depend for their supply. The rise of the water being from the circumference of the hills to the centre, the underground reservoirs form more or less dome-shaped masses, the surface of which is constantly fluctuating in proportion to the difference between the amount of rain percolating through the strata and the quantity of water which escapes by the springs.

In the district we have to deal with, the crown of the curve often rises 50 to 200 feet or more above the permanent spring levels, while the actual height of the curve is known to vary in accordance with the variation in the rainfall, in many cases as much as 50 to 80 feet or more. Where the conditions are favourable to a large underground reservoir the springs hardly ever run dry. Mr. Beardmore, as the result of many years' observations in the chalk district of the Lee, sees reason to believe that the storing power of the chalk hills there holds out at least 16 months.

The darker water lines in the sections represent the upper portion of the head of water accumulating in the hills, and serving to feed the higher and smaller springs; the next shade shows the larger portion which goes to feed the lower and more perennial springs. The portion of the sections over which the faint water lines extend represents theoretically those portions of the permeable strata which are permanently charged with water, and from which wells can always draw a supply—in sand strata at once, and in the more compact limestones and in chalk as soon as any of the intercommunicating fissures or crevices are reached, unless any excessive exhaustion has produced a local depression of the water level.

Further, some of the water below the lines of permanent level inland has a slow underground movement to still lower levels, unless intercepted or thrown out by faults in the strata or by some other cause. This underground drainage is not, however, coincident with the surface drainage; and while some of the water-bearing strata of the Thames basin are not available as underground sources of supply by means of wells at or near London, other strata, on the contrary, out of the London basin, are so available from the circumstance of the dip of the beds being towards London. The extent of this underground area supposed to centre towards London is represented by dotted lines on the map, Appendix Y (1).

Where the permeable strata only cap the hills the springs issue of course on the sides of the valleys at the junction of the impermeable strata.

87. In the order of superposition the highest permeable strata near London, excluding the superficial beds of gravel, are—

The *Bagshot Sands*, which are from 100 to 350 feet thick and extend over an area of 211 square miles. As these strata consist almost entirely of loose quartzose sands, the underground water oozes out commonly at their junction with the London clay, and is rarely conducted into any particular channel of escape so as to form springs, and the loss by evaporation is large. There are in fact throughout this area no springs of any importance; only a few small tributaries of the Thames and the Wey have their sources in this district, and the supply to the wells is not large. The water generally is soft and pure, but in some places it is ferruginous. We cannot look to these sands for any additional water supply, (although they attracted a good deal of attention a few years since,) for the whole of the water now delivered by them passes into the Thames or the Wey. None passes elsewhere underground.

The *London Clay* underlies the Bagshot sands and forms a great impermeable bed from 400 to 450 feet thick.

Lower Tertiary Sands.—These beds, which are only from 50 to 100 feet thick, are of no importance so far as springs are concerned at their outcrop, but they have been useful sources of supply to some of the deep wells under London. Owing, however, to the great increase in the number of these wells, and the fall in the level of the water, the underlying chalk is now generally resorted to as the better source of supply. In many places round London where they have not been so drawn upon they still yield a good supply of water.

88. The *Chalk*, from its large area (1,047 square miles above Kingston, but more than double that in the whole basin); from its great thickness—500 to 1,000 feet—and from its peculiar lithological character, forms a very important source of water supply, both by springs and by means of wells. Almost all the rain falling on its surface is absorbed or percolates through the fissured surface. So close is its texture that the bulk of the rain takes weeks and months to filter down to the level of the water line in the interior of the chalk hills—a line the depth of which below the surface of the ground may vary from 100 to 300 feet according to the height of the hills. The water thus stored escapes in several ways—some by the streams rising within the chalk district,—some by springs feeding directly the larger rivers flowing through it,—another portion overflows at the outer escarpment of the chalk,—and a larger portion issues near its junction with the tertiary strata. A certain quantity also passes underground, supplies the wells, in the central tertiary area, and escapes in part at still lower levels at more distant points.

Where the rise of the bottom of the valleys is more rapid than that of the line of water level, the valleys assume the character so common in chalk districts, of dry valleys. Others of these valleys tap the springs in their lower part, whilst the upper part of the same valley is dry. In these cases the head of the stream will often change its position two or three miles higher or lower in the valley, accordingly as the rise and fall of the water level in the hills are influenced by the rainfall. Where the deeper and larger river valleys traverse the chalk area and intersect the line of water level, these valleys become fringed on the river level with a series of springs, as the Thames in its course from Wallingford to Taplow, the Lee above Broxbourne, the Ravensbourne, the Cray, and the Darenth, and the Thames again from Woolwich to Gravesend.

The springs along the line of outcrop of the chalk marl and gault being on a higher level than any others, the head of water supplying them is much smaller than that supplying the springs on lower levels within the chalk area, and consequently with few exceptions these springs are small. They are, however, extremely numerous. Almost every little village under the range of the chalk downs in Wiltshire, Oxfordshire, and further eastward, has its spring near the foot of the chalk hills. These collectively would furnish a considerable quantity of water, but they are too scattered and wide apart to be available for any general purpose. There are, however, a few large springs amongst them. There is one, for example, at Cherhill near Calne. This spring never fails, and is said to yield from two to three million gallons of water daily. It is represented at the end of section No. 4, Appendix Y (3). There are also copious springs near Ellensborough, at Barton-in-the-Clay near Prince's Risborough, near Swindon, and at many places along the foot of the North Downs of Kent and Surrey.

Another and more important class of springs are those which escape along the inner edge of the chalk along or near the line where it passes under the tertiary strata, and again where it approaches the sea level. These springs are all placed on relatively low levels, and derive their supplies from the large head of water which extends in the chalk hills beyond them up to the outcrop of the beds underlying that formation. As the difference of level between these exterior and interior springs varies often from 150 to 300 feet, the latter are necessarily much more powerful and permanent, and will continue to run long after most of the others have become dry. Among the more copious and remarkable springs of this class are those at Chadwell near Ware, Otter's pool near Watford, Froxfield near Hungerford, Beddington and Carshalton, Orpington, Grays Thurrock, Springhead near Gravesend, Ospringe near Faversham, besides a number of smaller ones. The origin and source of supply of some of these springs are indicated in the sections.

In the neighbourhood of London the wells in the chalk form an important auxiliary source of water supply, and they might, no doubt, be considerably increased in Kent without interfering with the springs in the valleys above London, as the store from which those wells draw their supplies overflows in numberless springs along the Thames below London at levels where they are not generally available.

The lower beds of the chalk are so argillaceous as often to hold up the water and to lose their ordinary permeable character.

89. The *Upper Greensand* forms so much a part of the lower chalk, and is so slightly developed near London, that we have grouped it with the chalk. It is only in Wiltshire that it acquires an importance entitling it to be considered apart. Under London it becomes also so argillaceous as to lose its water-bearing character.

The upper and lower Greensands are separated by 100 to 200 feet of impermeable clay, known as the *Gault*. The numerous small streams rising at the foot of the chalk hills have their source generally in springs thrown out by the chalk-marl, or the gault.

The *Lower Greensands* form a mass of siliceous sandy strata from 200 to 500 feet thick, and with an available area of above 500 square miles. Cropping out both to the north and south of London conformably to the chalk, which is known to pass below the tertiary strata under London, it was supposed that the Lower Greensands were also continuous below London, in the same way as the Lower Greensands of the plains of Champagne pass under Paris at the depth of 1,800 feet. The experience, however, obtained at Kentish Town, at the deep well sunk through the chalk a few years since by the Hampstead Company, showed that although the tertiary strata, the chalk, and the gault followed in regular order, a change took place at the base of the gault, and instead of the lower greensands, a series of red and grey sandstones were met with. These were bored into for a thickness of 188 feet without passing through them and the work was abandoned. (Appendix, Y 3, Section No. 2.) No organic remains were discovered to indicate the age of these sandstones, and the hand specimens were insufficient to determine the question. They may have belonged to some member of the New Red Sandstone, or possibly to the Old Red. In any case they seem to form part of an underground ridge of old secondary or palæozoic rocks which, ranging from Belgium, pass under the chalk at Calais and Harwich, at both which places they have been met with, and probably extend under London in the direction of Somersetshire. The width of this belt can only be determined by experiment.

It is known that the Lower Greensands exist at Reigate and are about 450 feet thick, and that they occur again in Bedfordshire with a thickness of about 200 feet. In both cases they dip towards London, disappearing beneath the gault. We know that they do not exist under London (Kentish Town). It follows, therefore, that in the one case they cease at some point between Reigate or Merstham and London, and in the other between Baldock and London. As at both ends they are of considerable thickness, and the gault is continuous, it is certain that the greensands must range from these outcrops some way towards London, probably thinning off gradually against the flanks of the underground ridge of old rocks. So far as they continue, so far will they form a valuable and copious water-bearing bed, the water from which would overflow at the levels lower than that of their outcrop. The extent of their underground range could only be determined by boring. It might be as far as Croydon, or even still nearer to London. The same would happen to the north of London, but the distance there is greater, the beds are not so thick, and the conditions generally are less favourable. The great purity of the water from the Grenelle and other artesian wells in the Lower Greensand is well known, and there is reason to suppose that the quality of the water obtained from the same formation in the vicinity of London would prove equally good. The excessive length of filtration would at all events ensure freedom from organic impurities.

The quality of the water flowing from the Lower Greensands is excellent for all domestic purposes, being bright and limpid, of a degree of hardness varying only from about 3° to 9° of Clark's test, and generally very free from organic matter. A considerable amount of evidence on the quality of this water was collected by the Board of Health in 1850.

The springs in this formation are not very numerous, owing to the prevalence of sandy beds, but in some of the more stony beds there are some fine springs, as for example :—

1. The springs in Bradbourne Park and at Riverhead near Sevenoaks.
2. Several springs near Dorking.
3. Spring at Weston Street.
4. Spring at Moorhead Park near Farnham.

90. To the south of London a great thickness of *Weald clay* separates the Lower Greensand from the *Hastings sand* of the weald of Kent and Sussex; but although these beds are thick they are very local, only partially permeable, and are of no avail.

91. The strata which next succeed are only developed in the north and north-west of the London basin.

The *Portland Stone and Sands* are from 35 to 50 feet thick, and are, in some places, of local importance, but none of the springs would be available for distant purposes.

The *Kimmeridge Clay* is impermeable and from 250 to 300 feet thick.

The *Coral Rag* and *Calcareous Grit* are from 20 to 50 feet thick and give rise but to a few small springs. These beds thin off as they range to the east and south-east, so that in Buckinghamshire and probably underground in Berkshire the Kimmeridge and Oxford clays come into contact, and the coral rag ceases to exist.

The *Oxford clay* is impermeable, and attains in Oxfordshire a thickness of 400 to 500 feet.

92. The *Great Oolite* and subordinate beds may for our purposes be taken together. They form in Oxfordshire an important group of permeable strata 250 to 300 feet thick. They have a collecting area of about 300 square miles, and give rise to a number of fine springs, amongst which those of Ampney, Bibury, Boxwell, and Thames Head have been described by Mr. Bravender and Mr. Brown, and are stated by Mr. Pole to have been yielding at the time of his visit probably not less than 10 million gallons of water daily.

Most of the springs of this series are thrown out by the *Fullers Earth*, an impermeable bed of no great thickness in this district—40 to 60 feet—and persistent only over a limited part of the area. (See section No. 3.)

The *Inferior Oolite* and underlying sands reposing on the lias form another important water-bearing formation. They are from 300 to 320 feet thick, and extend in the Thames basin over about 180 square miles. As the hills of this formation rise 230 to 300 feet above the valleys and have a considerable range, the head of underground water is large and furnishes several important and perennial springs, such as those of Syreford, and the Seven Springs, of which the yield is stated by Mr. Pole to have been at the time of his visit from three to four million gallons of water daily. (See section No. 3.)

These various oolitic strata consist of beds of rubbly limestones, soft freestones, sands and fissile sandstones, through which the water passes chiefly by fissures; and although often traversing a great thickness of strata, it is not filtered to the same extent as it is in the chalk and Lower Greensands.

Mr. Hull has shown* that the inferior oolite and underlying sands, which in the neighbourhood of Cheltenham are about 320 feet thick, thin off as they range eastward, and probably die out about the centre of Oxfordshire. In the same way he shows that the great oolite and accompanying beds, there about 300 feet thick, also thin to the eastward, and they apparently do not extend more than a few miles further east than the inferior oolite.

It follows that the underground passage of water through these oolites, which might, had these formations ranged in full force eastward, have been carried as far as London, the dip being in that direction, is stopped by the thinning out of those beds, and by the closing in, as it were, of the Lias, Oxford clay, and Kimmeridge clay. Although, therefore, the surface drainage of the Cirencester and Bampton districts runs into the Thames valley, the subterranean water channels are intercepted and do not reach London, and the oolitic series must be excluded as a possible source of supply by deep wells in the London district.

93. The exact proportion of the rainfall absorbed by the different permeable and porous strata, and which is given out again in the form of springs, yet has to be determined. It varies according to the lithological character of the water-bearing strata. The general results are, however, known in many cases. Thus the annual flow of the Thames at Hampton and of the Seine at Paris, both draining areas composed partly of permeable and partly of impermeable strata, is equal to about one-third of the rainfall. In a district where the impermeable strata predominate, the total deliveries will be larger, but they will follow close upon the rainfall; whereas, as the permeable strata predominate, so will the rainfall be stored in the hills, and its delivery be spread over a greater length of time. The summer flow in a dry season consists almost entirely of the supplies derived from deep-seated springs. Mr. J. T. Harrison, to whose evidence we would refer for many interesting details on these points, estimates this generally in the Thames district to be equal to one-sixth of the rainfall.

94. The importance of such a condition of things for the supply of this large metropolis cannot be over-estimated. It ensures that permanence and regularity which are necessarily among the most important elements in a metropolitan water supply. With natural subterranean reservoirs extending over above 2,000 square miles, a storage reserve is provided comparatively independent of the seasons, and maintained by the ordinary operations of nature, while no filtration can equal that effected through masses of sand, sandstone, earthy limestones, or chalk, from 50 to 300 feet thick. The quantity of mineral matter taken up is in most cases moderate, while the really objectionable ingredient—the organic matter—is reduced to a minimum. However different the results obtained in

* Quart. Journ. Geol. Soc., vol. xvi. p. 63.

other cases, the two under-mentioned eminent chemists agree in their conclusions on this point, as will be seen by the following table, the quantities having reference in the first case to 100,000 parts, and in the second to a gallon of water :—

	Dr. Frankland.			Prof. Wanklyn.
——	Organic Carbon.	Organic Nitrogen.	Nitrogen as Nitrates and Nitrites.	Albuminoid Ammonia (representing the Organic Matter containing Nitrogen).
Caterham well (chalk) - - - -	·020	·006	·027	0·000
Spring near Moor Park (lower greensand) -	·030	·010	·045	—
Cold Harbour (lower greensand) - -	—	—	—	0·000
Otter Spring (chalk) - - - -	·026	·012	·422	—
Loch Katrine - - - - -	·256	·008	·031	0·130
Welsh waters - - - - -	·289	·004	·022	—
Cumberland Lakes - - - - -	·211	·006	·009	—
Thames water at Hampton - - -	·260	·024	·192	0·134

At the same time the water is kept at a uniform low temperature and protected from light and air, conditions unfavorable to the existence of living organisms. Springs from such sources probably represent potable waters in their best state; and amongst the favourable specimens of such waters may be instanced many chalk springs, the water from the lower chalk at Caterham, and some of the springs of the Lower Greensands ot Surrey.

It is satisfactory to know that there exists within easy reach of London a supply of the best and purest spring water which, in case of need, could readily be rendered available as an auxiliary source of water supply for the metropolis, in quantity sufficient at all events for drinking, if not for other purposes.

PART III.

ON THE PRESENT WATER SUPPLY OF THE METROPOLIS.

95. We now proceed to consider "the present water supply to the metropolis."*

We have accounts of the existence, at a very early date, of artificial works for the water supply of London, in the form of certain conduits, some of whose names still survive in *Conduit Street*, *Lambs Conduit*, and *White Conduit*, and the object of which was to bring for the use of the inhabitants the waters of local springs; but about the middle of the sixteenth century the metropolis had so increased in extent that these were no longer sufficient, and attention became directed to procuring supplies, by mechanical means, from the fine river running close to the city walls.

96. The first systematic attempt to supply London from the Thames was made by Peter Morrys, an ingenious Dutchman, who in 1581 obtained the consent of the corporation to erect a water-wheel under one of the arches of London Bridge; this, being turned by the tidal stream, worked forcing pumps, which impelled the water through the leaden or wooden pipes in the streets, and thence by branches into the houses. The *London Bridge Waterworks*, thus established, subsequently increased in magnitude, and kept up a considerable supply for two hundred years.

97. But as London extended, Morrys's mains and pumping power were, in that infant state of hydraulic science, insufficient to supply the higher and more remote parts of the town, and attention became redirected to sources inland. In 1606 an Act of Parliament was obtained to enable the corporation to bring a stream of clear pure water to the metropolis, from certain copious springs in the chalk at Chadwell and Amwell, near Ware; but the corporation, alarmed probably at the magnitude of the plan, hesitated to commence the works, and nothing was done until, in 1609, an enterprising citizen, Mr. Hugh Myddelton (afterwards Sir Hugh Myddelton, baronet) offered to execute them single-handed, on condition that the authority obtained from Parliament should be transferred to him. This offer was accepted, and he at once commenced the work; but through a complication of difficulties, and the refusal of the corporation to aid him (although he had brought his canal to within a few miles of London), he was compelled to appeal to King James I. for the means of completing his work. The King furnished the necessary grant of money on condition that half the property in the undertaking should be ceded to him, and in September 1613, the canal, then dignified with the name of the *New River*, was completed, conveying the pure Hertfordshire spring water into the reservoirs at Clerkenwell. Thus was introduced into the metropolis a true systematic "water supply by gravitation," after the manner of the ancients.

98. The New River and the London Bridge works, aided by the local springs, with many public pumps and shallow wells, kept the greater part of the metropolis well supplied with water for the whole of the seventeenth century; but as buildings began to extend westward new demands arose. Soon after the opening of the New River, the chalk springs had been supplemented by tapping the River Lee, near to them, but parts of London required water where the London Bridge and New River mains did not reach, and again the Thames was resorted to for an increased supply. In 1691 a company was formed, called the *York Buildings Waterworks Company*, for supplying a part of Westminster with water pumped from a point in the river near Charing Cross. These works flourished for some time, but were in 1818 leased to the New River Company, and in 1829 were abolished altogether.

In 1723 a more successful attempt was made in the establishment of the *Chelsea Waterworks* for supplying Westminster and the parts adjacent with water from the Thames at Chelsea Reach. The company first purchased some small works at Millbank, but afterwards removed to a site near the foot of the present Victoria railway bridge, where they erected a pumping establishment.

* The information in this part, where not obtainable from official documents, has been taken from Mathews's "Hydraulia" and Weale's "London in 1851," or gained by communication with the officers of the companies.

99. The portion of the metropolis south of the river was supplied at a very early date by two wheels erected under London Bridge near the Surrey shore, and by separate works not far distant.

In 1785 the *Lambeth Waterworks Company* was established for supplying the parish of Lambeth and parts adjacent with water pumped from the Thames at a site opposite Charing Cross.

100. During the eighteenth century the existing waterworks were gradually enlarged and improved, and iron street pipes were introduced in lieu of wooden ones, a change which not only enabled the old works materially to extend their supplies, but gave a great advantage to new companies entering the field in competition with them.

101. In 1806 the *West Middlesex Water Company* was established for supplying the western suburbs from the Thames at Hammersmith; and in 1811 another company was formed who availed themselves of power granted by a clause in the Grand Junction Canal Company's Act for supplying, to the north-west of London, water brought by the canal from the rivers Colne and Brent, and from a large reservoir supplied by land drainage in the same neighbourhood. These waters were represented to be much superior to that of the Thames; but experience disappointed the hopes of the projectors; the water was found not only bad in quality, but deficient in quantity; and after vain expedients to remedy the evils, the company, which had taken the name of the *Grand Junction Waterworks Company*, resorted in 1820 to the Thames, taking their entire supply from a point near Chelsea Hospital.

102. While these works were going on in the west, the inhabitants of the other part of the metropolis had not been idle. The districts eastward, beyond the reach of the mains of the New River or London Bridge works, had hitherto been dependent on two small establishments at Shadwell and West Ham; but as the population increased, and further supplies became necessary, a company was established under the name of the *East London Waterworks Company*, for supplying water from the River Lee. Their Act was obtained in 1806; they immediately erected works at Old Ford, near Bow, and soon spread their mains over an extensive district.

In the south districts a new company was established in 1805 called the *Vauxhall Waterworks Company;* they took water from the River Effra, and afterwards from the Thames near Vauxhall Bridge. In 1822 the two ancient establishments at and near London Bridge, supplying Southwark, were combined under the name of the *Southwark Waterworks.*

103. By about the year 1820 the various water companies whose rise we have chronicled above had established a firm footing, and rendered themselves necessary to the inhabitants of London, in respect of the supply of this vital element of health. But the records show that no sooner did they become aware of this fact than they began to take advantage of it for their own interest, by combining together to raise their rates. The public complained loudly of this, and in 1821 a Committee of the House of Commons was appointed to inquire into the whole subject. They made a comprehensive report, in which, while they admitted that "a material improvement had taken place in the supply, both in "respect of abundance and certainty," they recommended that the maximum rates to be charged should be settled by Act of Parliament, and other salutary regulations enforced. No legislation followed this, but it seems to have had its effect in inducing the companies to remove the chief causes of complaint.

104. In a few years, however, discontent arose on another ground, namely, as to the *quality* of the water. The companies had hitherto pumped it into the districts just as it came to hand, without being over particular as to the state it was in. But it was seen that the water of the river was dirty and turbid, and an alarm arose that it must be unwholesome. Accordingly, in 1828, a Royal Commission consisting of three eminent scientific men—Mr. Telford, civil engineer, Professor Brande, chemist, and Dr. Roget, secretary of the Royal Society—was appointed to inquire into "the description, the quality, "and the salubrity of the water" supplied to the metropolis. They had careful examinations and analyses made, from which it appeared that the Thames water when free from extraneous substances was in a state of considerable purity, containing only a moderate degree of saline contents, and those of a kind which could not be supposed to render it unfit for domestic purposes, or injurious to health; but as it

approached the metropolis it became loaded with a quantity of filth which rendered it disgusting to the senses and improper to be employed in the preparation of food.

It appeared, however, that a very considerable part, if not the whole, of this extraneous matter might be removed by filtration through sand, and the Commission took into consideration various plans for effecting this object, which led them to the opinion that it was perfectly possible to filter the whole supply with the requisite rapidity and within reasonable limits of expense.

The general conclusion of the Commission is expressed in the following paragraph:—

"Taking into consideration the various circumstances to which we have now adverted, together with the details of evidence by which they are proved and illustrated, and also the facts derived from our own observation and experience, we are of opinion that the present state of the supply of water to the metropolis is susceptible of, and requires, improvement; that many of the complaints respecting the quality of the water are well founded, and that it ought to be derived from other sources than those now resorted to, and guarded by such restrictions as shall at all times ensure its cleanliness and purity."

From other passages in the report it is clear that the Commission attributed the pollution of the Thames water to its reception of the sewage and refuse from manufactories in the neighbourhood of London, operating within the tideway; it does not appear that they contemplated the possibility of any such large measure as the removal of the companies' points of intake above the range of the tidal flow.

105. Stimulated by this report, and alarmed probably at the prospect of a sweeping change of the sources of supply, the companies directed their attention to the purification of the water by filtration. This process had been well known on a small scale as a means of separating from water any impurities held in suspension, but its application to large public works was a novelty. It was soon found that the only appropriate material for mechanical filtration on a large scale was fine sand; but the great practical difficulty was to prevent the sand from becoming clogged, and to find an easy, practical, and cheap method for its renewal. After much consideration and long-continued experiments a means was discovered of getting over these difficulties. It was found that by far the greater quantity of the impurities were held in suspension by the agitation and motion of the water, and that if it was allowed to stand for some time at perfect rest, in a reservoir, the heavier and grosser particles were deposited by simple subsidence, leaving only a small proportion of lighter and finer matters to be dealt with by filtration. It was also found that when the water was allowed to filter downwards through a porous bed of sand, held up in its place by underlying layers of coarse gravel, the dirt did not penetrate into its mass, but was stopped at the upper surface, so that the whole cleaning operation necessary was to scrape this surface off to a slight thickness, and when it had become too much diminished to put fresh sand on.

The plan of filtration thus matured was at once carried into practice. The first large filter, of one acre area, was set to work by the Chelsea Company in 1829. It was found to work well, and the principle has since been universally adopted.

The other companies, though they did not all adopt the new principle of filtration, made improvements in some way or other. The New River Company constructed extensive settling reservoirs, as did also the West Middlesex Company; the Grand Junction Company removed their source of supply from Chelsea to Brentford, and formed filters there; the East London went higher up the Lee; and the Southwark and the Vauxhall Companies amalgamated, abolished their old sites, and established new joint works at Battersea. The Lambeth Company also formed elevated reservoirs at Brixton Hill and Streatham, to improve the service generally, and to maintain a supply in cases of fire.

106. It would seem, however, that the public had not full confidence in the improvements thus made, for in consequence of the report of the Commission of 1828 the House of Commons recommended that Mr. Telford should look out for new sources of supply, and he was accordingly instructed by the Government to take steps for the purpose. In 1834 he made his report, advising that the northern part of the metropolis should be supplied from the River Verulam above Watford, and the southern part from the Wandle. This report occupied the attention of the House of Commons in 1834, and of the House of Lords in 1840, but nothing was done.

107. The system of filtration was found to work well, so long as the impurities it professed to remove were only mechanical, and were not too great in amount; but it was found that the state of the river was gradually deteriorating, and, what was more

important, that it was becoming fouled in a way that filtration was powerless to purify, namely, by contamination of a chemical nature.

Drainage and sewage works were beginning to be more developed; ideas of what is now called sanitary science were arising; cesspools were beginning to be abolished; and as a consequence much larger quantities of sewage matter began to be poured into the river on all parts of its passage through London. These impurities were carried backwards and forwards by the tide, and their evil effect on the state of the river was enhanced by another circumstance which took place about this time, namely, the introduction of the small local steam boats plying on the Thames above London Bridge, the agitation caused by which not only kept the infused matter in continual mixture with the water, but washed and stirred up the mud at the bottom, which had before lain undisturbed. It was seen that these evils would go on increasing, and would shortly render the water so contaminated as to be beyond the possibility of purification by ordinary means.

108. The first steps towards meeting this difficulty were taken by the Lambeth Company. They had hitherto drawn their water from a site where the bad state of the Thames made itself very obvious, and after well considering the matter, they came to the decision that no measure short of the removal of the source of supply to a point above the highest range of the tide (Teddington lock) would be of any permanent benefit to the quality of the water. They therefore selected a point of the Thames a little above Kingston as their new source, proposing to establish large pumping engines there, and to force the water along a large main of ten miles in length to their existing reservoirs on Brixton Hill. An Act authorizing the works was obtained in 1848, and in 1851 the supply from the new source was delivered to the consumers.

109. Meanwhile the subject of the metropolitan water supply had been taken up by a public body who at that time assumed authority on all matters of a sanitary nature— the General Board of Health. In May 1850 this board issued a long report on the subject, which was followed shortly afterwards by numerous appendices and documents in explanation and justification. They pointed out the evils of drawing water from the Thames within the tideway, where it was exposed to sewage contamination; but not content with this, they objected to the Thames altogether, on the ground of its hardness, as they had adopted the idea that only very soft water was fit for public consumption. They therefore made a recommendation in the following terms:—"Whilst we believe "that Thames water, taken up beyond the influence of the metropolitan drainage, and "filtered, may be used without injury to the public health, and may be employed "temporarily until other sources can be laid under contribution, we advise that Thames "water and other water of like quality as to hardness, be as early as practicable "abandoned." The Board further directed their attention to finding other sources in substitution for the Thames, and fixed upon a tract of ground, of 150 square miles area, formed by the Bagshot sands and the lower greensands in Surrey, from the drainage of which they recommended that the supply for the metropolis should in future be taken.

110. This report was considered by a Committee of the House of Commons in the same year, but they did not endorse the opinions it contained. It happened that about the same time a company was projected, called the London Spring Water Company, which, on the strength of a favourable report made about ten years before by Mr. Robert Stephenson, proposed to supply the metropolis with spring water from the chalk in the neighbourhood of Watford. The Government, distracted by conflicting opinions, and desiring better evidence than they were yet in possession of, at the beginning of 1851 appointed a commission of three eminent chemists, viz., Professor Graham (now Master of the Mint), Dr. Miller, and Dr. Hofmann, to investigate the quality of the water actually supplied, referring to them also the proposals of the Board of Health and of the Watford Company. The report of this Chemical Commission was given in June 1851. It is a most able document, and as it treats of various matters connected with the subject in a manner which, even at this distance of time, is very pertinent to our inquiry, we shall have occasion often to refer to it hereafter.

The Commission expressed their opinion that the Thames water was perfectly wholesome, palatable, and agreeable; uniform, plentiful, and safe in use; but they recommended that to avoid the liability to contamination by the London sewage, the supply should be drawn at a point above the tidal range. They reported unfavourably of the Board of Health scheme, but drew particular attention to the proposed supply from the chalk at

Watford, which, assuming that the hardness could be got rid of by a softening process suggested by Dr. Clark, they considered much preferable to any other from its greater purity.

111. The result of all these investigations was to lead the Government to the opinion that legislation on the subject was desirable, and in 1851 they introduced a Bill to amalgamate all the companies into one great whole, whereby improvements might be introduced more effectively and economically than by dealing with them singly. It was to be one condition that the new company should be compelled to obtain water from such sources as the Secretary of State might direct.

This proposition, which was long and ably fought between its supporters and the companies, also proved too sweeping for the acceptance of the Legislature, and it was modified, the following session, into an Act (15 & 16 Victoria, cap. 84), which, while it did not interfere with the property of the companies, imposed on them many new and important conditions.

112. It is this Act which now regulates the general water supply of the metropolis. It is entitled "An Act to make better provision respecting the Supply of Water to the "Metropolis," and it received the royal assent the 1st of July 1852. Its principal provisions are as follow:

Clause 1 provides that it shall not be lawful for any company supplying the metropolis to take water from any part of the Thames below Teddington lock, or from any part of any of the tributary streams within the range of the tide.

Clause 2 stipulates that every store reservoir within five miles of St. Paul's shall be covered; and Clause 3 makes the same provision for aqueducts, unless the water is subsequently filtered.

Clause 4 provides that all water supplied for domestic use shall be effectually filtered, unless it be pumped from wells direct into covered reservoirs.

Clauses 15 and 22 provide for a constant supply at high pressure being given where demanded by four fifths of the inhabitants of any district, on certain conditions being complied with by them.

Clause 16 makes any company liable to a penalty of 200*l*., and 100*l*. per month in addition, for violation of the Act, or neglect to comply with its provisions.

The other clauses are of minor importance to our present inquiry.

113. After the passing of this Act the water companies proceeded to comply with its more important provisions, expending about 2,500,000*l*. in works for this purpose; and in 1856, the Government caused chemical and engineering examinations to be made, under the direction of the General Board of Health, to ascertain the results of the changes. The chemical report was made by Professor Hofmann, and Mr. Lindley Blyth, and it showed that while the hardness and solid contents of the water remained about the same, there was a very positive and considerable diminution in the amount of organic matter. This, though doubtless due chiefly to the removal of the intake above the tideway of the Thames, was also attributed in great degree to the considerable improvement which had taken place in the collection, filtration, and general management of the supply of water. The engineering report made by the inspectors of the Board of Health gave a satisfactory account of the new works of the various companies, and of the manner in which they had carried out the provisions of the Act of Parliament. It was suggested, however, that further inquiry should be made into the removable causes of contamination of the Thames above the new sources of supply, and the inspectors recommended the introduction of the constant service system.

114. London is now supplied with water by eight companies, five on the north side of the river, viz.,

The New River Company,
The East London Company,
The Chelsea Company,
The West Middlesex Company,
The Grand Junction Company;

and three on the south side, viz.,

The Lambeth Company,
The Southwark and Vauxhall Company,
The Kent Company.

Each of these companies supplies a certain district, marked by definite boundaries, the whole metropolis being mapped out between them. These districts, together with the sites of the principal pumping stations, filters, mains, and reservoirs, are shown in colours on the map attached to this Report, and marked Appendix AV.

Formerly different companies were often engaged in competition with each other over the same ground; but this course, while it produced no substantial good to the public, was so hurtful to the companies themselves, that it was put an end to by separate limits being assigned to the operations of each company.

115. The *New River Company* supply a very large district, comprehending the whole of central London. The western boundary is a line drawn from Charing Cross by the Haymarket, Tottenham Court Road, and Hampstead Road, northwards to Highgate; the eastern boundary is a line running directly north from the Tower to Stamford Hill.

This company derive the great bulk of their water from sources in the valley of the River Lee, near Hertford, namely,

1. From a copious spring called the Chadwell Spring, situated between Hertford and Ware.

2. From wells sunk into the chalk at Amwell, near Ware, and at Hoddesdon and Cheshunt, a little lower down the valley.

3. From the River Lee itself, in the same neighbourhood.

The waters from these sources are united and conveyed to London by an artificial channel, called the "New River." The distance of the sources from London in a direct line is about 20 miles, but as the New River winds considerably, in order to take advantage of suitable levels of the ground, its course is much longer. The original length was nearly 40 miles, but it has been lately shortened by extensive cuts, leaving its present length only about 28 miles. It is an open river, protected by fencing, for about 25½ miles of its course, the remainder being tunnel or pipe.

The average dimensions of the New River are about 18 feet wide and five feet deep; in its original course it had an average fall of about five inches in each mile of length; but the diminution of length has given a much greater proportionate fall, and has consequently much increased the quantity of water it is capable of conveying.

Leaving Ware, the New River turns southward, and passes through or near Broxbourne, Cheshunt, Enfield, Winchmore Hill, Hornsey, Stoke Newington, Ball's Pond, and Islington, to a site at Clerkenwell known by the name of the New River Head. The water is allowed to subside in reservoirs at Stoke Newington and Clerkenwell, having a joint area of 43¼ acres. In addition to the supply brought by the New River, the drainage of a small district, of three or four square miles area, is collected by two reservoirs at Cheshunt of 18½ acres area; this water is admitted into the New River as required. The filtering reservoirs are at Stoke Newington, Hornsey, and Clerkenwell, and occupy 11¼ acres.

At Stoke Newington, Hornsey, and Clerkenwell, there are large pumping engines for forcing the filtered water into store reservoirs at a higher level, situated at Claremont Square and Maiden Lane; and near the Archway, Highgate, is another pumping station, which forces water into still higher reservoirs at Highgate and Hampstead. These reservoirs contain in the aggregate about 20 millions of gallons, and are covered in as required by the Act.

From these reservoirs the district is now supplied, and to meet the varieties of level in the several localities, the district has been divided into several distinct levels, each having its own reservoirs and separate systems of supply. The whole pumping power of the company amounts to nearly 1,700 horses. The length of their mains is about 620 miles.

The company have an engine at Tottenham, by which they can, when necessary, obtain water directly from the Lee, taken at the same point of the river as the water of the East London Company; but this is only intended to be used in case of emergency, such as accident, or stoppage by frost, &c. They have also power to draw water from the Thames below Blackfriars Bridge, to be distributed by separate mains for street watering and sewer flushing, the use of this for the general supply being forbidden by the Act of 1852. It is stated that neither of these supplementary supplies has been used for several years.

The company have further a deep chalk well in the Hampstead Road, and also one formerly belonging to the Hampstead Waterworks, taken by them a few years ago; both these wells, though not at present used, are available to increase the general supply. They also took to the Hampstead Company's springs and ponds at Hampstead and Highgate, the water of which is used only for street watering.

116. *The East London Waterworks Company* supply also a very large area, comprising the whole of London eastward from the boundary of the New River district, and extending from the St. Katherine's docks to North Woolwich, and from the line of the Shoreditch and Kingsland roads to Woodford.

The supply is derived from the River Lee at Higham Hill, in the parish of Walthamstow, about nine miles above the junction of the Lee and the Thames.

The company have reservoirs at Walthamstow containing about 110 acres of water area, and capable of holding 220 millions of gallons, 170 millions of which can be withdrawn by simple sluices, and the remainder by pumping.

From these reservoirs the water passes by a special private canal about $1\frac{1}{4}$ mile in length to the filtering beds at Lee Bridge, which are 13 in number, divided into two series, and having a united area of 12 acres on the surface of the sand; and after filtration it passes to large pumping engines established at two stations, Lee Bridge and Old Ford.

From the universal flatness of the district this company have no elevated reservoir, but the supply is afforded by the continuous working of one or more engines, and the pressure is kept up by high stand pipes attached to the pumping mains.

They are now executing works for bringing an additional supply from the Thames, under powers to which we shall allude more particularly hereafter.

117. *The Chelsea Waterworks Company* supply a district extending from Charing Cross westward to Fulham, and from the Thames northwards to the Uxbridge Road, and comprehending Chelsea, Knightsbridge, the whole of Belgravia and Pimlico, and a large portion of Westminster.

The water is taken from the Thames at a point on the right or south bank, at Long Ditton, nearly opposite Hampton Court Palace, three miles above the highest range of the tide. It is first allowed to subside in reservoirs constructed for the purpose, and then filtered through sand and gravel, after which it is pumped by steam engines through two large cast-iron main pipes, six miles long, to elevated covered reservoirs, containing 20 millions of gallons, on Putney Heath. From this the water flows, by its own gravity, through mains passing over the Thames at Putney into the company's district.

118. *The West Middlesex Waterworks Company* supply a district extending west of Tottenham Court Road and north of Oxford Street, as far as the Edgware Road, and in addition a large western suburban area, including Kensington, parts of Fulham and Brompton, Hammersmith, Chiswick, &c., and as far north-west as Hendon.

The water is taken from the Thames on the north bank, at a point a little above the town of Hampton, and $5\frac{1}{2}$ miles above the termination of the tidal range at Teddington lock. From this point it is passed by pumping power, through a cast-iron main 36 inches diameter, and $8\frac{3}{4}$ miles long, crossing the river to a site at Barnes, from which the company formerly took their supply. Here the water is first allowed to subside in reservoirs of $20\frac{1}{2}$ acres area, and then filtered in five filter beds of about eight acres. It then crosses again under the bed of the river to the north bank at Hammersmith, where the pumping station is situated for supplying the district. There are two elevated covered reservoirs, one at Kensington, containing about $3\frac{1}{2}$ millions of gallons; the other on Primrose Hill, at a high level, containing $4\frac{3}{4}$ millions of gallons. For some parts which lie higher it is necessary again to pump, from Primrose Hill, into another more elevated covered reservoir, containing $2\frac{1}{2}$ millions of gallons, at Hampstead.

119. *The Grand Junction Waterworks Company's* district comprehends that part of the parish of St. George, Hanover Square, which lies north of Piccadilly, a small portion of Marylebone, the larger part of Paddington, and St. James's to Pall Mall.

They take water from the Thames, close to the point of the West Middlesex supply, and force it along a 33-inch main to Brentford, $7\frac{1}{4}$ miles distant. It is allowed to subside in reservoirs partly at Hampton and partly at Brentford, covering $8\frac{1}{4}$ acres, then filtered in beds occupying $5\frac{1}{6}$ acres, and then is pumped into the district, there being an elevated covered reservoir on Camden Hill, Bayswater, containing 6,000,000 gallons, with additional engine power for still higher levels.

120. *The Lambeth Waterworks Company* supply a large district on the Surrey side'

extending from the Thames on the north to Croydon on the south, and from Lewisham and Beckenham on the east to Thames Ditton and Esher on the west.

They take their water from the Thames near Long Ditton at the place adopted by the Chelsea Company. Here filter beds and pumping engines are established, forcing the water along a cast-iron main, 10¼ miles long and 30 inches diameter, to elevated covered reservoirs at Brixton, containing 12,000,000 gallons; from these it flows by gravity into the whole of the low-lying district, and is again pumped to supply higher covered reservoirs at Streatham, Selhurst, and Rock Hill, the highest service given being at Norwood, about 350 feet above the Thames.

121. *The Southwark and Vauxhall Water Company* supply a still larger district, comprising the borough of Southwark, portions of Lambeth and Clapham, and the whole of Battersea, and extending east to Rotherhithe, west to Richmond, and south to Camberwell. In some parts supplies are given both by this and the Lambeth Company.

They obtain water from the Thames above Hampton, at the same site as the West Middlesex and Grand Junction, and it is forced along a 36-inch main 13 miles long to their old establishment at Battersea, where it is pumped by large engines directly into the district mains; like the East London they have no elevated store reservoirs. There are large subsiding reservoirs and filters, both at Hampton and at Battersea.

122. *The Kent Waterworks Company* supply the whole of the south-eastern suburbs, their district comprising Deptford, Greenwich, and Woolwich, and extending from Camberwell to Dartford, and from the Thames southward to Bromley, Chiselhurst, and Bexley.

This company was incorporated in 1810, when they took possession of some ancient works on the river Ravensbourne at Deptford, established as early as 1699. Down to 1857 they continued to take water only from this source, but the river proving insufficient, the supply was then supplemented by wells sunk into the chalk, and, this source proving so much more plentiful and so much better in quality, in 1862 the Ravensbourne was entirely abandoned.

The principal station is at Deptford, where there are three wells on the site of the old works, each with a pumping engine, the water being conveyed for distribution to other engines, which pump directly into the district mains. There are also two wells at Charlton, one at Plumstead, one at Crayford, and one at Bromley; at each of these wells an engine is placed which serves both for pumping and for distribution.

In addition to the pumping power at the different wells, there are other engines near Shooters Hill for supplying the more elevated districts, and there are elevated reservoirs in Greenwich Park, on Woolwich Common, and at Plumstead and Chiselhurst, to regulate the pressure, and keep up a supply in case of fire. The water does not require filtration.

The following data refer to the wells furnishing this company's supply:—

—	Maximum Quantity pumped (Gallons per hour).	Levels with reference to Ordnance Datum, in feet.			
		Of Surface of Ground.	Of Bottom of Well or Bore-hole.	Of Surface of Water when not pumping.	Of Surface of Water when pumping Maximum Quantity.
3 Deptford wells -	287,000	+20	−230	+12	− 44
2 Charlton wells -	70,000	+25	−225	+10	− 45
Plumstead well -	57,000	+80	−420	+10	− 20
Bromley well - -	25,000	+120	−130	+115	+103
Crayford well -	38,000	+30	−120	+20	+ 14

123. In addition to the supplies of the water companies, there is a considerable quantity of water furnished from wells sunk, in 1844, by Messrs. Easton and Amos, on behalf of the Government, near Charing Cross. They are nearly 400 feet deep, penetrating into the chalk, and they furnish a quantity of about 430,000 gallons per day, which is used to supply the Government offices and several public establishments in Westminster and the neighbourhood, and the fountains in Trafalgar Square.

A small further addition to the supply of the suburbs of the metropolis is obtained from the chalk springs at Grays, in Essex, described in Mr. Meesom's evidence, and alluded to in Part II. of our Report. A company was incorporated in July 1861 for this purpose, under the name of the South Essex Water Company, and a pumping establishment was formed at Grays, with a store reservoir at Brentwood, and distributing mains ramifying in various directions. The water is now delivered at Brentwood, Shenfield, Warley (including the great barracks there), Grays, and several neighbouring villages. The quantity pumped is about 450,000 gallons per day, and the number of inhabitants supplied between 15,000 and 16,000.

124. The following table gives the statistics of the principal water companies in a combined form:—

STATISTICS of present LONDON WATER SUPPLY.

——	Capital.	Approximate Area of District supplied.	Number of Houses supplied, 1867.	Estimated Number of Inhabitants supplied, 1867.	Average daily Supply, 1867.
From the Thames.	£	Square miles.			Gallons.
Chelsea Company - -	785,600	6½	26,875	170,000	8,087,258
West Middlesex - -	798,571	10	36,881	275,000	8,816,486
Grand Junction - -	850,000	24	27,190	245,000	9,533,432
Southwark and Vauxhall -	1,100,440	30	71,558	465,000	13,629,758
Lambeth - - -	736,245	25	38,320	230,000	8,975,530
					49,042,467
From the Basin of the Lee.					
New River Company -	2,609,418	19	113,462	800,000	23,790,667
East London Company -	1,400,000	50	92,652	675,000	19,298,241
					43,088,908
From Chalk wells in Kent.					
Kent Company - -	489,240	60	34,504	240,000	6,468,873
Total -	8,769,514	224½	441,442	3,100,000	98,600,248

In reference to the quantity supplied, it must be observed that the amount in the last column expresses only the average daily supply for the whole year; but a reference to the table in Appendix N will show that, as might be expected, the supply is much greater in summer than in winter. The *maximum* daily supplies in June or July were as follows:—

	Gallons.
Chelsea - - - - -	9,042,800
West Middlesex - - - -	9,776,707
Grand Junction - - - -	11,032,742
Southwark and Vauxhall - - -	13,975,000
Lambeth - - - - -	10,257,800
New River - - - - -	26,710,000
East London - - - - -	20,321,152
Kent - - - - -	7,196,708
Total - -	108,312,909

This shows that the maximum daily quantity supplied in the summer months is about 10 per cent. in excess of the average of the whole year, and this is an important fact in considerations affecting the quantity of water required.

The following table gives particulars of the reservoirs, filter beds, and pumping engines of the various companies:—

WORKS OF THE COMPANIES.

Subsiding Reservoirs.		Filter Beds.		Store Reservoirs.			Pumping Engines.	
Number and Situation.	Area in Acres.	Number and Situation.	Area of Sand Surface in Acres.	Number and Situation.	Available Contents in Gallons.	Height of High-water Line above Ordnance Datum.	Number and Situation.	Horse Power.
				CHELSEA COMPANY.				
						Feet.		
3 at Seething Wells, near Kingston, with vertical rough filters attached.	4½	2 at Seething Wells, near Kingston. NOTE.—Two additional filter beds similar to the above are in course of construction at Seething Wells.	2	2 for filtered water, situate on Putney Heath. 1 for unfiltered water, situate on Putney Heath.	10,000,000 1,000,000	182½ 182½	8 at Seething Wells, near Kingston.	1,025
				WEST MIDDLESEX COMPANY.				
3 at Barnes, Surrey -	20½	5 at Barnes, Surrey -	8	1 at Kensington - 1 at Barrow Hill - 1 at Kidderpore -	3,672,000 4,750,000 2,500,000	124½ 190 323	2 at Hampton - - 5 at Hammersmith - 2 at Barrow Hill - 1 at Barnes (for sand washing machines).	210 900 85 6
				GRAND JUNCTION COMPANY.				
2 above Hampton - 2 at Kew Bridge - 1 „ -	2 5¾ 3⅛	3 at Kew Bridge -	5¼	1 at Campden Hill - 2 „ „ -	6,000,000 12,000,000	132½	2 at Hampton - - 4 at Kew Bridge - 2 at Campden Hill -	220 660 300
				SOUTHWARK AND VAUXHALL COMPANY.				
2 above Hampton - 2 at Battersea - - 1 at Hampton - -	2 6½ 3½	5 at Battersea - - 3 at Hampton - -	8 3	None - - -	None -	None.	3 at Hampton - - 6 at Battersea - - 2 at Hampton - -	400 915 450
				LAMBETH COMPANY.				
3 at Long Ditton, near Kingston, with vertical rough filters attached.	3	4 at Long Ditton, near Kingston.	1⅝	2 at Brixton - - 1 at Streatham - 1 at Rock Hill (Sydenham). 1 Ditto ditto 1 at Selhurst (near Croydon). 1 at Coombe (near Kingston).	12,000,000 3,750,000 500,000 115,000 2,500,000 1,150,000	115½ 197½ 362½ 385½ 218½ 192½	7 at Long Ditton, near Kingston. 5 at Brixton - -	970 210
				NEW RIVER COMPANY.				
2 at Stoke Newington 1 at New River Head 2 at Hornsey - - 2 at Cheshunt - - 13 at Highgate and Hampstead (for street watering only).	42½ ¾ 8 18½ 30	7 at Stoke Newington 3 at New River Head 3 at Hornsey - -	7 2¼ 2	1 at Claremont Square 2 at Maiden Lane - 1 at Highgate - - 1 at Hampstead - 1 at Camden Park Road (uncovered, for unfiltered water).	3,500,000 15,000,000 1,000,000 500,000 900,000	139 232 432½ 447½ 171½	8 at Stoke Newington 2 at New River Head 1 at Hornsey - - 2 at Highgate - - 1 at Amwell End - 1 at Amwell Hill - 1 at Hoddesdon - 1 at Cheshunt - 2 at Tottenham -	1,080 200 75 75 50 25 50 20 125
				EAST LONDON COMPANY.				
5 at Walthamstow, Essex.	110	13 at Lea Bridge -	12	1 at Old Ford - -	7,000,000	12½	6 at Old Ford (steam) 4 at Lea Bridge (ditto) 2 Ditto (water) 1 at Walthamstow (steam). 1 at Walthamstow (water).	640 600 65 100 30
				KENT COMPANY.				
None.		None.		1 on Woolwich Common. 1 on Plumstead Common. 1 on Chiselhurst Common. 1 in Greenwich Park (uncovered). 1 on Woolwich Common (uncovered).	325,000 750,000 450,000 1,125,000 1,600,000	314 170 306 163 240	7 at Deptford. 2 at Charlton. 1 at Plumstead. 1 at Bromley. 1 at Crayford. 2 at Dover Road.	740 238 63 33 54 47

125. The distribution of the water is on what is called the *intermittent* system. The supply pipes to the houses are not attached to mains in which the water is always under pressure, but to smaller service pipes, into which the water is "turned on," as it is called, during only one or two hours each day, the consumers receiving during this short time the whole quantity required for the day's consumption, and storing it for use in cisterns provided by themselves. On Sundays, as a general rule, no supply is given, but exceptions are made by many of the companies in poor neighbourhoods where the receptacles are insufficient.

126. We may now allude to the more recent public proceedings affecting the water supply of the metropolis.

In 1865 a Royal Commission was appointed to inquire into the best means of preventing the pollution of rivers, embracing also the question of water supply. In March 1866 they reported on the River Thames; and their report, so far as bears on our present inquiry, was to the effect that the river was at present fouled by various causes, but principally by the sewage of towns, villages, and houses on its banks, but that this sewage might be so utilized on land as to be rendered innocuous. They recommended that the whole river should be placed under the superintendence of one governing body, who should amongst other duties take steps to ensure its freedom from pollution.

This recommendation bore immediate fruit, for on the 6th of August in the same year an Act (29 & 30 Vict. cap. 89) was passed, altering the constitution of the existing Conservancy Board of the Thames, and considerably enlarging their powers. It extended their jurisdiction up to Cricklade in Wilts, and made two important provisions for ensuring the purity of the water:—

1. The surface of the river was to be effectually scavenged, in order to the removal therefrom of substances liable to putrefaction.
2. The admission of sewage or any other offensive or injurious matter into the Thames, or into any tributary stream or watercourse within three miles of its junction with the Thames, was declared illegal, the Conservators giving due notice to all offending parties to discontinue the practice under heavy penalties.

To enable towns and villages more easily to comply with the requirements of this law, there was passed in August of the next year an Act (30 & 31 Vict. cap. 113) for facilitating the distribution of sewage matter over land, and otherwise amending a law previously passed with the same view.

127. In May 1867 the Rivers Pollution Commission made a report on the River Lee, which they found liable to pollution from sewage and refuse from manufactories, and beset with peculiar difficulties as to its purification and general management; they recommended certain measures with a view to improvement.

During the same session, the East London Waterworks Company, who were requiring to increase their supply, applied to Parliament for powers to enlarge their works; and having been led by the experience of the extreme dry season of 1864 to distrust the capability of the River Lee to afford all they wanted, they promoted a bill for enabling them to draw 10,000,000 gallons per day from the Thames at Sunbury. Both these bills were passed, with certain controlling provisions.

It had happened, however, that in the previous year there was a severe outbreak of cholera in the east of London, and, from certain peculiarities in the phenomena exhibited, suspicion was entertained that it might be connected with the water supply. The suspicion was strengthened by the circumstance that the Registrar General for the metropolitan districts had established a monthly analysis of the water supplied, and that his reports had produced an impression unfavourable to the quality. When therefore the East London bill was referred to a Committee of the Commons, the House took the opportunity of instructing them to inquire generally into the operation and results of the Metropolis Water Act, 1852, of which, as it came into full operation in 1856, ten years' experience had been gained.

128. This committee, of which Mr. Ayrton was chairman, inquired fully into the whole subject, and reported at the end of June 1867.

As to the main question, they declared they were satisfied that both the quantity and quality of the water supplied from the Thames were so far satisfactory that there was no ground for disturbing the arrangements made under the Act of 1852, and that any attempt to do so would only end in entailing a waste of capital and an unnecessary charge upon the owners and occupiers of property in the metropolis.

The water of the Lee they found naturally not only wholesome, but comparing favourably with that supplied to other places. They agreed with the Rivers Commission that it was liable to serious contamination, but they suggested certain alterations in the remedial measures proposed, and expressed their opinion that when these were carried out the water supplied by the companies would be of unquestionable character.

They also approved the North Kent water, and considered this company had an adequate command of quantity for many years to come.

They went elaborately into the question of constant supply, and recommended that it should be enforced, under strict provisions to prevent waste, and to ensure the suitable condition of all the house fittings.

They finally recommended that the duty of seeing that the water companies properly fulfilled their obligations should be imposed on the Metropolitan Board of Works; and that a new Act should be passed consolidating all the laws at present in force as to the metropolitan supply, and introducing the new measures they had proposed.

129. In 1868 an Act (31 & 32 Vict. cap. 154) was passed to make better provision for the preservation and improvement of the River Lee and its tributaries. It was analogous to the Thames Conservancy Act of 1866, altering the constitution of the managing body, and rendering illegal the admission of sewage or offensive matter into the river, except in the case of certain towns where measures had been adopted for its purification.

PART IV.

ON THE SUPPLY OF WATER AVAILABLE FROM THE BASIN OF THE THAMES.

130. We have now to consider the eligibility, for the future service of the metropolis, of the great source from whence its supplies have hitherto been drawn, namely, the basin of the River Thames.

The gigantic schemes proposed for supplying London with water gathered in the distant mountain ranges of the country have been projected on the assumption that the nearer and more natural supply derived from the Thames valley was either deficient in quantity or unsuitable in quality, or both. It becomes, therefore, our duty to inquire whether there is sufficient justification for either of these suppositions; and we will consider them each in turn.

SECTION I.

AS TO QUANTITY.

131. At the end of Part II. of this Report we have endeavoured to give a general view, scientifically considered, of the most important natural features of this great basin, having reference particularly to its underground storage, and the nature and distribution of its springs. It will be here our object more practically to consider the evidence as to the quantity of water actually obtainable from the rivers and wells in this district.

On this point we have received a large amount of information from a great number of witnesses, who, from their position, experience, and knowledge, are most competent to judge of the subject.

132. The portion of the basin first to be considered is that above Hampton and Ditton, where the water companies have their intake. This portion extends over a length and breadth of 80 or 90 miles, its superficial area being given as 3,676 square miles.

The Thames first assumes importance near the small town of Lechlade in Wilts, where a number of small streams, forming the head waters of the river, unite. From this point down to Ditton it follows a tortuous course of about 120 miles in length, and is joined on either bank by several important tributaries.

133. The rainfall in the Thames basin has been determined with considerable accuracy by many years' observations by numerous persons at various localities from London to Cirencester. It is found to vary, on an average, from about 25 inches at the former place to 30 inches at the latter. Taking the mean of the whole area, Mr. J. T. Harrison estimates the average rainfall to be 27¾ inches, and of this it is estimated that one-third flows down the Thames. 4671. 6838. 2966. 3036.

134. It is desirable, however, to investigate the volume of the stream more particularly; taking our data at the point most important for our purpose, namely, at the intake of the companies, a little above the highest point reached by the tide, and where the natural fresh water stream has its maximum volume.

It has been shown that the total discharge at Kingston for eleven years was 5,432,418 millions of gallons, which is equal to an average of about 1,350 millions of gallons per day, or equivalent to about nine inches of rainfall. If this were the constant flow, no question could arise as to its sufficiency; but we need hardly say that it varies very widely at different times. In floods the stream is so large as scarcely to admit of accurate measurement; but in dry seasons it is much reduced; and it is in reference to the volume in these seasons that the doubt has arisen. It is therefore to this that we must direct attention. 3904.

135. Several witnesses have spoken to this point; we may first give Mr. Bateman's views as to the supposed deficiency in quantity, which has been one ground why he has considered the Thames ineligible, and has proposed to go to the mountains of Wales. He says:

App. E. "When the Acts of 1852 were passed it was estimated that the minimum quantity of water at Hampton was 362,000,000 gallons per day, and this minimum has been habitually considered, in round numbers, as 400,000,000. During the month of September in this year (1865) the river has been carefully measured above the waterworks at Hampton, and the gross daily quantity for a considerable period together has scarcely exceeded 300,000,000 gallons."

6515*a*–6522. 6540–54. In subsequent evidence he explains that the actual quantity given by his gaugings at Hampton in 1865 was 308,720,000 gallons per day, and he describes fully the mode in which the measurements were taken.

4561–4651. 136. Other witnesses give larger amounts. Mr. Simpson states that he has gauged the quantity flowing down at Kingston daily since 1852, and found the minimum in 1864, the driest year known, was 380,000,000 gallons per day, after the whole of the companies had taken their supply. He adds that this was in extreme drought, the usual flow in dry seasons being seldom lower than 600 to 700 millions of gallons.

3266. Mr. Beardmore states that the mean flow at Kingston in the months of June, July, August, and September, for 1864 and 1865, the two driest years, was between 380 and 390 millions, including the companies' supplies, and the absolute minimum only a little lower.

2931 *et seq.* Mr. John Thornhill Harrison, C.E., member of the Royal Commission on the Pollution of Rivers, (who specially investigated the subject, and during their inquiry received much information on the capacity of the basin for affording a water supply,) has put in an extensive series of tables illustrating the meteorology and hydrology of the Thames basin. Confining our attention to those portions of the tables which illustrate the state of the water in the driest seasons, we find that he has given particulars of the actual discharge in the three years 1858, 1859, and 1864, at the times when the quantity was under 400,000,000 gallons per day, and he shows the number of days in each year when the volume attained certain amounts.

The quantity was below 400,000,000 gallons

In 1858 for 36 days.
„ 1859 „ 32 „
„ 1864 „ 8 „

The lowest quantity noted was 350,000,000 gallons per day, and this was observed

In 1858 for 20 days.
„ 1859 „ 14 „
„ 1864 „ 2 „

4259. Mr. Leach, the engineer to the Thames Conservancy Board, says that having often gauged the river at Teddington, he has never found it less than 380,000,000 gallons per day.

6005–8. Mr. Quick, engineer to the Grand Junction and the Southwark and Vauxhall Companies, says the lowest gauging that has ever been taken of the Thames has amounted to 360,000,000 gallons at Teddington.

All these quantities, except Mr. Bateman's, are below the intake of the water companies, and therefore are exclusive of the quantity abstracted by them, which is at present about 50,000,000 gallons per day.

137. We think from this evidence we may fairly conclude that a daily flow of 350,000,000 gallons per day is a very exceptional thing, occurring only for a few days in the course of many years.

138. The companies are empowered, under their present Acts and agreements, to take as follows:—

	Gallons per day.
Chelsea Company	20,000,000
West Middlesex	20,000,000
Grand Junction	20,000,000
Southwark and Vauxhall	20,000,000
Lambeth	20,000,000
East London	10,000,000
Total	110,000,000

139. We are led to believe that it would be easy to make storage reservoirs and other works on the upper part of the river to collect the flood waters; and that by means of these the flow might be so equalized as to neutralize the effect of the severe droughts, and therefore to admit of a still larger abstraction of water if the growing requirements of the metropolis should render it necessary.

140. We will give a summary of the evidence we have received as to the quantity obtainable from the river.

Mr. Hawksley considers there is capacity in the Thames watershed to supply a suffi- 5055–70.
cient quantity for the metropolis. The companies might take the maximum supply they 5106–7.
are entitled to without injury to the river, or interference with the navigation. Below Teddington the river is tidal, and the abstraction of water would not interfere at all with the scour; for this reason, that the upland water of the Thames in its ordinary state has little or no influence upon it. It is chiefly when in flood that it has an influence on the scour, and the floods of the Thames are so enormous that practically the quantity taken by the water companies then disappears from the calculation altogether. The maximum flood in the Thames is about 20,000 to 25,000 millions of gallons per day. He considers that a quantity nearly double the statutory limit might be taken from the Thames without any storing process; half the lowest volume of the Thames (which he calculates at 360,000,000 gallons) might be taken, and he does not believe it would have any sensible influence.

He believes the average flow of the Thames in three consecutive dry years to be about six inches of rainfall, which would give nearly 900,000,000 gallons per day.

If more was wanted than could be taken at present it might be obtained by impounding 5071–3.
the flood waters, and there would be no difficulty in finding sites for reservoirs. 5094.

Mr. Simpson is of opinion that, by proper arrangements, the Thames basin is capable 4572–6.
of supplying 200,000,000 gallons per day. There is no necessity for making reservoirs 4596.
at present; there is plenty of water. The supply might be increased considerably, and 4646–7.
afterwards might be supplemented by reservoirs to double the amount. But it may be fourteen or fifteen years before such works become necessary.

He assumes that 200,000,000 gallons could be obtained from the Thames, and 4721–2.
60,000,000 gallons from the Lee, which would, at 30 gallons a head, be sufficient for a population of 8,700,000, and that practically, therefore, the Thames may be looked forward to as able to supply London beyond any probable increase.

Mr. Simpson says, that supposing it desirable that large works should be made in the 4587–93.
Thames valley to admit of the supply being increased to four times its present amount, the various companies to be benefited should contribute to the cost of such works, but that their execution and maintenance should be left in public hands.

Mr. Beardmore agrees that by the provision of storage reservoirs for the flood 3321.
waters it is quite practicable to take a much larger quantity from the Thames than at present, not only without any injury to the river below Teddington, but with very great advantage. He considers that from the Thames and Lee together 300,000,000 gallons 3328.
may be obtained.

Mr. J. T. Harrison is of opinion that reservoirs might be made, in the upper districts 3092–100.
of the Thames, sufficient to provide for a very large deficiency in droughty seasons.

The Rev. Mr. Clutterbuck, and Mr. Bailey Denton, whose plans and suggestions we 1839.
have noticed in Part II., agree in the opinion of the sufficiency of the Thames for any probable requirements for the supply of London, if proper provisions were made for 1532.
storage.

Mr. Rawlinson expresses his opinion that a supply may be obtained from the Thames 1360.
sufficient for London, both present and future.

Mr. McClean (whose plan for bringing water from Henley has been noticed in Part II.) 5637.
is of opinion that by storing the flood waters in the upper reaches of the Thames more water may be obtained than can ever be required. He quotes as follows from a 5498 *et seq.*
Report on the Thames by the late Mr. Blackwell, who was for many years engineer of the Kennet and Avon Canal:—

"In a geological point of view the River Thames is, of all the large rivers in England, that in which we may expect the slowest and most constant influence of the rain that falls. From the basins of its tributaries, the rivers Kennet and Loddon especially, consisting as they do almost entirely of chalk or other pervious subsoil, the water finds its way very slowly; and it is not until after many weeks of drought that any diminution of the quantity they supply is perceived.

"The results of my own carefully repeated experiments quite agree with the conclusions that a scientific consideration of the above data would lead to. The volumes of the Thames at Henley, as well as those of the

Kennet and the Loddon, have been repeatedly gauged, and the results obtained lead me to the conclusion that at the time of the shortest water the quantity passing the point at which we propose to take our supply is not less than 55,500,000 cubic feet, or 345,000,000 gallons daily. This is the minimum of the gaugings, and taken near the termination of an unusually long protracted season of drought."

5746–59. Mr. Thorpe, the acting chairman of the Thames Conservancy Board, is of opinion that the whole quantity of 100,000,000 gallons per day, which the companies are empowered to take, might be abstracted without any evil effects on the river as a navigable stream, and that if certain alterations were made, and certain works executed for storage, the quantity might be exceeded.

3601–13. Captain Burstal, secretary to the same board, considers that an enormous quantity more than is drawn already may be drawn above Teddington lock, without the river feeling it to any great extent. He considers reservoirs might be made above Oxford for this purpose with facility and advantage.

4244 *et seq.* Mr. Leach, engineer to the same board, has never observed any evil effects on the scour from the abstraction of water, nor does he apprehend any, supposing the companies to draw to their full authorized extent. For the greater part of the year the largest abstraction they could make could not be detected in the volume of the river. He thinks the Thames basin and the Thames stream are equal to the growing requirements of the metropolis without injuring the scour.

4300–14. He considers storage reservoirs would be desirable auxiliaries; they would equalize the flow, but still would give sufficient flood action for scouring purposes. There is a district above Oxford well calculated for the formation of reservoirs. The companies might take more than 100,000,000 gallons without reservoirs. With storage reservoirs he thinks 200,000,000 gallons might be taken per day and the river still maintained in a perfect state.

In reference to complaints which are stated to have been made as to the effect of abstracting the water on the upper part of the tideway, he says :—

"I think that more complaint has been made from persons residing in that part than any other of the ill effects which have been presumed to follow the abstraction of the water. In my opinion they have been quite mistaken upon that, they have attributed to the abstraction of the water from the river that which has arisen from an entirely different cause. The fact is that the Thames in the tideway for the last 30 years or more has been undergoing very great changes. The bed of the river in and about London has been depressed by the excavations which have been made in it, but at the upper extremity of the tideway it has remained pretty nearly the same. The consequence is that the inclination from that point down to where the excavations have taken place has become much greater, and consequently the stream is much more rapid, and therefore instead of the normal flow of the river passing off gradually as it did formerly, it now runs off very quickly, producing a much sharper stream in the upper part of the tideway towards the time of low water than there used to be, and whatever supply there is of water is consequently carried off more rapidly."

6005–8. Mr. Quick thinks there is no doubt that the basin of the Thames would be able to supply a larger quantity than the companies have power to take. If it were necessary storage reservoirs might be provided in the upper Thames; but as the companies only take now one-seventh of the minimum flow, it would be a long time before anything of that kind would be required.

It will be seen by the above extracts that there is a general accordance among the witnesses as to the sufficiency of the Thames. Mr. Greaves, however, the engineer of the East London Waterworks, says,—

5182–9. "I do not think these rivers are going to last as long as Mr. Hawksley does ; I think it is necessary to be cautious in time ; I would not like speculating upon any one of those rivers round London lasting for the next half century; not only the Lee or the Thames, but other rivers ; I mean lasting as a source of water supply independent of any foreign aid. I think it is quite a fair thing in prospect to talk about going beyond the Thames basin ; that is to say, you will either have to do that or to store very largely, more largely than anyone has entered into the practical estimation of."

At the same time Mr. Greaves adds that he does not think the time is yet come for going beyond the Thames ; and when further examined as to his reasons for doubting the capacity of the river, he appears to base them on the assumption of a possible change of climate as affecting the flow.

It is to be regretted that there is almost an entire absence of reliable information as to the flow of the river except at one point. It would be very desirable to establish a series of gaugings of the Thames at various points of its course, and of its chief tributaries, showing the variations at different times.

141. Considering the whole of the evidence above referred to, we believe we are justified in inferring, in the first place, that the quantity at present authorized, namely, 110,000,000 gallons per day, might safely be drawn from the main stream of the Thames in its present state; and, secondly, that by means of proper works for storage this quantity might be doubled if required.

Subsidiary Basin of the Lee.

142. But apart from the main stream of the Thames it is also necessary to inquire into the additional quantity which may be obained from the subsidiary basin of the River Lee. Full information as to this basin is contained in the Report of the Rivers Commission. Its area is about 500 square miles; and the mean rainfall, which is equally well determined with that of the Thames, is given by Mr. Beardmore, the engineer of the river, at about 25½ inches. The upper part, above Hertford, is entirely chalk, the lower part almost entirely London clay.

The two companies who draw water from the river appear to have the right of appropriating the whole flow, with the exception of a quantity of about five millions of gallons per day reserved for lockage on the navigation. The actual mean quantities at present drawn by the companies from the river are:—By the New River 18 millions of gallons 3961.
per day, taken at the upper part of the river, between Hertford and Ware (this being part of their whole supply of 23¾ millions):—by the East London Company 19¼ millions of gallons, taken lower down:—making on the whole 37¼ millions of gallons per day on the average of the year, the quantity in the summer months being increased to about 40 millions. Adding to this the lockage, it gives a total present demand on the river in the summer of about 45 millions.

We may now compare this with the quantity naturally flowing down the river.

Mr. Beardmore has given us tables of the flow of water in the Lee for 19 years. He 7444.
makes the average daily flow at Feilde's weir over this time 108·8 millions of gallons; and in the months of June, July, August, and September, of five dry years, he makes it (including the companies' supplies) average 45·2 millions, which is increased by springs in the valley below the weir.

It is therefore clear that in dry seasons little or no increase is to be relied on from the river in its present state; the only question is, to what extent might the dry weather flow be augmented by storage reservoirs.

143. The evidence on this point is as follows:—

Mr. Beardmore believes that reservoirs may be made within practicable and reasonable 3313–4.
limits of expense, so as to store the winter flood waters, and deliver about 70 to 90 millions 3438–9.
of gallons daily.

Mr. Muir, the engineer of the New River Company, states that the company calculate 3972–80.
that by making such reservoirs they might obtain an additional 10 million gallons; and 4020–1.
he believes the East London Company might do the same.

Mr. Greaves, engineer to the East London Waterworks, says that at one time in 1864 5131–9.
they took the whole volume of the river, after the New River had served themselves; there was nothing went by: they are now increasing their reservoir room to store partially the flood waters, which would give, say, five millions of gallons extra over 100 days' drought. He adds, however—

"I am of opinion that as the larger portion of London is dependent upon the Lee, it ought not to continue 5177.
any longer dependent upon the Lee alone for its supply of water as to quantity. The caution that we had from the drought of 1864 was convincing. There is no room to doubt the question any longer."

Mr. Greaves's attention being directed to the propositions of the New River engineer above quoted, he says:

"I am not inclined to store so largely, or to depend upon storage to that extent, because I know that there 5178–9.
are winters when it is quite likely those reservoirs might not be filled; the winter of 1858 went off without a single flood; we have charge of the floodgates ourselves on the river at Lee Bridge, which govern the whole flow, and in the winter of 1858 we did not draw a single gate; therefore where would the reservoirs be filled from in such a season? I consider the Lee alone not to be depended on, even for the East of London, and less so supposing the New River Company do an equal amount of work."

Mr. Mylne, whose plans for increase of the supply from the basin of the Lee we have noticed in Part II., conceives that by these plans the quantity derivable from this source might be raised by storage to 70,000,000.

The Rivers Pollution Commission, in their Report on the River Lee, 1867, say:

"With regard to the capability of the River Lee to meet the increasing demand for water supply in the eastern districts of London, it may be taken that no dependence can be placed upon an increase of the supply from the river without the construction of impounding reservoirs on a much larger scale than those now in existence."

144. We believe that we ought not to calculate on any material increase from this source, and that we may consider the quantity which the Lee valley can contribute to the supply of London as not more than 50 millions of gallons daily.

Subsidiary Supply from the Chalk.

145. We have referred fully in Part II. to the great store of water contained in the chalk round London.

6141. The only use now made of this for the metropolitan supply is by the Kent Company; who draw at present from it above seven millions of gallons daily, and appear to rely on an almost unlimited power of increase.

Many witnesses before us have testified in favour of this source, and the suggestions of Mr. Clutterbuck, Mr. Homersham, Mr. Barlow, and Mr. Meesom for utilizing it will be found noticed in Part II.

2520. Mr. Hawksley says that there are large districts of chalk where an immense quantity of
5083. water might be obtained, and that there is very fine water surrounding London in all directions, which only wants utilizing.

4045. Mr. Muir also speaks of the ease with which water is obtained in the chalk, and the abundant supply.

146. We do not agree with those who expect to get an almost unlimited increase of quantity of water by simply tapping the natural reservoirs in the chalk, for the supply to them must obviously be limited by the amount of rainfall. Moreover, as the water which penetrates into the reservoirs, raising the water line more or less above the level of the adjoining valleys, ultimately in greater part finds its way by springs into streams at the lower level of the district, any water drawn from the store by artificial means will most probably be at the expense of those streams.

If this be true, it follows that any water obtained by tapping the chalk reservoirs that feed either the River Lee or the Thames above Hampton, would only *pro tanto* diminish these streams, and would therefore be little or nothing gained to the general supply.

147. But there is, in the large area of chalk to the south and south-east of London, a reservoir which does not feed either of these streams, as its surplus waters find their way by innumerable springs into the Thames below London. From this reservoir, in all probability, large quantities might be drawn, and these quantities would be real additions to the supply.

We have no complete data as to the quantities which could be so obtained; but looking to the facts that the present few wells of the Kent Company are supplying above seven millions of gallons, and are said to be capable of supplying twice as much; that the Grays springs are said to be capable of supplying 10 millions; and that a small district near Gravesend has furnished an equal quantity; we believe we are very moderate in estimating the addition that might be made from this source by proper works at 30,000,000 gallons per day.

It is further probable that a considerable quantity of water, soft and of good quality, might be obtained in the neighbourhood of London by means of artesian wells in the *Lower Greensands;* but of this quantity there is no means of forming an estimate without further investigation.

Summary.

148. Combining now these several sources, we may estimate that if ever the metropolis should increase to such an extent as to render necessary such a large supply, and to justify the outlay for works necessary to obtain it, we may calculate on getting, from the basin of the Thames—

	Gallons per day.
From the main stream, supplemented by the aid of store reservoirs, say - - - - - -	220,000,000
From the Lee - - - - - - -	50,000,000
From the chalk to the south and south-east of London - -	30,000,000
or say, a total of - - - - - -	300,000,000

Section II.

AS TO QUALITY.

149. We now proceed to consider the part of our subject which is probably the most important as well as the most difficult of the whole, namely, the *quality* of the water obtained or obtainable from the basin of the Thames.

The importance of this point is indisputable. It admits of no question that the metropolis ought to be supplied with water that is perfectly wholesome in quality. Water is a necessary of life; the consumers in a place like London have no power to choose their own source, but are at the mercy of the parties undertaking the supply; the health, often even the life, of the inhabitants is in the hands of these parties, and it is therefore a matter of paramount public interest that the manner in which they exercise this immense power should be jealously watched, and efficiently controlled. And if it could be clearly proved that either now, or in a proximate future, wholesome water could not be obtained from the Thames basin, the question of the abandonment of the source would demand prompt attention.

We have alluded to the difficulty of this question, because we have found not only that opinions are divided upon it, but that the elements which enter into its determination are of a very subtle character, and by no means admit of the satisfactory kind of treatment which we are in the habit of expecting from the modern advanced state of physical science. We have endeavoured to get the best information possible, from scientific men of the highest reputation, and who have had the best means of making themselves acquainted with the subject, and we have given their evidence its due weight; but we have also been obliged on some points to rely on other considerations in arriving at our decision.

150. It is nearly half a century ago that attention was first directed to the quality of the water supplied to London, and the Royal Commission of 1828, appointed in consequence of complaints on this head, reported to the effect that the water was naturally good, but was fouled by the admixture of foreign matters; and this led to the introduction of filtration, by which the quality was much improved.

The Board of Health report of 1850 pointed out the impure state of the Thames within the tideway, but objected generally to the Thames water, even in its purest state. The Chemical Commission of 1851 reported fully on the subject, in terms we shall have to quote hereafter; and in 1852 a great improvement was effected by the passing of the Metropolis Water Act, which compelled the companies to take their water from a point above the tideway, to filter it effectually, and to preserve it in covered reservoirs.

In 1866 and 1868, in consequence of the reports of the Royal Commission on the Pollution of Rivers, Acts were passed compelling towns and villages within certain limits to dispose of their sewage without polluting the Thames and the Lee; but the effects of these Acts have not yet been proved.

151. We may most conveniently divide this part of our inquiry into two heads:—

A. What is the evidence as to the present quality of the water in the Thames and its tributaries?

B. What are the influences likely to affect its quality for the future?

A.—ON THE PRESENT QUALITY OF THE WATER IN THE THAMES AND ITS TRIBUTARIES.

152. We have taken a large amount of evidence, tending to illustrate this question, from persons of the highest authority, and whose opinions on the various points involved in the inquiry we shall quote in their proper places. But as, on several previous occasions, the waters of the Thames have been analysed and reported on, we have deemed it right also to refer to such of these analyses as appear to us most authoritative and trustworthy. And we may mention the following as deserving of special attention:—

The Chemical Commission of 1851 gave a full analysis of the waters then supplied to London, which we have reprinted in Appendix A F.

In 1856, after the water companies had removed their sources of supply from the Thames to points above the tideway, in accordance with the Act of 1852, a further analysis was made on behalf of the Government, by Messrs. Hofmann and Blyth. We have reprinted portions of this analysis in Appendix B G.

On the inquiry by the House of Commons Committee in 1867, analyses were put in evidence, made by Dr. Letheby, Dr. Odling, and Professor Abel; these we have reprinted in Appendix A G.

The same chemists have also made for the London water companies a later analysis, which has been sent to us, and which we have printed in Appendix A H.

Another set of analyses that deserve special attention are those published monthly by the Registrar General. It appears that after the cholera epidemics of 1849 and 1854 the attention of this department was drawn to the water supply of the metropolis, and an arrangement was instituted by which a monthly analysis of the waters was made, in the first instance by Dr. Robert Dundas Thompson, then by Professor Hofmann, and latterly by Dr. Frankland. The results are published once a month in the Registrar General's returns of the health of the metropolis, and a summary is made at the end of each year. We give some examples of these documents in Appendix A J.

153. The analyses above referred to all apply to waters actually delivered in London by the various companies, and taken from their ordinary sources of supply; but we found that the extended nature of our inquiry rendered these data insufficient. It was our business to report on the water of the Thames basin generally, and therefore it was necessary that our information should not be limited to one point, but that we should know something of the general quality of the water in different parts of the basin, and should endeavour in the first place to ascertain its natural condition when in its pristine state of purity, and then to trace, as far as we could, the various influences it was subject to during its flow. For this purpose, with the sanction of Your Majesty's Treasury, we determined to have samples of water collected from various parts of the basin and analysed in the same manner as in the cases of the Welsh and Cumberland districts. The selection of the samples was entrusted, as before, to Mr. Pole, whose report thereon will be found in Appendix O, and the analyses of the waters by Drs. Frankland and Odling are given in Appendices A X, 1 and 2.

154. We shall, in treating of the chemical quality of the waters, adopt the usual plan of making a broad distinction between the *mineral or inorganic contents*, such as metallic and earthy salts, which in the case of river waters are found present in their first sources; and the *organic contents*, which become added to the waters by accidental circumstances during their flow.

155. The mineral or inorganic contents of the Thames water supplied by the companies from Hampton appear to amount usually to from 15 to 20 grains per imperial gallon of water, of which more than one half is carbonate of lime, and the rest sulphate of lime with salts of magnesia, soda, potash, and silica, and traces of alumina and iron.

The waters of the Lee valley, as supplied by the New River and East London companies, differ little from those of the Thames; but those of the Kent Company being drawn directly from the chalk, contain a considerably larger quantity of the salts of lime.

156. The point, connected with these mineral contents, which is of the main importance in our present inquiry, is their influence (chiefly caused by the presence of lime) in giving to the water the peculiar quality called *hardness*. In the investigations that have taken place from time to time on the water supply of the metropolis, the hardness of the water has always been a prominent topic of discussion, often involving elaborate general comparisons between the eligibility of hard and soft water respectively for the supply of towns. It is, therefore, necessary that we should give a summary of the information we have obtained on this point, and the conclusions at which we have arrived thereon.

On the Hardness of the Thames Water.

157. Owing to the solvent power of water, all waters percolating through or flowing on the surface of the earth take up more or less mineral matter, consisting in almost all cases of carbonate of lime as the essential ingredient, and of a few other salts as subordinate ones. When these mineral matters are in excess the waters are called mineral waters; but in moderation, say 15 to 30 grains to the gallon of 70,000 grains, they are present in almost all river waters.

Water charged with salts of lime has the property of decomposing soap to a certain extent, by the combination of the lime with the alkali, and this is what is meant by the popular description of the water being "hard." Soft water makes a lather freely, but hard water curdles a portion of the soap, and requires consequently more of it for the purpose of washing.

158. The first attempt to investigate the hardness of water in a way combining scientific research with practical utility, was by the late Dr. Clark of Aberdeen, who shortly before his death wrote to our chairman the letter on the subject which we have printed in Appendix G. His attention was directed about thirty years ago to the hardness of the London waters, and in March 1840 he took out a patent for a mode of softening them. This invention has proved to be a practicable process of much utility, and we shall have occasion to refer to it hereafter; it is important to our present object that in his patent Dr. Clark described a mode by which the hardness of water could be *defined* with great exactness. He first formed a series of artificial waters of several grades of hardness, each containing a known proportion of bicarbonate of lime; and when any unknown water was to be tried he compared its effect on soap, by an ingenious process, with these as standards, and so at once obtained an accurate measure of its hardness. He proposed to designate the hardness of water by the *number of grains of bicarbonate of lime contained in one imperial gallon* (or 70,000 grains) of a standard water producing the same curdling effect. This process is known as "Dr. Clark's test," the number of grains being called "degrees." It is exceedingly easy of application, even by persons without any chemical experience; it is very definite and accurate; and it has been very generally approved and adopted by chemists treating of the subject. The Registrar General's reports, however, give the number of grains of carbonate of lime in 100,000 grains instead of 70,000, so that to compare these degrees of hardness with those usually adopted, they must be reduced in the ratio of 10 to 7.

159. The water of the River Thames, supplied as it is in great part by springs from chalk and oolitic limestone, is naturally somewhat hard. It is, however, well known that flowing water tends to part with a portion of the carbonate of lime it holds in solution, and therefore, whatever may be the hardness of the water as it issues from the chalk or any calcareous strata, after a flow of some miles it falls to a nearly uniform standard, varying from about 12 to 15 degrees in the imperial gallon.

The Chemical Commission of 1851 gave the hardness of the metropolitan waters as follows:—

"The hardness was remarkably uniform in the water of the eight principal metropolitan water companies.

"The degrees of hardness, by Clark's soap test, of the waters of the eight principal London companies, observed on the 29th, 30th, and 31st of January, were as follows:—

"From other sources than the Thames.	New River	14°·9
	East London	15°·0
	Kent*	16°·0
"From the Thames.	Grand Junction	14°·0
	West Middlesex	14°·6
	Vauxhall and Southwark	15°·0
	Chelsea	14°·4
	Lambeth	14°·2
	Lambeth (from Thames Ditton, March 8)	14°·2

"The variation observed in this property is from 14° to 16°; or if the Kent water be excepted, from 14° to 15°, or one degree only. It appears also, from observations made at different seasons, that this range is not considerably exceeded at any period of the year, except during floods, when the hardness of Thames water may fall to eight or nine degrees."

The analyses by Drs. Letheby, Odling, and Abel of waters taken between December 1866 and February 1867 give the hardness from 13 to 14½ degrees; that of waters taken in May, June, and July 1868 is somewhat less. They say,— App. A G. App. A H.

"On reference to Table No. 1, it will be observed that the hardness of the water supplied by the Thames companies ranges from 11·3° to 12·5°—that from the New River being 11·9°; while the water from the East London Company has a hardness of 11·7°; and that of the Kent Company a hardness of 17·6°.

"After boiling for fifteen minutes, the hardness of the water from the Thames companies is reduced to between 2·4° and 3·5°; the New River water to 2·3°; the East London water to 2·6°; and the Kent Company's water to 6°.

"On comparing these results with the return of analyses made by us in the winter of 1866–7 (in reference to the Metropolis Water Inquiry, conducted by a Committee of the House of Commons in 1867), it will be observed that in all instances excepting that of the Kent Company's water (derived solely from deep wells), the hardness is less than that of the water collected during the winter season, a result which is in accordance with previous experience regarding the fluctuations in the composition of river water at different seasons."

The analyses of the Registrar General, when corrected on account of their unusual form, give a variation in 1847 from 11¼ to 16 degrees, omitting the Kent water, which varied from about 15 to 20 degrees.

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* At this time the Kent Company took water from the river Ravensbourne.

App. A X. The analyses made for ourselves by Drs. Frankland and Odling show the following results when reduced to Dr. Clark's scale :—

	Hardness according to Dr. Clark's scale.	
	Before boiling.	After boiling.
HEAD WATERS.		
Oolite Springs - - - - - - -	15·3	3·4
MAIN STREAM OF THE THAMES.		
At Lechlade - - - - - - -	15·3	3·6
Above Oxford - - - - - - -	12·7	5·4
A little below Oxford - - - - -	13·4	5·7
Seven miles below Oxford - - - - -	15·4	6·3
Above Reading - - - - - - -	14·7	5·7
A little below Reading - - - -	12·7	4·0
Five miles below Reading - - - -	14·0	5·3
At Medmenham - - - - - - -	13·6	5·3
Above Windsor - - - - - - -	15·5	5·2
Below Windsor sewer - - - - -	15·7	5·2
Three miles below Windsor - - - -	14·6	7·4
At Hampton - - - - - - -	14·0	3·0
TRIBUTARIES.		
Cherwell - - - - - - - -	15·9	3·6
Thame - - - - - - - -	17·9	4·5
Chalk Spring, Watford - - - - -	17·3	2·6
Kennet above Hungerford - - - - -	15·2	2·5
„ „ Reading - - - - -	13·7	1·7
Bagshot Sands - - - - - - -	1·0	1·0
Wey - - - - - - - -	5·8	5·6
Mole - - - - - - - -	11·3	3·1
OUTLYING WATERS.		
Lee and Mimram mixed - - - - -	14·0	1·5
Amwell Well - - - - - - -	14·7	4·1
Caterham Well - - - - - - -	16·4	6·3
Croydon Well - - - - - - -	15·4	6·4
Wandle at Mitcham - - - - -	14·8	6·8

160. The hardness of the London water does not seem prominently to have attracted attention, as forming any serious objection to the source, till the appearance of the Board of Health Report of 1850. Indeed, on the contrary, the more general desire seems to have been, when the Thames was found fault with, to resort to the chalk springs, whose water was harder still. The Board of Health, however, were of a different opinion, and laid so much stress on the supposed evils of the hardness of the water as to recommend the abandonment of the Thames almost on this ground alone.

161. The effects of hardness have been discussed in regard to the use of the water—

a. For drinking.
b. For culinary use.
c. For washing and for manufacturing purposes.

We propose to give a summary of the evidence we have been able to collect on each of these points: but before doing this we may quote a few explanatory observations, by the Chemical Committee of 1851, who devoted much attention to this branch of the subject, and to whose opinions on it we attach great value.

162. They say—

"It may be useful to distinguish the quality known as the 'hardness' of water according as it is of a temporary or permanent character. Perfectly pure or soft water, when exposed to contact with chalk (carbonate of lime) is capable of dissolving only a very minute quantity of that substance; one gallon of water, in weight equal to 70,000 grains, taking up no more than two grains of carbonate of lime. This earthy impregnation is said to give the water two degrees of hardness. But waters are often found containing a much larger quantity of carbonate of lime, such as 12, 16, or even 20 grains and upwards in the gallon. In such cases the true solvent of the carbonate of lime, or at least of the excess above two grains, is carbonic acid gas, which is found to some extent in all natural waters. But this gas may be driven off by boiling the water, and the whole carbonate of lime then precipitates in consequence, or falls out of the water, with the exception of the two grains which are held in solution by the water itself. The gas-dissolved carbonate of lime gives therefore temporary hardness curable by boiling the water. An artificially prepared hard water, containing 13½ grains of carbonate of lime to the gallon, was observed to decrease from 13·5 to 11·2 degrees of hardness, merely by heating it in a kettle to the boiling point. Boiling for five minutes reduced the hardness to 6·3 degrees, 15 minutes to 4·4 degrees, 30 minutes to 2·6 degrees, and one hour to 2·4 degrees. The softening effect of boiling does not therefore appear all at once, but the greatest proportional effect is certainly produced by the first five minutes' boiling. The West Middlesex and New River waters were both found to soften by boiling, very much in the same manner as the preceding pure chalk water, except that the ultimate hardness of the two waters specified was somewhat higher. By an hour's boiling the West Middlesex fell from 14·6 to 5·5 degrees, and the New River from 14·7 to 4·1 degrees.

"Other salts of lime, such as sulphate of lime, are generally dissolved in water without the intervention of carbonic acid gas, and therefore remain in solution although the water is boiled, imparting hardness.

"The carbonate of lime in water decomposes about 10 times its weight of soap in washing (more exactly 8·8 white curd soap and 10·7 common yellow soap), and other salts of lime act injuriously upon soap, in proportion to the lime they contain; the soluble soap containing soda being converted into an insoluble and useless compound containing lime. The water is then deprived of lime or softened at the expense of the soap. The lime in 100 gallons of Thames or of New River water thus occasions the destruction of about 34 ounces of soap, before any portion of it becomes available as a detergent."

a. Effects of Hardness of Water for Drinking Purposes.

163. The Board of Health collected evidence on this point, and expressed an opinion "that the presence of lime and other mineral matter deteriorates the wholesomeness and "value of waters for the purposes of drinking."

The Chemical Commission of 1851 held different views. Their Report says :—

"When in good condition, the Thames water possesses the peculiar and agreeable brightness of chalk waters, arising from the entire absence of colour, combined also usually with good aëration.

"The Thames water may be described to be, in circumstances not unfavourable to purity and coolness, a palatable water. The amount and nature of its saline constituents probably contribute to its general acceptability as a beverage.

"It may be safely stated, that no sufficient grounds exist for believing that the mineral contents of the water supplied to London are injurious to health. No reasonable doubt indeed can be entertained of its salubrity. The shallow well waters of London vary from 32 to 80 degrees of hardness, yet these waters have never been pronounced unwholesome.* An aërated water is manufactured and safely consumed to some extent which contains 92 grains of carbonate of lime to the gallon, instead of 12 or 14 grains, as in Thames water. The portion of lime and magnesian salts in the water drunk must indeed be greatly exceeded in general by the quantity of the same salts which enters the system in solid food. The only observations, from which an interference of the lime in water, in deranging the processes of digestion and assimilation in susceptible constitutions, has been conjecturally inferred, have been made upon waters containing much sulphate of lime and magnesia, as the Brighton shallow well water, or the hard selenitic water of the New Red Sandstone, and have no force as applied to the Thames and its kindred waters, as the earths exist in these principally in the form of carbonate."

164. Mr. Bateman expresses his firm conviction that soft water is very much more wholesome than hard water, but he remarks at some length on the difficulty of finding any tests by which the effects can be truly ascertained. 6680–6700.

Mr. Hawksley says on this point: 2600.

"I imagine there are quite as many fine-raced people living in hard water districts as there are living in soft water districts. I am well acquainted with districts of both characters, and I may say that quite four-fifths of the whole surface of the globe yields hard water—in fact, the cretaceous strata and the other lime formations occupy a large portion, from which alone hard water can be obtained. I think these extend quite to four-fifths of the earth's surface."

Mr. Beardmore states that his experience leads him to consider hard water is preferable 3381–7. for drinking purposes, and Mr. McClean agrees in this opinion. 5641.

Mr. Rawlinson thinks the evidence conflicting as as to what is the best water for health, 1363–80. and believes that change either from hard to soft water, or *vice versâ*, is prejudicial. He considers that by far the greater quantity of water drunk in England is hard water, all above six degrees of hardness being so designated.

Mr. Way thinks the question of hardness would have a reference more to habit than any- 1457–61. thing else. It is exceedingly doubtful whether water of two or three degrees of hardness is more healthy, because people are in the habit of drinking waters of 17 or 18 degrees of hardness without any apparent injury to health. The waters which are the brightest and most liked are the hard waters—the chalk waters. There is no reason to believe chalk water injurious, except perhaps in some special instances. As to the question of health, he does not attach importance to the hardness, either one way or other, if it is in moderation.

Mr. Duncan mentions the opinion of the medical officer of Liverpool, that a change 2185–97. from hard to soft water was prejudicial.

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* The objection more recently brought against the shallow well water in London, is on account of its pollution by the infiltration of organic matters from the soil, and not from the natural mineral contents or hardness.

3934. Dr. Letheby considers a moderately hard water best for drinking purposes and for the general supply of cities. He illustrates this opinion by reference to the supplies of Paris and Vienna. A large proportion of the earth's surface consists of calcareous districts, supplying hard water. He is not aware of any instance of moderately hard water producing gravel or surgical affections.

2646-2719. Dr. Lyon Playfair gives evidence as follows:

As a sanitary question, if the water is otherwise pure, I do not think that mere hardness is of much importance as to health; in extreme cases I would consider a hard water injurious to health, but in ordinary cases, such as the Thames water, I do not thinki t injurious to health, if there are no other impurities in the water than the mere differences in the amount of carbonate of lime.

In some cases hard water might prove injurious, as in calculous affections and in dyspepsia, still, generally, a tolerably hard water may be taken without much inconvenience; but water of 20 degrees of hardness is very hard water, and I would much prefer, even for purposes of health, that it should be softer.

2661. Taking the water which comes from the springs in the chalk, do you consider that water generally to be prejudicial to health?—No, not prejudicial to health, except in the circumstances which I have mentioned.

2691. Are you aware of any experiments which have been made with regard to the advantages of the use of either hard water or soft water for drinking purposes?—I can only rely upon the experiences of large towns where they have been supplied with hard water and the supply has been suddenly changed to soft water; of course I do not know of the reverse instances where soft water has been suddenly changed to hard, but in the former cases I never saw any deterioration of health.

2692. Do the returns of the mortality of the towns now supplied with soft water show any improvement in consequence of the use of soft water?—I might mention such towns as Liverpool, for instance, where there has been a very large improvement in the health, but the introduction of soft water was only one of many hygienic improvements which took place at the same time; therefore, the proportion which should be attributed to that is difficult to distinguish from the others.

2693. That probably would be the case in almost all instances where a new water supply has been introduced?—It is; for a new and enlarged supply of water generally arises when a population has become awakened to the necessity of hygienic improvements generally.

3124-3218. Dr. Parkes's evidence on this subject is as follows:

With regard to the effect upon health of the use of hard waters, distinguishing between the carbonate of lime water and the sulphate of lime, and sulphate of magnesian waters, the carbonate of lime waters appear in some cases certainly to produce some effect upon health, for instance, dyspepsia, and they do not agree with some class of persons, whereas to others they appear to be quite harmless. There is a large population living upon chalk water, and we cannot trace any very decided effect upon their health in the production of any class of disease—calculus or anything of that kind, but at the same time persons do sometimes suffer from indigestion.

3125. What degree of hardness would, in your judgment, be a safe water, taking an average constitution; some people will live in spite of difficulties; their resistive force being such that nothing seems to affect them, but my question has reference to an average constitution?—I do not think with regard to pure chalk water that there is any evidence that a moderate amount of carbonate of lime in the water does any harm, certainly not on the large scale; in some individuals it produces indigestion.

3126. Would 16 or 20 degrees of hardness be prejudicial?—I think that that degree of hardness would be certainly prejudicial. I think that very probably it might disagree with a great many persons; but supposing it reached to 8 or 10 or 12 degrees of hardness from carbonate of lime, it might be considered probably good water as far as that was concerned, but I should draw a marked distinction between that and the hardness arising from sulphate of lime, or sulphate of magnesia, or chloride of calcium, which would certainly disagree in much smaller quantities, so that the goodness of water for drinking purposes I would estimate according to its permanent hardness rather than according to its temporary hardness.

3134. But supposing the water was equal in purity and free from organic matter, does the question of simple hardness or softness enter into the consideration of those whose special duty it is to care for the troops with regard to the kind of water that they should use?—In all cases we would prefer a soft water if it were possible to obtain it; and if the water were permanently hard, to a large extent that water would be reported upon unfavourably, and better water as regards that property would be procured if it were possible.

3137. Speaking generally, you are of opinion that the mere presence of carbonate of lime of 15 degrees of hardness would not be injurious to health?—With 15 or 16 degrees of carbonate of lime hardness I should say that it would be hard water, and with some persons it would disagree and produce dyspepsia. I think it should not exceed 10 or 12 degrees if possible. At the same time I should wish to state that one would prefer water free from that even, if it were possible to get it.

3201. The greater part of the troops I presume in this country are located in districts where the water is of a moderate degree of hardness; for instance, Dover, Portsmouth, Southampton, Plymouth, and the greater part of Ireland?—Yes, and at Chatham. At Southampton we have no troops, and at Aldershot the troops are upon soft water. At Chichester the water is hard, and at Colchester it is hard. For the most part they are chalk waters.

3202. Have you known instances of any ill effects from the use of such waters?—Not of the good chalk waters.

3203. Have you known any instances where troops have been located in districts where they have been using water of a moderate degree of hardness, and have suffered when they have been removed to a district where the water was soft?—I have never seen any reports of that kind.

3212. Are you aware whether a certain quantity of carbonateof lime may not in many cases be rather beneficial than otherwise to health?—I think that is again very doubtful. The fact is, that almost all kinds of food contain enough lime for the supply of the body, and the quantity of carbonate of lime supplied in water might no doubt be applied to the wants of the system, but I can hardly think that it would be necessary, that is to say, I do not think it should be an argument for the supply of chalk water that lime is thereby supplied.

3217. I see that one disorder which you mention is calculi; have you been able to trace that back to the use of water?—In Germany especially there is a very strong opinion in certain parts that the phosphate of lime calculi and calculi generally are more common in districts where the inhabitants use very hard waters, but in this country the evidence is so far negative; we have not many districts supplied with limestone waters or the magnesian limestone waters; most of our lime waters are chalk waters, and so far, I think, in this country there is no evidence of there being a greater amount of calculi than in other districts not supplied with this water, but in Germany and, perhaps, in France the evidence is stronger that the use of some of the lime waters may have an influence in the production of some of the calculi.

3218. Would that be in the case of water of an ordinary degree of hardness, or of an excessive degree of hardness arising from the chalk or from the presence of sulphates?—I believe especially from the large amount of hardness arising in most cases from the mixture of chalk and of sulphates, at least it is so in most of those waters.

Mr. Simon says:— 2777–2835.

2777. Has your attention been directed to the quality of the water in London for drinking purposes, as to the effect upon the health of the inhabitants, as compared with water of a softer and purer character?—I have no evidence upon that subject. I think that, practically, the only very important sanitary question as regards the quality of the water supply to London is the question of organic admixture. I do not think that the question of a few grains of lime in a gallon of water can be regarded as a very important sanitary question.

2778. Then, in your judgment, the presence of lime, or two or three degrees of hardness in the water, would not be a matter of much consideration, supposing the water were free from organic impurities?—Quite so, as regards the public health.

2779. For drinking purposes, probably a little hardness in the water would add to its life and pleasantness to the taste?—I would not quite say that; I have found soft waters, or at all events, hard water artificially softened, very agreeable.

As regards drinking purposes, I am not sure of any important difference, but am inclined to prefer the soft water.

2791. Do you know of any experiments which have been made with regard to the use of soft water and hard water upon health?—If by hard water is meant such water as we have in London, I am not aware of any facts of the smallest value showing difference of effect between such water and soft water.

2792. It has been stated that there are certain classes of diseases more prevalent in districts where hard water is used than in others, for example, diseases of the bladder and the stone; can you give us any evidence on that point?—I do not think there is any evidence that is worth a rush upon that subject.

2793. That evidence which was given by Dr. Prout some years ago you do not attach much importance to?—I do not remember the exact language of Dr. Prout upon the subject, nor know whether he professed to argue from any large field of observation; but I believe that no statistics of value exist in proof of such an assertion.

2823. Although it is a hard water, in some cases to even 18 or 20 degrees, yet it would not be in your mind, in a sanitary point of view, objectionable to use that water?—It would not make it unwholesome water, so far as I know, for drinking, but there would remain of course the economical question.

2824. Therefore we may assume that the question, as between the existing water in the Thames basin and pure soft water, would be practically reduced to its economical results for the purposes of washing and culinary purposes and domestic use?—Yes.

2825. As far as the simple sanitary question goes, you see no objection at all to it?—No.

As regards health my bias is in favour of soft water, but I cannot say that I think the case established against hard water (*i.e.*, against hard water of such comparatively few degrees of chalk hardness or carbonate of lime hardness as you have in the London waters) that it acts injuriously on health. It is different, of course, when you come to certain other hardnesses of water; but I do not think that the hardness, for instance, of the New River Company's water can be considered detrimental to health.

Dr. Frankland says:— 6259. 7777.

6259. You have spoken as to the properties of the London water with regard to health; what is your opinion as to the effect upon health as between hard water and soft water?—My opinion is that there is no difference. 352–6.

6277. For drinking water you say you attach no importance to that difference of degree of hardness?—Not as regards its effect upon health, but I attach great importance to it in the use of water for cleansing purposes.

6352. Some difference exists, does there not, in the opinion entertained by medical men and chemists with regard to the effect on health of soft and hard waters?—There has been some difference of opinion on the subject, but I think the general impression now is that there is not much to be said upon that point, that they are equally good as regards their effect upon health.

6355. Have you any reason to suppose that hard water as drinking water might exercise, not any direct influence in the way of supplying carbonate of lime to the body, but in taking away less organic or mineral matter from the body than soft water?—I have never considered the subject from that point of view, I confess; but the quantity of matter dissolved in the hardest water ever used for drinking purposes is such a very small fraction of the total solvent power of the water, that I should not imagine that there could be any substantial difference between the two kinds of water in that respect.

6356. Have there been any experiments upon that point?—No, not that I know of.

Dr. Odling says:— 7054–8.

6439. On the score of health do you make any distinction between soft and hard water?—I do not think there are any facts which enable one to give a positive opinion. Some gentlemen who have considered the subject entertain very strong opinions both ways; but I do not know any facts upon which one can speak positively.

6478. What is your opinion with regard to the presence of carbonate of lime?—For mere drinking purposes I do not consider it a matter of any disadvantage at all.

Sir Benjamin Brodie's evidence is as follows:—

7023. Have you any reason to suppose that the use of soft or hard water as a drinking water produces any difference of effect upon health?—I cannot say I have reason to think so.

7024. Have you any reason to suppose that the health of a district is independent of that?—I have no reason to think it to be dependent upon it.

7025. Is there not a want of direct experiment upon that subject?—Oxford is a place where the spring water is extremely hard, and injuriously hard for every purpose, but I never heard that it had been made out that Oxford was liable to any particular class of complaint from that reason. If it were so, I think it would have been discovered; but perhaps some physician from the infirmary might tell you to the contrary.

Dr. Miller thinks any precise observations on this point are difficult to obtain, but he thinks, so far as observation goes, it is a matter of indifference whether it is hard or soft water. He adds:—

"It depends upon the quality of the hardness. Chalk waters, I consider, are waters which are perfectly wholesome, but waters which have a similar degree of hardness from sulphate of lime there appears to be some reason to believe are found occasionally to disagree with persons. Still there are waters which are supplied to large populations containing sulphate of lime, and very hard sulphate of lime waters. For instance, the population of Wolverhampton and Birmingham are supplied with water of this kind. It is certainly objectionable, but what I was going to say was that the evidence in that case is that there is no sensible injury to health directly traceable to the water as far as observations go. I believe, generally speaking, the impression is that the hardness caused by sulphates of lime and magnesia is more likely to produce certain slight derangements than the use of chalk waters of a similar degree of hardness. I should not think there was the slightest reason to suppose that any injury would result from such water. From long habit I should certainly prefer hard water for drinking purposes to soft water."

7095. Are not a very large proportion of the waters consumed in this country, or in any other country, flowing as they do over calcareous formations principally, hard waters?—Yes, they are.

7096. And the proportion of soft water used is comparatively small?—The Scotch waters are many of them very soft, and some of the waters in Cumberland are soft. Whitehaven and several large towns are supplied with soft water now, but in the south of the island the water supply is generally hard.

7097. Have you had occasion to notice whether the change from one water to the other produces any ill effects upon the health of the inhabitants?—I have no observations upon that point.

"Have you formed any opinion yourself as to the comparative value of a supply of water of a moderate degree of hardness to a town, or of a soft water supply?—I should say that for drinking purposes a hard water is preferable, and it is liable to a less frequent change than a soft water. The principal objection which appears to me to arise in the case of soft water is that it is liable to peaty discolouration, which makes it at times very disagreeable for drinking purposes, and it is also more liable to absorb organic impurities. I should prefer, merely looking at it as an abstract question, water of a moderate degree of hardness for drinking. I must say that for domestic use soft water is preferable on account of its economy, but for dietetic purposes I think hard water has the preference.

"Do you know of any experiments bearing directly upon that question with regard to the effect upon health?—No, I have no observations upon that point. Having always lived in a hard water district I certainly prefer it for drinking purposes, but I believe persons who live in soft water districts are equally favourable to the use of soft water."

7124. Dr. Angus Smith gives evidence as follows:—

7260. Have you been able to form any opinion as to the effect upon health of the use of soft water or hard water?—I do not think there is good evidence upon that point. I have heard of horses losing their appearance when they used hard water, and of persons of my own acquaintance who got indigestion by coming into hard water districts; but then I must say that those cases are somewhat balanced by people being rather disagreeably affected on going to soft water districts, and especially some of the hilly districts of the north.

7261. That depends a good deal, I presume, upon the previous habits of people?—Yes. I do not think that there is a great deal of evidence on either point. I do not think it is fair, in fact, to take the appearance of the population as any criterion. If we did so, we might find some arguments in favour of soft water. I should think that the tallest people in Great Britain are to be met in soft water districts; for instance, in Cumberland and, probably, in Aberdeen; I may say that the tallest people I have seen in Great Britain are in Aberdeen, which is a very soft water district.

7264. Are not soft water districts generally mountain districts, where they have the purest air as well as pure water?—Yes; I believe, however, it is quite possible for the blood to take up matter which is inorganic dissolved in water.

165. From the above evidence, at any rate, there is no reason whatever to suppose that the hardness of the Thames water would be in the least degree prejudicial to health.

Some eminent chemists have contended that a moderate quantity of carbonate of lime is not only harmless, but that it is actually useful in supplying material for the bones of men and animals. Considering, however, the much larger quantities of carbonate of lime taken in our solid food, such an additional source of supply would seem to be unnecessary. Judging in fact from the condition of the inhabitants of soft water districts well supplied with a variety of food, it is evidently perfectly immaterial, although it may be otherwise in districts short of carbonate of lime, and when the local produce suffers from the same deficiency as the water. Still it remains to be shown whether when large quantities of water are drunk, those waters which contain the smallest quantities of mineral ingredients may not dissolve and take away more from the body than harder waters, and whether there should be any cause for preference on these grounds.

It may also be a question whether, from the better keeping qualities of waters of a moderate degree of hardness, from their general better aëration and greater freshness, and from their lesser solvent power, such waters are not the best for drinking purposes. Perfectly pure water does not exist in nature. All spring and river waters contain more or less mineral ingredients, and it is only in limited mountain districts, where hard and non-calcareous rocks prevail, that water is found approaching a nearer standard of purity. That the use of these purer waters is more conducive to health is without proof; there is, however, a great want of exact evidence on the subject of the dietetic value of soft and hard waters.

b. For Culinary Purposes.

166. Another of the objections of the Board of Health to the Thames water was that, by reason of its hardness, it was unfit for the preparation of tea, by occasioning waste, and for all culinary processes by diminishing their efficiency and increasing their expense.

167. The Chemical Commission of 1851 remark on this point as follows :—

"The hardness of the metropolitan water supply, which is due to its mineral constituents, may be considered as the same whether derived from the Thames or the Lee, and amounts on an average to about 14 degrees. Although this degree of hardness is considerable and highly objectionable, still it is exceeded by the hardness of pure chalk waters, such as are supplied by water companies to the towns of Gravesend, Dover, and Brighton, and which may be estimated at from 18 to 20 degrees. The deposit which Thames water gives rise to in boilers is also friable and less coherent than the stony deposit from selenitic waters ; and means exist, such as the use of sal ammoniac, for entirely preventing the occurrence, in steam boilers, of deposit from chalk but not from selenitic waters.

"The hardness of the London water is also of the least objectionable kind, being chiefly, as has been already stated, temporary hardness, which is removed by boiling. The whole 14 degrees of hardness can be ascribed only to that portion of the water which is used cold. To ascertain the average state of hardness of heated water, portions of water were drawn on six different occasions from the fixed boiler of a kitchen range supplied with New River water ; the hardness was found to be 5·4, 4·9, 4·1, 4·1, 4·9, and 5·3 degrees, of which the mean is 4·8 degrees. The hardness of London water, as it is commonly used after boiling, appears, therefore, to be about five degrees, while without heating it amounts to 14 degrees. The distinction between permanent and temporary hardness was illustrated to us at Greenwich, where the brewer described the deep well-water of the Hospital (which is only occasionally pumped up) as a soft water, although its hardness is 21 degrees ; but it is only used by him for mashing after being boiled, when, being a pure chalk water, its hardness is reduced to about four degrees. The importance of this distinction was likewise shown, though in another manner, at Whitehaven, where a great and apparently disproportionate advantage has been experienced, from a change in the town supply, from a water which we found to be of 6·7 degrees of hardness to another water of 1·4 degrees. The hardness of the former water, however, although not great in amount, proved to be of the permanent description, as after an hour's boiling the water of the old supply was still of 6·4 degrees, that is, harder than even the Thames water is after boiling. The hardness of the former town supply in Lancashire, although often inconsiderable, was generally of the same permanent character as the old Whitehaven supply.

"The hardness of water forms an objection to its use, both in cooking and washing, but the force of the objection to the Thames water for culinary purposes is much diminished by the large amount to which that water is softened by boiling. Tea is prepared in London with water which, it appears, is practically of only five degrees of hardness. It appears impossible to obtain any standard or test, by which the strength of an infusion of tea can be expressed in numbers, or to find any means of judging of its quality more precise than the indications of taste. On carefully comparing infusions, prepared as for family use, of an equal quantity of tea in the New River water before described, which averaged about five degrees of hardness, and in water of 2·4 degrees only, the observation made on several different occasions was, that the inequality in strength and flavour of the two infusions was altogether insensible to some palates. But an increase in the bitterness was more generally remarked in the soft water infusion, without enhancement of flavour. Where a preference was expressed it was in favour of the quality of the hard water infusion, but the difference between the two infusions was not considered material by anyone.

"Hard water is disadvantageous for making tea chiefly, it appears, by requiring the heat to be longer maintained in preparing the infusion. Tea is habitually made of excellent quality and with economy, in some families, by means of spring water of a high degree of permanent hardness ; but then the infusion is continued for half an hour, and the temperature maintained near the boiling point during that period. The tea for the Greenwich pensioners is infused in a large copper, surrounded by a steam case, with water from a well in the superficial gravel, of 24 degrees of hardness, of which 18·6 degrees are permanent. But in the private residences adjoining it is found necessary to use carbonate of soda for softening, with the same water, in the absence of the efficient means of infusing described. Where any great loss of strength of the tea infusion has been observed, in passing from a soft to a harder water, it may be probably referred to the circumstance that the mode of infusing has not been properly adapted to the hard water. The use of hard water must on this account be attended with a frequent waste of tea. The rapid process of infusion generally employed in London indicates the use of a comparatively soft water. The water to which M. Soyer gave a preference for tea-making, even over distilled water, in experiments reported to the General Board of Health, was the London deep-well water. This is usually softer than Thames water after boiling, and contains, in addition, a sensible quantity of carbonate of soda, to which its superiority is probably due in part. The water of the Trafalgar Square deep well has an original hardness of 5·4 degrees, which is reduced to 1·1 degree by boiling. No great objection can be taken to the use of the London water for other culinary purposes. The presence of much sulphate of lime in water makes it unsuitable for cooking vegetables, owing to the tendency of that salt to form an insoluble compound with their legumine; but this effect is insensible with Thames water."

168. Mr. Bateman refers to the evidence of M. Soyer before the Board of Health, substantiating, as he considers, an economy in cooking. 55–63.

Mr. Hawksley coincides in opinion with the Chemical Commission, and refers to the fact that the London water, and all chalk waters, are very soft after they are boiled ; adding that for manufacturing and many other purposes water is boiled, and also for many domestic purposes. 2511.

Mr. Rawlinson considers there would be great economy in household purposes by the use of soft water. 1345–6.

1457–61. Mr. Way also thinks soft water would be economical for cooking purposes. But he adds:—

"Hard water makes better tea than soft, although this is contrary to the general impression. The truth is that soft water makes a darker coloured tea, and dissolves a quantity of bitter extract, which makes the tea strong; but to a refined taste hard water gives much the best flavour, as it leaves the disagreeable matter undissolved."

6267–8. Dr. Frankland, while preferring generally soft water, states that boiling the London water causes it to lose more than half its hardness. As to making tea, he says: —

6359–61. "It is generally held that soft waters make better tea than hard waters, but I do not think that, as an abstract proposition, that is the case. I think that both waters are capable of making equally good tea, but the difference depends upon the length of time that the brewing is conducted. A hard water requires to be longer in contact with the tea at an elevated temperature than a soft water does, and there may be some influence of that kind in dyeing, so that by prolonging the operation you get an equally good result, and it may be perhaps in some cases a better result from hard water than you can get from soft water.

"What is the case with regard to brewing?—With regard to brewing, the case I think is this, that where you want to brew a pale ale it is absolutely necessary to have hard water, and not merely hard water, but water that is permanently hard, that is, water which contains sulphate of lime; but in brewing any other kind of ale, where the colour is not of importance, probably soft water is best to be used as extracting a greater amount of matter from the malt.

"In brewing tea with the London water, which I suppose would probably be softened down to six or seven degrees of hardness, or seven or eight degrees at all events, if the boiling has been continued for half an hour, the length of time during which the tea ought to be brewed to get the most delicate beverage is not more than five minutes, and therefore with a very soft water like that supplied to Manchester it ought not to be more than two minutes. In fact I remember that the best tea was obtained there by pouring the water on to the leaves and almost immediately off again. If you allow a soft water to remain upon the leaves for 10 or 15 or 20 minutes you get a bitter principle out of them, which is unpleasant to me, although I believe it is pleasant to some tea drinkers. Some tea drinkers think that kind of tea the best, and that is more easily got out by soft water than by hard, and therefore from that point of view it might be said that the tea would be more likely to be spoilt by hard water than by soft."

App. D. He further adds that a constant supply of hot water has become almost a necessity in every household, but refers to the difficulties thrown in the way of its attainment by the use of hard water, owing to the formation of thick calcareous crusts in the heating apparatus.

7124. Dr. Miller says:—

"I think that one of the principal objections to hard water is the manner in which deposits take place from it when it is used in boilers. There is always, in our chalk districts, a considerable deposit of hard adherent fur in the inside of boilers, kettles, kitchen ranges, and so on, which in time chokes the range and obstructs the passage of heat, and may occasion accidents. That seems to me to be one of the serious practical inconveniences from hard water which I do not think has been prominently touched upon.

"No inhabitant of London can be unacquainted with that inconvenience?—No doubt they are, and I suppose they feel the inconvenience to some extent."

169. We cannot gather from this evidence any important objection to Thames water, by reason of its hardness, for culinary purposes, except the incrustation in kitchen boilers. With water containing a large proportion of carbonate of lime this would be a serious objection, but practically with the Thames water the inconvenience is not great. A deposit is certainly slowly formed in the boilers or kettles, but it is in most cases of a loose incoherent character, and is removable without difficulty, while in the pipes beyond the reach of the fire very little deposit takes place, and they may remain for years without the necessity for cleaning.

c. For Washing and for Manufacturing Purposes.

170. This is the point on which the greatest stress of the objections to hard water has always been laid; the Board of Health considering that great economy, principally in the saving of soap, would accrue by the substitution of soft water for hard.

171. The Chemical Commission of 1851 say:—

"The injury sustained in washing, from the hardness of the present water supply, is greatly more important; but the estimation of its amount is difficult, and involves the consideration of a variety of circumstances.

"The softer the water the better is it adapted for washing with soap; the earthy salts present causing a definite and calculable loss of soap, which may be taken as amounting, with every gallon of water used in washing, to 10 grains of soap for each degree of hardness of the water. Thus, with one gallon of Thames water, at 14 degrees of hardness before boiling, the loss of soap would be 140 grains and at five degrees of hardness after boiling the loss of soap would be 50 grains; or with 100 gallons of water, the loss in the first case would be 32 ozs., and in the second about 11½ ozs. But such data are not alone sufficient for calculating the saving of soap effected by the use of a soft over a hard water; for soap is used in washing not merely in quantity sufficient to soften the water, but in excess to act as a detergent. The problem is to determine how great the portion of soap lost in softening is, compared with the portion profitably used for washing in the softened water. Such data, however, are not easily obtained. In the bleaching of white goods, as scientifically pursued, soap is not made use of, the process being a series of operations in which the cloth is exposed to lime-water, carbonate of soda, chloride of lime, and acid. The only practice in cotton manufactories, where quantities are exactly noted, analogous to common washing, is the soaping of dyed goods; we have found 7 lbs. of curd soap then used with 250 gallons of water, which is nearly 45 ozs. of soap for 100 gallons of water. Now if this water were of 14 degrees of hardness, 32 ozs. more of soap would be required for softening; and of the whole 77 ozs. consumed, 45 ozs. would be available, and 32 lost, which is a sacrifice of nearly 42 per cent. of the soap. With boiled Thames water of five degrees of hardness, 11½ ozs. would be required for softening with the 45 for washing, making 56½ ozs. together, of which 11½ ozs., or about 20 per cent. of the whole soap, is wasted. In the washing of woollens, we find water employed with so much as one-eightieth part of its weight of soap, that is, 200 ozs. of soap with 100 gallons of water. Here the loss of soap by using water of the two different degrees of hardness referred to, being constantly 32 and 11½ ozs., would form a much smaller proportion of the whole soap consumed than before, namely, about 14 per cent. in the one case, and 5 per cent. in the other.

"The maximum loss of soap by the use of Thames water employed cold, would therefore be estimated from such data at 42 per cent. of the soap employed with linens, and 14 per cent. with woollens; or when the same water is softened by boiling, at 20 per cent. with linens, and 5 per cent. with woollens.

"With woollens the loss is too small to entitle it to further consideration, particularly when it is also known that the proportion of woollen articles washed is very small with the poorer classes who frequent the public wash-houses; not more it is believed than two or three per cent. of their whole washing.

"Nor is it to be supposed that in the washing of linen a loss of 42 per cent. of soap is necessarily sustained in all cases. Carbonate of soda is generally employed by laundresses in London to soften water for washing. Indeed, this salt is used in the public wash-houses in a considerably larger proportion than is necessary to precipitate the hardening salts of lime, on its own account, as a powerful detergent, particularly in the first boiling of the linen, and is not omitted although the water is soft, as with the Trafalgar Square water used in the St. Martin's public wash-houses. This use of soda does not appear to be attended by any injury to the linen, with the excellent means of wringing, by which the discoloured water is got rid of, and the abundant supply of cold water for rinsing, which are provided in these establishments.

"The proportion of dyed articles washed by the poor is small, and the colours are generally of a permanent kind which resist soda. In all their washing of woollens and coloured cottons, as well as white cottons, soda is in consequence equally used.

"The following opinion of Mr. W. Hawes is recorded in the evidence upon this subject collected by the General Board of Health, that 'Since the manufacture of crystals of soda at a very low price, and its 'almost universal use in washing, the waste of soap from washing in hard water has been very trifling. 'The quantity of soda used to soften water, as it is called, is a source of expense, but of a trifling amount.' This appears to be strictly true, at least of the washing of the poorer classes as conducted in the public washhouses.

"In regard to the extraordinary injury and wear of linen from London washing often observed, and which has been ascribed to the hardness of the water, it may be remarked, that no such injury to the linen occurs in many private laundries, where handwashing only is practised, and the use of chloride of lime and acids entirely avoided. It is most marked in the larger establishments, where much of the washing of the metropolis is conducted.

"It is in the more careful washing for the middle and upper classes that the advantages of soft water become fully sensible. In the digestion of linen in hot water with soap and carbonate of soda, preliminary to the proper washing, the hardness of the water can only occasion a trifling loss of soda; but afterwards in the wash-tub, where soda is avoided, the earthy salts must occasion a loss of their full equivalent of soap. It is found proper also to avoid boiling any portion of the Thames water that is used in the wash-tub, or even heating the water above a certain point, for the carbonate of lime precipitates on the linen, carrying down the colouring matter of the water with it, and producing stains which there is the greatest difficulty in afterwards removing from the linen. The colour from the water is thus indeed fixed upon the cloth, by the precipitated lime, with the tenacity of a mordant. The evil of the hardness of the water is therefore aggravated by the flood-tinge or clay-colour which the London waters often exhibit for several months in the year.

"The number of gallons of water generally used with a certain weight of soap appears also to be considerably greater in London washing than in the practice of the Lancashire bleachers, so that the waste of soap from hardness cannot fall below, but may exceed, the previous estimate.

"In the washing of the person the saving of soap by the use of soft water is most obvious. For baths soft water is most agreeable and beneficial, and might contribute greatly to their more general use. Its superior efficiency to hard water in washing floors and walls is calculated also to promote a greater cleanliness in the dwellings of all classes, both within doors and externally. While in the occasional domestic washing of linen, the smaller preparation necessary for washing in soft compared with hard water, the saving of soap which would then be sensible to its full extent, and the more easy and agreeable nature of the operation, would make a supply of soft water in a high degree desirable. The use of soda in washing would be gladly avoided by most housekeepers, owing to its injurious action on the colours of certain prints, and the permanent yellow tinge and weakness of fibre which it may occasion even in white linens when exposed to heat before the soda is entirely washed out, as in ironing. A strong desire exists to avoid its use, and where soda is avoided there is no doubt that a saving of about one-third of the soap would be made by washing linen in water entirely soft; supposing the comparison to be made with water of the ordinary hardness of the London supply, but of which one third part was previously softened by boiling. The saving in labour would be even more considerable, if the comparison be still made between washing in soft water, and washing in hard water without the aid of soda."

172. Mr. Bateman thinks there is great advantage and economy in using soft water, because it produces a lather with a less amount of soap; and he refers to the saving effected in Glasgow and Dublin after the introduction of soft water supplies. He estimates the saving in the former of these cities to have amounted to 36,000*l.* per annum. He quotes evidence by Mr. Hawes and by Dr. Clark on the same subject, and also mentions the experience in his own family. 55–63. 66–80.

Mr. Hawksley states that the quality of water most suitable to a large population depends very much on their habits and their necessities with regard to trade and manufacturing purposes. In the north of England, where the great manufactures of the country are concentrated, it is very important the water should be soft, its quality 2504–15.

in other respects being a minor question. He explains the preference for soft water in the manufacturing districts. He points out, however, that the saving of soap is often much exaggerated, the error of calculation in this respect being often enormous. In dyeing, hard water is sometimes advantageous as regards certain colours.

1345–6. Mr. Rawlinson explains that great economy would result in manufactures by the use of soft water, and also refers to its superiority for personal ablutions.

1499, 1520. Mr. Way considers that for most manufacturing purposes soft water has a great advantage. In dyeing they much prefer soft water; the quantity of soap used in this trade is immensely large. For the dyeing proper, however, particularly with bright colours, harder water is considered preferable. At Lyons hard water is preferred. Still the washing process is so much the more important that on the whole soft water is preferable. For brewing soft water is not good, except for the darker kind of beer. It will not brew bitter ale or light coloured beer; all the Burton ales are brewed with hard water. For London porter, however, soft water might be desirable. In washing, the saving of soap and of linen from soft water are undeniable. In scouring cloth this is of much importance. He believes the manufacturers of Yorkshire went to the valleys of the Aire and the Calder more for soft water than for the supply of coal; though now the streams are so foul they cannot use them.

2185–97. Mr. Duncan agrees that soft water is preferable for general manufacturing purposes.

Dr. Letheby gives evidence on this point as follows:—

3938–40. "Are you acquainted with the evidence which was given before the Board of Health, with regard to the economy in the use of soft water, some years ago?—Yes.

"What opinion have you formed with regard to that?—My opinion is, that it is very much exaggerated, and that exactly coincides with the opinion which the chemical commissioners, Messrs. Hofmann, Graham, and Miller, formed of it. I think that those statements which were made by the old Board of Health upon that subject were founded upon wrong premises. They were founded upon the supposition that water was always taken of the degree of hardness that it has in its unboiled condition.

"You would separate the permanent from the temporary degrees of hardness?—Yes, the permanent hardness being that upon which I founded my calculations, while the non-permanent is that upon which the Board of Health founded their calculations; and this makes a good deal of difference in the result."

2646–719. Dr. Playfair states, at considerable length, his opinion that soft water is generally preferable for detergent and manufacturing purposes. He says:—

"Hardness is of the greatest importance as regards the economical use of that water, and its comfortable use for the population. The effect of a hard water upon its ordinary detergent use is seen in the waste of soap and the difficulty of washing which washerwomen experience, and they are far more important members of the industrial community than is generally supposed.

2647. I gather from your statement also that the mass of the population would be likely to be more cleanly, and therefore more healthy, if the water were soft, and less soap were used, than if the water were hard, causing a great difficulty in producing lather?—Yes.

2648. And it is therefore more conducive to health?—Yes, a more thorough cleansing takes place.

2649. So that if it were a question of obtaining either hard or soft water for a population at the same price, you would give the preference largely to soft water, taking all the purposes into consideration?—At a very great difference of price I would give the preference to soft water, because the economy in manufactures is so enormously great with soft water.

2650. Could you give us any illustrations of the economical use of soft water in manufactures?—I could give an instance to show the great difference caused by even a small per-centage of additional impurity in a water. In the River Clyde there is a dam or weir across the river to dam up the fresh water for the supply of the manufactories; below this dam several sewers come in and deteriorate the water very slightly as regards analysis, but very greatly as regards its effect upon manufactures. A piece of calico above this dam, although the difference in value of the water is only about half a grain per gallon of impurities, requires four ounces of madder less to bring it up to the same dye; below the dam of course it requires four ounces more, and the difference of that to an ordinary work where they dye 1,000 pieces a day is 1,562*l.* in the year.

2651. Do you mean that that represents the difference between the use of the water above this dam and below?—Yes, the calico printers dyeing with the water above the dam would save 1,562*l.* a year, supposing they dyed 1,000 pieces a day, which is what good works would do, and they would have to spend that money if they used the water below the dam.

2652. Therefore, that is not a distinction between softness and hardness, but a question of purity or impurity?—In this case the deterioration of the water is owing to its containing iron; the water contains half a grain of oxide of iron below the weir more than it does above.

2705. You have referred to the effect of soft water in the use of dyes; could not that question be looked at in two points of view, one with regard to the economy in the use of the dyes, and the other with regard to the effect of the dyes themselves?—Yes; it has three influences upon dyeing: first, upon the original bleaching of the cotton; secondly, in the waste of the material used in dyeing; and thirdly, in the cleansing or clearing operations after the dyeing is completed; and in all those cases a pure water is preferable to a water containing any hardening matter.

2706. Does not water of a moderate degree of hardness bring out many colours better than soft water?—I have never found it so; I have carefully experimented, and I have found that distilled water brings out the best colours, and in all the experiments that I have made I have found that hard waters do not bring them out so well; but you will get plenty of manufacturers and dyers to tell you differently, and for this reason, that a dyer gets thoroughly accustomed to the water with which he operates, and he uses his materials and his mode of operation to suit that water; and if any other water is brought to him suddenly, seeing he is guided almost entirely by experience, he will get a worse result with a better water, because he is not accustomed to use it; and it requires the experiments of a chemist to elicit those sources of error. Every brewer who has been accustomed to brew with hard water will inform you that hard water is much better and more suitable for brewing, whereas a brewer who has been accustomed to brew with soft water will tell you that soft water is better than hard ; manufacturing use is entirely a matter of experience, in which people suit themselves to the case before them.

2707. Are you acquainted with the experiments of Dupasquier with regard to the effects upon dyes in using distilled water, river water, and spring water ?—No, I am not. I may mention that I was once the chemist to large calico printing and dyeworks, and that therefore my attention has been practically directed a good deal to that question. In early life I was chemical manager to Messrs. Thompsons' calico printworks in Lancashire.

Dr. Parkes and Mr. Simon agree with the opinion of Dr. Playfair. Mr. Firth and 3138.
Mr. Jubb, cloth manufacturers in Yorkshire, state that they find an economy, the one 2782.
of 25 per cent. and the other of 15 per cent., in soap for scouring by the use of soft 5212. 5320.
water, and they prefer it for dyeing purposes, though for some colours they find hard water do as well; but it appears that their hard water contained iron, in the one case in considerable quantity, and that the total amount of solid residue was 50 grains in the gallon.

Dr. Frankland considers there is great advantage in the use of soft water in manufactures 6261.
and for cleansing purposes. He explains the disadvantages of hard water for personal 6277.
ablutions. As to the saving in soap, he says: 6357–8.

"You have, I presume, seen various estimates of what might be the saving if soft water were used instead of 6368–9.
hard water ?—Yes.

"Do you think that those estimates are generally correct, or do you consider them as rather in excess ? —I think that there ought to be considerable latitude allowed in them. I do not think that the estimate would be correct as regards the amount of soap used in personal ablution, for the reason which I have just now mentioned. It is somewhat different in the case of washing linen. Supposing that the water were not softened with soda, then I believe that the estimate would be correct, because you must get the whole of the lime salts precipitated in the water before this washing of the linen can be effectually carried out."

He further expresses his opinion that the advantages of temporary over permanent App. D.
hardness have been considerably overrated; as water used hot for domestic purposes is either not boiled, or boiled for too short a time to produce the full softening effect.

Dr. Odling thinks that except for drinking purposes soft water is on the whole preferable 6437–8.
to a hard or even to a moderately hard water like the Thames. For manufacturing purposes soft water has great advantages over hard, except in very special cases.

Dr. Miller says there is no doubt that soft water, for all purposes except dietetic, is 7046–53.
preferable to hard. There would be a certain saving in soap, but he thinks the amount of saving has been somewhat exaggerated in some estimates which have been made regarding it. As regards personal ablution, undoubtedly soft water is far more agreeable than hard.

Dr. Angus Smith concurs in the advantage of soft water for manufacturing purposes, 7218–22.
but he considers the saving in soap has been somewhat exaggerated.

Mr. Heron says that in Manchester the supply of soft water for manufacturing purposes 7343.
is an enormous benefit. There are many cases where calico printers and others pay a very large sum per annum to the corporation for the water in preference to water which might be obtained at a less cost probably, but which is not of the same quality. The income derived from the water sold for trading purposes is very large, and it is by that income alone that the corporation are enabled to supply the water at the low price they do for domestic purposes within the city.

173. There is no doubt that this evidence is conclusive and cogent as to the great advantage of soft water over hard for washing and, with some few important exceptions, for general manufacturing purposes; and if we were treating of the supply of a town like those in the manufacturing districts of England, where large quantities of water were required for these purposes, the objection to the present supply would assume a more serious aspect. But the amount of manufacturing industry in the metropolis, of a kind to demand large supplies of soft water, is exceedingly small in proportion to the population, and it must be recollected that the softening influence of boiling largely diminishes the evil. To these exceptional cases, also, the softening process of Dr. Clark would be easily applicable.

There is no doubt also that in personal ablutions and washing generally the use of soft water is more pleasant and economical, but we think the latter advantage has been much over-estimated. The soap is usually applied out of the water, and therefore it is with the small quantity of water adherent to the object washed that we have to deal, and not with the total quantity used for rinsing to remove the soap. It is certain, however, that when a soft water or rain water can be obtained for these purposes it will always be preferred.

All the witnesses have deposed to the general great economy of soft water for most manufacturing purposes, but we find it difficult to reconcile the opinions of some of the witnesses respecting the advantages in dyeing (except on the score of economy) with the fact that the largest and most important manufactories in France for silks, woollens, and cottons have risen in Lyons, Rheims, Amiens, and Rouen—all using hard waters, and the three latter towns situated in chalk districts. Dupasquier, a well-known chemist, when called upon some years since to report on the waters of Lyons, showed as the result of his researches that waters of a certain degree of hardness were preferable generally for dyeing purposes, so far as regarded brilliancy of colour generally.

On the whole we cannot see that the advantages of soft water in this respect are of sufficient importance to justify going to a great distance to obtain it, in place of the ample supply nearer at hand.

Other Elements of Comparison between Hard and Soft Waters. Action on Lead and Iron, &c.

174. When speaking of the quality of water proposed to be supplied by Mr. Bateman's plan, we have alluded to the danger which may arise in some cases from the action of soft water on lead; and there is, further, the inconvenience of its acting on the iron pipes, leading to the deposition of concretions, interfering with the flow, and eventually destroying the pipes. Several witnesses have deposed to this action, especially Mr. Duncan, who states that at Chorley "they had to take up and relay a number of pipes "in the town, because they had become choked up in consequence of corrosion." In the same way the pipes at Grenoble became so damaged and choked after ten years' use that they had to be removed. A similar thing, but in lesser degree, happened at Cherbourg. Like, however, the action on lead, this action on iron is uncertain and irregular, and may most probably be guarded against by artificially coating the pipes.

From both these evils the water supplied from the present sources is perfectly free. The Chemical Commission of 1851 say: "The water at present supplied may be circulated "through leaden pipes, or preserved in leaden cisterns, with an unusual degree of safety. "The corrosion of water cisterns in London is generally occasioned by the mud which "subsides to the bottom. This corrosion is not attended by any sensible solution of "lead in the water. The London water may indeed be said to exert the least degree "of solvent action upon lead.

"The circulating system of iron pipes appears also to receive a certain amount of "protection from the alkaline character of the present supply. The erosions and bulky "deposits in cast-iron pipes, which have given great trouble in the distribution of certain "waters, are quite unknown in London."

Further, in considering the relative advantages of a water in a dietetic point of view, it must not be overlooked that hard water is less absorbent of gases and of organic impurities, and is therefore less liable to change than soft water. This, it is true, is in most cases a matter of very little importance, but in large towns, and with a poor population, it is to be weighed in the balance.

The Commission of 1851 say: "Putrefactive decomposition appears also to occur less "rapidly in hard than in soft water, and hard water seems to be the more easily preserved "in reservoirs or tanks without deterioration for a short time."

Artificial Softening.

175. It has been frequently suggested that the hardness of the London waters might be removed by the softening process invented by the late Dr. Clark, who has given a full account of it in his letter, Appendix G.

The Chemical Commission of 1851 had so good an opinion of this process, that on the ground of its peculiar applicability to chalk waters, they recommended that these waters, so softened, should be resorted to for the supply of the metropolis. As to its application to Thames water, they, after witnessing certain trials made at the Chelsea Waterworks, came to the conclusion that it was not attended with any peculiar difficulty on the large scale, and that the softening of Thames water in its ordinary condition to a point under four degrees of hardness was perfectly practicable. They estimated that the cost would be about 20*s*. per million gallons. They added, however, the following remarks:—

"The liming process, even when combined with filtration, proved to be unequal to remove the yellow flood tinge of Thames water, nor did it appear to abate an objectionable taste of vegetable matter which the water also then possessed. Had the result been different, the grounds for the adoption of the softening process would have been most cogent. But it seems that it is not to river waters that this elegant and useful purifying process is most advantageously applicable."

4026. Mr. Muir states that the New River Company have been prevented from adopting this process by the difficulty of accomplishing it on a very large scale, and also by the risk of deposit in the pipes. He adds:—

"I think, taking into account the fact that the temporary hardness of the New River water is so much greater than its permanent hardness, that the gain would not be very great; and from the difficulty of applying the process on a large scale, and the large quantity of water used for sewer flushing and street watering and other purposes (where the softening process is really useless), we have not much encouragement to go into the thing."

Mr. Homersham tells us that he has applied the process with perfect success to chalk waters supplied at various places; the current expenses being about 27*s.* per million gallons. He adds, however, that a river water is not adapted for being softened by it. He says, alluding to the trials at the Chelsea works:— 6762 et seq.

"The effect was this, that if the water operated upon is filtered water, so that it is clear before you apply the lime, the deposit settles quickly and you have no difficulty; but if the water contains any clay or is discoloured by a flood, as river water frequently is, the organic matter in the water, or whatever it may be which discolours the water, mixes with the crystals of the carbonate of lime and alters the specific gravity, and they do not fall down, but keep floating about in the water. The result is, that you must filter that water after it is softened." 6812.

176. Apart from the expense of this process (which would be very large for the whole supply of London), it does not appear to be applicable to the Thames waters on a large scale. It appears more suitable for small districts supplied from chalk wells, or for private use in manufactories where soft water is specially required.

On the Organic Impurities and Contamination of the Thames Water.

177. We now approach the more difficult part of the subject. If the waters of the Thames had no impurities beyond the solid mineral contents, the question as to their wholesomeness and general suitability for the supply of the metropolis would be easily disposed of.

But attention has been called strongly to the *organic impurities* contained in Thames water, which, though more indistinct in their form, and less appreciable in their quantity, are said to be more deleterious in their nature, and to render the water, if not dangerous and unwholesome, at least liable to suspicion.

178. It is easy to understand how streams and rivers may become contaminated with organic matters. The pure rain or spring water, flowing over the surface of the land, will dissolve vegetable matter with which it comes in contact, and if the land be highly cultivated there will also be taken up animal refuse from the manures, or from the droppings of live stock kept upon the farms. But the contamination may go further than this. In spots where the population is collected into villages, the excretions from the inhabitants will often find their way, to a greater or less extent, into the streams forming the natural drains of the land; and in the cases of large towns this effect is artificially aided by the establishment of waterclosets and systematic sewerage.

179. The waters of the Thames are of course liable to organic contamination from all these sources, though perhaps not in so great a degree as is generally supposed. In the first place, as regards the matters, vegetable and animal, washed from the land, it must be remarked that although the greater part of the basin of the Thames is cultivated, and some of it very highly, yet nearly half the area consists of porous permeable strata, such as chalk, oolite, and sand; and that the waters falling on these, except on occasions of large and sudden floods, will be rapidly absorbed, filtering through the earth and going to form the springs. It is from the retentive soils that the washings will be most plentiful and most charged with organic matters.

As regards the excretions from the inhabitants, the basin of the Thames above Hampton is comparatively thinly populated, from the absence of minerals and the non-attraction of any large manufacturing interests. Taking the area of the watershed above the point of intake of the companies, we find by the Report of the Rivers Pollution Commission that the number of inhabitants is about 888,000, and the area is 3,676 square miles, which gives about 230 persons per square mile, or rather less than three to an acre. Then a very large portion of the inhabitants live in villages or small towns dispersed about the agricultural districts, where no regular sewerage is either applied or required, the produce being considered valuable and used for direct application to the land. The population in towns of above 2,000 inhabitants amounts to only about 212,000, and it is only in the larger of these towns, such as Oxford, Reading, Windsor, and probably some few smaller places, that human excrements can be considered as being turned systematically into the stream; and even in some of these cases, from the incompleteness of the drainage arrangements, the effect is at present only partial. Thus it may be shown that only a portion of the inhabitants of the basin can effectively contribute to the sewerage contamination of the river. 2591–5.

180. But though for these reasons we believe that the organic contamination of the Thames is much less than is commonly imagined, still it would be sufficient to do great mischief, were it not for a most beneficial provision of nature for effecting spontaneously the purification of the streams. Some of the noxious matter is removed by fish and other animal life, and a further quantity is absorbed by the growth of aquatic vegetation; but in addition to these abstractions, important changes are effected by chemical action. The organic compounds dissolved in the water appear to be of very instable constitution and to be very easily decomposed, the great agent in this decomposition being oxygen, and the process being considerably hastened by the motion of the water. Now as such waters always contain naturally much air dissolved in them, the decomposing agent is ready at hand to exert its influence the moment the matter is received into the water; in addition to which the motion causes a further action by the exposure to the atmosphere; and when (as in the Thames) the water falls frequently over weirs, passes through locks, &c., causing further agitation and aëration, the process must go on more speedily and more effectually.

The effect of the action of oxygen on these organic matters, when complete, is to break them up, to destroy all their peculiar organic constitution, and to rearrange their elements into permanent inorganic forms, innocuous and free from any deleterious quality. This purifying process is not a mere theoretical speculation; we have abundant practical evidence, which we shall hereafter refer to, of its real action in the Thames and other rivers.

181. The question now naturally arises, can we not, by careful analysis of the Thames water, discover what quantity of organic matters it contains; what is the nature and character of such matters; and how far they are deleterious or otherwise? We have endeavoured to arrive at a solution of this question, but unfortunately without much success. The inquiry seems beset with difficulty. The organic matter is present only in very small quantities, and in shapes and conditions which are very difficult to identify and to reduce to actual measure. The treatment of them is still a problem in chemical science, only now beginning to be effectually studied, and the most eminent chemists are yet by no means agreed either as to the processes most proper to be followed in the analyses, or as to the value and bearing of the results obtained.

It does not follow that all organic matter in water is prejudicial; great mistakes have arisen on this point, as it is often given out that the very suspicion of organic contents of any kind in a drinking water should disqualify it for use. But almost all our drinks other than water owe their distinctive qualities to the varieties of their organic contents, and hence it is clear that the presence of organic matter *per se* is not necessarily prejudicial. It is however necessary, in potable waters which contain organic matter, carefully to distinguish between such combinations as are innocent and such as are noxious; and here lies one of the greatest difficulties.

We now proceed to state the evidence before us on the quality, as regards organic contents, of the water supplied to London.

Earlier Analyses.

182. The Scientific Commission of 1828 called attention to the organic impurities of the Thames water, as taken in the immediate neighbourhood of the metropolis; and added the following general remarks on its salubrity:—

> "The statements which have been made respecting the insalubrity of the Thames water as supplied by the companies have also been considered by us, and although, from the few cases which have been brought before us of disorders imputed to this cause, we do not feel ourselves warranted to draw any general conclusions, we think the subject is by no means undeserving of further attention. There must always be considerable difficulty in obtaining decisive evidence of an influence, which although actually operating to a certain extent as a cause of constitutional derangement, may yet not be sufficiently powerful to produce immediate and obvious injury. It cannot be denied that the continued use of a noxious ingredient in diet may create a tendency to disorders which do not actually break out until fostered by the concurrence of other causes, for we unquestionably find an influence of the same kind exerted by other agents which occasion merely a certain predisposition to disease, and of which the immediate operation must therefore be extremely insidious and difficult to trace. It is obvious that water receiving so large a proportion of foreign matters as we know find their way into the Thames, and so far impure as to destroy fish, cannot, even when clarified by filtration, be pronounced entirely free from the suspicion of general insalubrity."

App. A F. The Chemical Commission of 1851, who tested the water with all the chemical skill then attainable, report in the Thames water (then still taken within the tideway) a quantity of organic matter varying from 1½ to 3 grains per gallon, on which they remark as follows:—

> "The soluble organic matter from two of the Thames waters was submitted to ultimate analysis, and found to give 0·105 grain of nitrogen in the Grand Junction water, and 0·031 grain of nitrogen in the Southwark

and Vauxhall water. The existence of nitrogen is generally supposed to imply the animal origin of organic matter, and on such evidence a minute and probably unimportant portion of animal organic matter would be admitted to be present.

"None of the waters had any marked taste or odour, nor betrayed any indication of putrescence, either when first taken up or after being kept in bottles for several weeks at a temperature between 50° and 60°; nor even after remaining in close vessels for two weeks at 80°.

"In these waters when submitted to microscopic examination no animalcules were observed in any case. But the period of the year was not that at which any considerable development of animal life is to be looked for."

They allude to the colour and contamination to which the river is liable in the late autumn and early winter, from the extensive decomposition of vegetable matter, which they state to be a serious evil; but they appear to draw, in a sanitary point of view, a broad distinction between this and organic matters of animal origin, on which they remark as follows:—

"As the main drain of a large and populous district, the Thames becomes at all seasons polluted by the sewerage of several considerable towns, and by the surface drainage of manured and ploughed land. At the same time, we doubt whether the existence of organic contamination from town drainage is at present perceptible in the Thames above the reach of the tidal flow, or amounts there to a sensible evil. The indefinite dilution of such matters in the vast volume of the well aërated stream is likely to lead to their destruction by oxidation, and to cause their disappearance. The river may reasonably be supposed to possess, in its self-purifying power, the means of recovery from an amount of contaminating injury equal to what it is at present exposed to in its higher section."

They add further observations tending to justify a recommendation that the supply should be drawn from a point above the tideway.

Messrs. Hofmann and Blyth's analysis in 1856, made after this recommendation had been carried out, in pursuance of the Act of 1852, showed in a striking manner the advantage of the change. The chemists found that the hardness and mineral contents had undergone little variation; but in regard to the organic matter they reported as follows:— App. B G.

"*A very considerable diminution, however, is observed in the amount of organic matter.*

"In fact, in 1856 the water supplied to the metropolis contained not more than one-half of the organic matter which was present in the year 1851.

"This result is certainly not accidental. The diminution is not merely an average result, but uniformly observed throughout. The waters examined in 1851 were taken in January; those investigated in 1856, partly in January and partly in April. The diminution of the organic matter cannot therefore be due to the influence of the season. Nor can it be due to any difference in the mode of determining the organic matter in 1851 and 1856. These determinations were made by exactly the same method; for it so happens that the analytical part of the inquiry in 1851 which refers to the organic matter was likewise made in the laboratory of the Royal College of Chemistry. The diminution is obviously partly due to the alteration of the localities from which many of the companies derive their supply. The Grand Junction, the West Middlesex, the Southwark and Vauxhall companies, formerly supplied respectively at Kew, Barnes, and Battersea, derive their present water from Hampton; the Lambeth Water Company used to take their water at Lambeth, but have now erected extensive works at Thames Ditton. The diminution of the organic matter in the London water supply is, however, by no means confined to the companies that have changed the locality of their source, and it must therefore be attributed in a great degree to the considerable improvement which has taken place in the collection, filtration, and general management of the supply of water to the metropolis."

The analyses of Letheby, Odling, and Abel, in 1867, state that the quantity of organic matter in the filtered water could not have exceeded one grain per gallon, and shew the ammonia to be almost infinitesimally small. The average total quantity of organic matter in the water supplied in 1867 appears only about two-thirds of that in 1856, and only about one-fourth of that in 1851, showing the beneficial change effected from further improvements in the supply. App. A H.

In the Returns of the Registrar General, there are now given monthly reports by Dr. Frankland on the condition of the waters supplied by the different London companies. The analyses which accompany these reports show a general agreement with those just referred to. As, however, they are elaborated on a principle not ordinarily employed, it is not easy to compare them with those of other chemists. They give very careful and definite determinations of organic matter, but on the value of the mode employed, and on some of the inferences, there is a difference of opinion amongst men of science; and we shall presently have to make some remarks on this subject.

183. We have had before us many witnesses conversant with the subject, including some of our ablest chemists, and have endeavoured to ascertain fully their opinions on this question, which we will now give, as far as practicable, in their own words.

Evidence on the Organic Impurities of Thames Water.

Chemists and Medical Men.

184. Dr. Lyon Playfair, Professor of Chemistry in the University of Edinburgh:—

2681. Will you allow me to ask you whether in soft water the same proportion of organic matter would not be more injurious than in water of an ordinary degree of hardness, and what would be the effect of the presence of organic matter in such water ?—The effect of organic matter in the water depends very much upon the character of that organic matter. If it be a mere vegetable matter, such as comes from a peaty district, even if the water originally is of a pale sherry colour, on being exposed to the air in reservoirs or in canals leading from one reservoir to another, the vegetable matter gets acted upon by the air and becomes insoluble, and is chiefly deposited, and what remains has no influence on health. But where the organic matter comes from drainage it is a most formidable ingredient in water, and is the one of all others that ought to be looked upon with apprehension when it is from the refuse of animal matter, the drainage of large towns, the drainage of any animals, and especially of human beings.

2682. No doubt a large proportion of organic matter of such a nature would be injurious, but in ordinary cases of a river, such as the Thames above London, the action of the aëration of the water would be in that case to destroy any moderate amount of organic matter, would it not ?—It would gradually, but such matter becomes insoluble more slowly than the matter of which I have been speaking; and in any case the presence of it is dangerous, and as one does not know the stage to which the oxidation has gone, the presence of any such animal matter in water is always most objectionable. It is impossible to tell at what stage it is by a mere general examination ; by a chemical examination you can do so, but the presence of the most highly oxydised form of organic matter when it passes into the stage of nitrate is, I think, quite sufficient to condemn the water, because you are never sure whether it has fully passed into that stage.

2683. Is it not considered that by the time the Thames water, with which London is now supplied, reaches the delivery pipes all organic matter is converted into the state of nitrates and nitrites ?—I think that the evidence from the cholera of last summer was quite conclusive on that point, that it was not.

2684. That was confined to one particular district, was it not ?—Yes.

Mr. Simon, Medical Officer to the Privy Council :—

2751. You of course have analysed, and you are well acquainted with the quality of the London water ?—Yes.

2752. What is your opinion as to its character ?—Judging by chemical analyses, performed on it in what I may call its normal state, I am not aware that there is much fault to be found with it.

2753. You are speaking now of all the water supplied by the various companies ?—Yes, speaking quite generally. Speaking of it in its broad ordinary chemical characters, as it would be reported on from a chemical laboratory, I should say it is a fair water supply.

2754. Are you now speaking of the whole supply of the metropolis ?—Yes, speaking generally of it. But what I thus say of its average chemical constitution in its normal state does not touch the question of the water's liability to accidental very dangerous pollutions. There are dangerous qualities of water supply, with regard to which, so far as I know (but I do not speak as a skilled chemist), chemists are totally unable to measure, even to demonstrate, the fatal influence that a water may have. A water may be, for instance, capable of spreading cholera, but chemists be unable to identify the particular contamination which produces that effect.

2812. My practical point is, that what one has to do is not to take water out of a reservoir or out of a tap and give it to a chemist and say, "Tell me, is this wholesome water"? What one has to do is to guard the supply with the utmost strictness against every foul admixture. It ought to be made an absolute condition for a public water supply, that it should be incontaminable by drainage.

2837. Have you, apart from the question of sewage, considered the condition of the Thames basin as a gathering area, having regard to the high state of cultivation of the land and the use of manures, artificial and other, and the washing of water into the Thames, what the effect upon the water would be for domestic purposes ?—The earth is a most powerful absorbent and disinfectant of the materials used as manure, and I do not think that practically any important danger would attach to the outflow from cultivated lands.

7135. I think when you were examined before you were asked your opinion as to the effect of sewage contamination in rivers, and after how long a period, and at what distance of flow, the river would get rid, if at all, of that sewage contamination; have you formed any opinion upon that point ?—I cannot venture to answer that question with any confidence ; it is a very difficult question to answer.

7136. But are you of opinion that the water of a river which had been under the influence of such contamination would ever after be a safe water for domestic purposes ?—The answer to the question, if it is to be absolutely correct, must vary with the quantity of sewage, the volume of water, and the distance between the point of contamination and the point to which the question applies.

7137. Supposing that sewage is discharged from one of the sewers, say, at Windsor, would it be possible to detect the presence of that sewage seven miles lower down the river, having regard to the volume of water in the river ?—I believe it would be absolutely impossible for chemists to discover it, but the practical sanitary question is different. Supposing tape worm eggs to be sent into the river with that sewage, would those tape worm eggs be alive seven miles down ? Or, supposing cholera discharges to be sent into the river, or the discharges of typhoid fever, and assuming (which is a frequent pathological opinion) that the respective contagia of typhoid fever and cholera are living germs, would those germs be alive seven miles down ? It is not a question whether a chemist would find out the organic matter so much as it is a question whether those particular molecules would still have their property seven miles down. I cannot say that they would not.

7138. Could you detect them at that distance ?—Only by their effects.

7139. Might not the same disease be produced from any other cause ?—The particular parasite will only come from its particular egg. You would not get hydatids except from eggs any more than you would get chickens without eggs.

7140. Are the Commission to understand you to state that it is impossible for a chemist to discover the existence of sewage at the distance named ?—The possibility varies with the conditions I have stated.

7141. If it is not possible for a chemist to discover it, is it not presumptive evidence either that it does not exist, or that if it does exist it is in such minute quantities that it is in no way deleterious to human health ?—I am very decidedly of opinion that that principle is not a safe one to adopt as a basis for sanitary regulations in the matter. I think the rule ought to be that no sewage should go into any water that can be used for drinking purposes. I think, even, that allowance should be made for the proper decent taste of people. Water into which sewage has been discharged is, in relation to the matter now under consideration, an experiment on the health of the population, and I do not think that that experiment ought to be tried. Moreover, as a mere matter of taste, people would rather not drink water into which sewage has been discharged, and I think that that in itself deserves consideration.

Dr. Farr, Superintendent of the Statistical Department of the General Register Office, has given us lengthy information as to the outbreak of cholera in 1866 in the East of London, and has put in valuable statistics, &c., thereon. The following extracts will illustrate his general views:— 2845 et seq.

2876. Am I to understand you to say that in those districts where the cholera prevailed very largely the principal cause was the impure water?—I conceive that the cause of cholera existed here, and that the elements of disease from cholera patients were distributed all round London. Cases occurred in every part of London, but in the other districts the mortality was inconsiderable. For instance, in all the districts supplied by the Grand Junction, the West Middlesex, and the Chelsea Water Companies, the mortality was about 3 in 10,000, in those supplied by the Southwark and Lambeth Companies, which were formerly so heavily visited, it was about 6 in 10,000, and in those supplied by the New River Company about 8 in 10,000, but in those supplied by the East London Company from the Old Ford reservoirs it was 79 in 10,000. I do not ascribe the whole of that mortality to the water, but I ascribe a large portion of it to the circumstance that the impurity causing cholera was distributed through the water of that company.

2877. Will you be good enough to tell us what you consider those other circumstances to be?—The density of the population also had an influence. We found that where people were packed very closely together they suffered more than where they were distributed more widely over the ground. We have found also that the condition as determined by the annual value of the houses that the people lived in, their poverty had a considerable influence, but not so striking as I should have imagined it would have had. We found also that the elevation of the ground in which the people were living had a very marked influence. In the first report I showed that the mortality on the low banks of the Thames both on the south and on the north side, was from 100 to 150 per 10,000, but as you ascended on successive terraces the mortality was reduced, and at the higher points it came down to 8, so that the elevation of the soil had a considerable influence. That I have been led to suppose since had a good deal of influence upon the purity of the water also.

2890. Do you think that if this London water could be free from all its impurities it is a good quality water for consumption?—I confess that when I see that this Loch Katrine only contains in 100,000 grains three grains of impurities of any kind, and that it contains no trace whatever of sewage or anything like sewage, I should have greater confidence in water brought in that way from the hills than I should in water taken from the river; at the same time I am not prepared to say that the water from the river, with great precautions as to letting sewage into it, might not be made a very decent sort of water.

2929. As far as your experience goes, are we to take it that this view which is conveyed in the report of Dr. Frankland is one that you concur in, namely, that at the present moment taking his analysis there is nothing that is really bad in the water supplied to London?—Not on that particular day. I should qualify it myself always in that way. I can conceive that the character of the water varies from day to day; it varies with the temperature and with the rainfall, and with a variety of circumstances. All we know is that from the analyses which Dr. Frankland has hitherto made he has come to the conclusion that the water supplied to London has contained something very noxious, but that it did not contain anything noxious at the time that he took it at the mains.

Dr. Parkes, Professor of Military Hygiène in the Army Medical School at Netley:—

I have made a list of diseases all of which are occasionally communicated by means of water, not solely communicated by water, but occasionally. For example, typhoid fevers; of which I have collected about 23 instances of local outbreaks of severe typhoid fever, and some six or eight more, the particulars of which I have not got, are known to me, arising from water impregnated with typhoid sewage, or possibly with simple sewage.

3123. As far as your special observation has gone, in all cases where there has been a discharge of human excreta into water where the parties have been suffering from typhoid fever, that has generated disease in every district where the water has been taken for domestic purposes?—It has not generated typhoid fever in all cases, because in some cases it has generated diarrhœa and dysentery; typhoid fever has prevailed in some cases and not in others, and therefore that is an argument in favour of the view that it requires the typhoid sewage especially to pass into the water for the development of that particular fever, and that simple sewage will not cause it. But the question is surrounded with difficulties; it is so difficult to get reliable scientific evidence that it is still *sub judice*.

Dr. Parkes proposes to divide potable waters into several standard classes. He says:—

I would propose to form a class of "wholesome waters," under which two sub-classes of waters may be included, first, the purest and most wholesome water, which is free from suspended matters and contains very little dissolved organic matters, say under one grain per gallon, and that probably vegetable, and of dissolved mineral matters under seven grains per gallon. That will include all the best waters supplied from the primitive rocks, and from some of the sands which contain under that quantity of mineral matter, and is probably the purest water on the whole which can be obtained in that way.

Then the second sub-class in the first order would be what I would call pure and wholesome water, to which no objection can be taken, I believe, in a sanitary point of view, but which is not so pure as the former. This water is also free from suspended matters, having dissolved organic matter under two grains per gallon, the greater part of that being vegetable. Of dissolved mineral matters it would contain under 12 grains per gallon, consisting principally of carbonate of lime and alkaline carbonates and chlorides. That second sub-class would include the best chalk waters, which are often very free indeed from organic matter. Then the second grand class I would make I would propose to call "useable waters;" waters which cannot, perhaps, be very much objected to, not so good as the former class, but yet which in many cases might be used, and which would not produce, perhaps, any bad effects. Those are all waters with no suspended matters or suspended matters easily separated by the coarse filtration usually resorted to by the water companies. The organic matter would be chiefly vegetable, but it should not exceed three grains per gallon, owing to the diseases which would probably arise if it exceeded that quantity, and if the organic matter is apparently of a mineral origin it ought not to exceed two grains per gallon. Then it should contain mineral salts not exceeding 20 to 30 grains per gallon, and consisting of a class of salts which do no injury to the system, such as alkaline carbonates, alkaline chlorides, chloride of sodium, and chloride of potassium, in less quantity, and possibly a little carbonate of lime also.

3149. The third class would be what I would call "suspicious water," which would be any water with much matter suspended, which would be separated readily by coarse filtration. Such a water as that would in all probability contain either fine particles of mineral matters, which are hurtful, such as clay, or possibly it might contain suspended organic matters very finely divided, and not very readily separable by filtration. It might contain dissolved organic matters vegetable and animal, amounting to about three or four grains per gallon, and mineral matters of large amount, such as alkaline and chlorides, carbonates, and carbonate of lime in large amount, that is to say, perhaps over 9 or 10 grains per gallon, or sulphate of lime or magnesia, and chloride of calcium or magnesium in certain quantities; all those I should consider make a water suspicious; or if it contains any indication of nitrites, nitrates, ammonia, &c., showing that organic matters had passed into the water and had there been oxidized; any indications of that kind I should consider would bring the class under the head of suspicious water. Then the fourth class would be "impure water," which would include any turbid and bad smelling water with suspended matters not easily separated by coarse filtration; also dissolved organic matters above four grains per gallon, especially if of animal origin, large quantities of mineral substances, especially of sulphate of lime and sulphate and chloride of calcium and magnesium, which all give permanent hardness to the water, or large indications of nitrites, nitrates, fatty acids, ammonia, &c., all of which indicate the passage of organic matters, animal in all probability, into the water.

3150. Under which of those heads would you put the London water?—I should put the London water under head No. 3, suspicious.

3151. Would you do that because there are indications of nitrates?—Yes; I should call any water containing large indications of nitrates and nitrites suspicious water. Such indications may, however, come from water not impregnated with sewage, as some soils give off nitrates and nitrites. . . . . I think that the mere presence of nitrates and nitrites in water in small quantities would not be hurtful at all; their importance is as indicating their source, and showing that there must have been contamination, probably by animal inorganic matter, in most cases sewage, and of course rendering the chances of such organic matter passing in in sufficient quantities to affect the health very probable, but when such organic matter has been oxydized, then no doubt it becomes, at any rate in most cases, harmless.

3160. Sewage is the most dangerous parent of those things, is it not?—Yes. But any indication of them should lead at once to an examination, so as to trace the origin of nitrates and nitrites, and the water would be suspicious in the proportion that it contained any large quantity.

3161. It would not be a certain inference that it was from sewage?—Certainly not.

3177. Is there in your judgment an objection to the Thames basin as a gathering area for water by reason of the high state of cultivation in some parts, and from the manuring that it undergoes?—Yes, I think there is a very great objection. No doubt the effect of water passing through a soil with manure is to cause a very rapid oxydation of the organic matter, and a very large quantity is converted into nitrates and nitrites and ammonia, but there is a limit to that, and it is impossible to ensure the safety of water where there is the possibility of contamination on a large scale with organic matters derived from sewage.

3178. If it passed through a sufficient depth of earth it would be deprived, would it not, of this matter?—The earth would be a great purifier, no doubt.

3181. Have you observed in a case where sewage has been discharged into a river that after running for three or four miles the effect of that sewage has been destroyed?—Yes, we have that in the case of the Southampton water supply; some sewage passes into the Itchen river, but it is quite destroyed by the time the water is distributed in Southampton, at least there is no detectable quantity.

3182. What is the distance?—The distance is six or eight miles. I could not undertake to say the distance in which water would purify itself in that way, but there is no doubt that it does purify itself, although in what distance, or what time, or under what precise circumstances I could not say.

3183. I presume that the sewage, probably by the action of the water and the atmosphere, would really be broken up into other elements of a less injurious character?—Yes, broken up into compounds of nitrogen and ammonia, nitrates and nitrites.

3184. You do not get rid of it, you have it in a different form?—Yes.

3185. And in a less objectionable form?—Yes, in a form I presume quite unobjectionable in a small quantity. A very large quantity might be irritant, but in a case in which they would be in water not very largely impregnated with sewage, I should think that they would not be hurtful.

3186. Do you think, taking the upper part of the Thames as a gathering area, that any injurious result from manuring or other washings into the river would by the course of such water down the Thames be somewhat neutralized?—I think that very likely it would be neutralized to a very considerable extent. That would rather depend upon the amount passing in; if any experiments could be made as to the amount of manuring and the number of acres that would furnish sewage matter, and the amount of sewage matter which would pass in, and the rapidity of the flow of the Thames at different parts of the year, and the volume at different times in the year, we should be able to form a better idea. It would be modified by a great many circumstances.

3187. But there would in your judgment be a process of purification going on?—Yes, it would be simply a question of degree.

3237. Do you think that in point of health the population of London generally suffer from any impurity in the existing water apart from any special case of cholera in the east of London?—I think that where the population of every town shows a considerable amount of diarrhœa, and also of typhoid fever, it makes one believe that there must be some impurity in the water at times, and the health of the population as regards those diseases of the intestines seems to be very much influenced by the purity or impurity of its water supply.

3245. If the subject had been considered one of vital importance by the medical profession generally, do not you think it would have been proposed that it should be scientifically investigated by some specially appointed body either of medical men or chemists?—We must remember with regard to the effect of different things upon the health of the community in this country that it has only been the subject of investigation for the last 30 years. Till we began to have statistics of deaths we had not learnt to know the relative prevalence of the several forms of disease, and it was impossible to form any opinion as to the condition under which the people were living. We may say that these questions are almost in their infancy.

Dr. Letheby, Medical Officer of Health to the Corporation of London:—

3879. Having regard to those waters, and the several tests which you have yourself made, what is your opinion generally of the water supplied to this metropolis?—My opinion is founded in the first place upon the actual analyses of the waters over a long period of time, monthly analyses; it is founded in the next place upon an observation of the use of those waters very extensively, and I am bound to admit that there is no evidence whatsoever that those waters are in any way objectionable as a public supply. I am now speaking of the whole of the metropolitan waters.

3880. Notwithstanding the amount of organic impurity, that is your opinion ?—The organic impurities are not large in the London waters. The loss by incineration, although a grain, is not regarded as a serious quantity, because the loss by incineration represents a great deal more than the organic impurities.

3891. When that interception takes place, will the water of the Thames in your judgment be greatly improved ?—I do not think that it will be much improved. Not but that I am quite ready to admit that the discharge of sewage into such a river is a most improper thing, but considering the powerfully oxydizing influence of water upon sewage, the many agencies which are at work destroying it, the power of precipitation, the using of it up by vegetables and aquatic plants and by fish, and above all by the power of oxydization, I think that none of the sewage discharged into the Thames can at the present moment be discovered at Hampton, but nevertheless it is very possible that there may be a still further improvement of the Thames water by the adoption of these measures. Certainly there will be an improvement in this manner, that if the discharge of the sewage into the Thames were to go on increasing during the next 20 or 30 years, as it has been during the last 20 or 30, we should then probably have such an excess of sewage in the water of the Thames as would render it very unwholesome. But at the present moment I cannot perceive through the most refined chemical processes the existence of a particle of sewage in the water at Hampton where the Thames Companies take their supply.

3894. Have you at all ascertained in what length of time or distance polluted matter will be decomposed and transformed in its chemical qualities ; for example, supposing we had the sewage from Richmond poured into the Thames, how far down the river would it be lost as sewage and broken up into other chemical elements ?—I have made a very great number of chemical experiments to determine that. I have examined most of the rivers in England, and this is the conclusion that has been come to, not only in my mind but in the minds of all the engineers who have devoted their attention to this subject, that if ordinary sewage, containing we will say nearly 100 grains of solid matter per gallon, such as our London sewage, out of which probably something like 14 or 15 grains are organic, be mixed with twenty times its bulk of the ordinary river water and flows a dozen miles or so, there is not a particle of that sewage to be discovered by any chemical processes.

3898. Taking the case of the cholera disease and the discharges from the human body being mixed up with the sewage, do you consider that any germs of that disease would be carried down in water ?—At the present moment we do not know what the germs of the disease are. If the germs of the disease be decomposing matter, then I do not think that they would exist in the water; but if the germs of the disease be living matter, then it is possible that they may exist in the water, but as nobody as far as I am informed can tell us what the germs of cholera are, it would be premature for me or anybody to theorize as to the probability or the possibility of their existing in the water.

3901. You are aware that it has been alleged that the main cause of the cholera in the east end of London was due to the water supply, do you entertain that opinion ?—No, I entertain the opposite opinion. It was a matter of duty with me to investigate the whole of the circumstances connected with the East London supply. In the first place it was supplied to the hospital to which I am attached, in the next place it was supplied to the eastern division of the city, where, as officer of health, it was my duty to look well into the matter, and in the third place I had a general interest in it scientifically, apart from any official connexion with the subject, and I was very desirous to ascertain whether or not the water had been in any way concerned in the propagation of the disease. I therefore investigated it very fully.

3902. Are there two distinct waters supplied to that district ?—Yes, but I will tell you this with regard to it, there is hardly anybody who can say, except in certain parts of the East London Company's district, whether the water had come from the reservoir at Old Ford or whether it had been received from the filter beds at the Lee, which is considered to be a good water, for the water was oscillating backwards and forwards in the mains in such a manner that the engineer himself had no knowledge what water was in any main at any particular time. But on the other hand there are places at which Old Ford water, and that water alone, is supplied, namely, Stamford Hill, Upper Clapton, Walthamstow, Woodford, Wanstead, Leytonstone, North Woolwich, and Silvertown, and excepting the two last-named places there was no cholera in any of them; there was a little in Silvertown towards the end of the epidemic, but the other places were free from it, and those were the only places where we actually knew that that water did go.

3904. Do you think the present supply of water to the London people is wholesome water ?—I do, a thoroughly wholesome water.

Mr. Wanklyn, Professor of Chemistry at the London Institution, Finsbury, informs us that his attention has recently been directed to a new method of analyzing water for organic matters, and which he now considers sufficiently perfect to be worked. The preliminary experiments he has made show a larger quantity of free organic matter in the Thames water than Dr. Frankland's method, which he considers cannot detect all the nitrogenous matter. He says :—

. . I have to remark that the method of determining the organic matters which I use is a very simple one, and can be carried out in about three hours, and the determination is a perfectly direct one. I do not determine the total nitrogen in a water and then determine the nitrogen present as ammonia and nitric acid and give you the difference, but I determine directly the nitrogen present as organic matter, and that you will see is an important thing. The project of 10 years ago, (and it has been tried to be carried out, and it is admitted that it will be very difficult to carry it out,) was to give you the organic matter by a double process, giving you a difference; but my method is a direct one. I give you directly the nitrogen which is present in the organic matter.

5482. It has been stated in evidence before us that if you pour into water a volume of sewage equal to five per cent. of the volume of water into which it is cast, the water will so operate upon it in deodorizing and destroying and breaking up its elements into its primitive elements in fact, that it would no longer be sewage or possess any of its noxious qualities You apparently hold a contrary opinion ?—This I am sure of ; the urea in the sewage in such a water would be very readily broken up into ammonia and carbonic acid, and a little exposure would dispose of the urea, but the albumenoid matter in sewage is extremely persistent, and one of the results of the whole investigation is this, that albumenoid matter is very persistent indeed, and you could not depend upon any treatment such as you have mentioned getting rid of the albumenoid matter.

5485. But will not certain changes take place, even in the albumenoid matters?—Yes, certainly; but the change is very slow, and it is very irregular. The change in urea is very rapid, so that you have to operate upon water recently taken in order to get your full quantity of urea.

Mr. Wanklyn subsequently sent us further testimony in a letter (Appendix A K), which is to the following effect:—

The result of a prolonged examination carried out by myself, Mr. Chapman, and Mr. Smith on the water supply of London, Manchester, Glasgow, and Edinburgh, last summer is the following:—

The water of the Thames at Hampton Court, where the companies draw their supply of water, is not very good, as it exists in the river; but after the filtration effected by *some* (but not all) of the companies, it becomes excellent, and in point of purity from organic nitrogenous matter is then fully equal to the water supplied to Manchester, Edinburgh, or Glasgow.

The water supplied by the New River Company is also very good.

Dr. Frankland, Professor of Chemistry in the Royal Institution and the Royal School of Mines:—

6222. What does your experience tell you is the effect of the quality of the present supply in London upon the health of the population generally?—I cannot of course trace any direct connexion between the present supply and the health of the metropolis; but I consider that water contaminated with sewage contains that which is noxious to human health. There is no process practicable upon a large scale by which that noxious material can be removed from water once so contaminated, and therefore I am of opinion that water which has once been contaminated by sewage or manure matter is thenceforth unsuitable for domestic use.

6224. Are we to understand that you are of opinion that this noxious matter exists in the water from analysis, or from knowing that sewage runs into the river from whence the companies draw their supply?—From both circumstances.

6225. Take the analysis first. What leads you to believe that there is that amount of sewage matter in the water which would be detrimental to health?—I find on analysis, as is shown in the table at page 17 of our report, that there is present in the waters delivered into London the following quantities of material, which may be regarded as the skeleton of the sewage which has been previously poured into the water; namely, of nitrogen, in the form of nitrates and nitrites, a mean quantity of ·192 part in 100,000 parts of water, that is, in the Thames water; in the river Lee water, as delivered by the New River Company, ·221 part in 100,000 parts; in the water delivered by the East London Company, which is also river Lee water, ·132 part; and in the chalk water delivered by the Kent Company, ·365 part in 100,000 parts. This skeleton, as I have called it, of previous sewage corresponds to the following quantities of average filtered London sewage, namely, in the Thames water to 1,751 parts of sewage in 100,000 parts of water; in the river Lee water, delivered by the New River Company, to 2,013 parts of such sewage; in the river Lee water, delivered by the East London Company, to 1,077 parts of such sewage; and in the chalk water delivered by the Kent Company, to 3,393 parts of such sewage. I must mention, however, that this chemical record is defective, especially in the summer months. It is defective in one direction, namely, that it gives the minimum amount of sewage only, with which the water has been contaminated; because in rivers we have vegetation in a state of activity during the spring and summer months, and also to some extent in autumn, and those aquatic vegetables remove this skeleton of the sewage to a greater or less extent from the water.

6226. You state that you have come to the conclusion that sewage has been the cause of the contamination of this water because you find a skeleton there in the form of nitrates and nitrites?—Yes, and also of ammonia, which I think I omitted to mention, but that is a very insignificant part of the skeleton.

6227. Is it possible that those nitrates and nitrites could be present in the water without its having been contaminated by sewage?—Could they be produced by some other cause than that of sewage?—They could be caused by manure thrown into the water, and by manure applied to the land.

6228. But are they attributable to nothing else?—To nothing else, I believe.

6233. With regard to the Kent water, we had some evidence yesterday to the effect that you must have been mistaken in finding traces of sewage in those chalk wells, the water being taken at a depth of 250 feet in the chalk, and the upper part of the wells themselves being lined; therefore the water must have filtered through the chalk, and there could be no trace of the skeleton of sewage. Is it your opinion that the skeleton of sewage as you describe it will find its way down to a depth of 250 feet, and that after filtration through gravel, and ultimately through the chalk, its presence will still be detected?—There cannot be a doubt about it, that this skeleton of which I speak, but which is a very different thing from the sewage itself, is present. I have never stated that the water which has filtered through the chalk in this way contains unaltered sewage; it is this inorganic skeleton of sewage that I find in water so filtered.

6234. Is it prejudicial to health?—It is not in a moderate quantity, such a quantity, for instance, as is contained in this chalk water of the Kent Company.

6235. With regard to the Kent water, the mean of the nitrates and nitrites according to the figures which you have just given us is ·365, and that amount in water in your opinion would not render it injurious to health?—That amount of nitrates I should say would have no deleterious effect upon health.

6236. It is scarcely necessary to say that in the case of the water delivered by the East London Company, which has ·132, the water of the New River Company, which has ·221, and the Thames water delivered by the Chelsea and Grand Junction and other companies, which has ·192, none of those four waters as at present supplied to London could have an injurious effect upon the health of the metropolis, in consequence of the presence of those nitrates which you say are the skeletons of previous sewage contamination?—Certainly not. Those nitrates would not in any case, I believe, be in the least prejudicial to health; but they reveal the fact that those waters have been previously contaminated with sewage, and, as I have already stated, there is no method which, with certainty, can be applied to water by which the noxious qualities of sewage can be effectually removed from it.

6237. But in all those four waters, as I understand you to say, after having had them analysed, you find the presence of those nitrates and nitrites, which shows that the waters had been in previous contamination with sewage?—Yes.

6238. But although they are in that state, you state, do you not, that there is nothing in them that could be injurious to health, and therefore the water is a wholesome water to drink?—I did not intend my statement to go so far as that. I meant only with reference to those nitrates in themselves, that the skeleton of the former sewage which is represented by nitrates and nitrites is not injurious to health; but we have no guarantee that other portions of that sewage may not have escaped the process of filtration through the chalk, and filtration through the land or over the land, and may be present in that water. Those substances are in too minute a quantity to be capable of detection by chemical analysis.

6239. Then your answer would apply as far as the nitrates would enable you to judge?—As far as the nitrates themselves are concerned that quantity of sewage matter which they represent is an innocuous form in the water.

6240. The presence of what other elements would lead you to a conclusion upon the quality of water as regards health?—In the first place when water is once contaminated with sewage, there is no process to which it is afterwards subjected which will effectually remove all that sewage contamination from the water. Filtration will not do it in certain cases, at all events. I have proved that the excrements of cholera patients cannot be filtered out of water; that after a degree of filtration which I believe is never attained by the water companies, and rarely attained perhaps by the passage over soils in irrigation, this water still remains opalescent, from the rice-water evacuations with which it has been mixed. The degree of danger which still remains in waters from different sources varies obviously according to the amount of filtration that the water undergoes. I would much rather drink the chalk water of the Kent Company, even if it had been contaminated to four times the extent of the Thames water, than I would drink the Thames water, because if I could have the assurance that none of that sewage or manure water had found its way into the wells through fissures in the chalk, the chalk water having passed through say 100 feet of chalk, would be very much better filtered than any water which finds its way to the Thames.

6241. When you speak of the difficulty of removing the effects of sewage contamination, does that difficulty apply to that which is held in mechanical suspension, or to that which is held in solution?—To that which is held in mechanical suspension. I believe that the noxious part in sewage is that which is held in mechanical suspension, not that held in solution.

6402. Still you are able to detect those globules?—No, they are beyond the reach of the chemist, and so far of the microscopist, I believe.

6242. Will no system of filtration remove it?—I would not say that it is impossible to remove it, but no system of filtration will secure its removal. There are only two processes by which it can be effectually removed; the one is by boiling for a long time, and the other is by distillation; and therefore it is that I say that, inasmuch as those two processes are impracticable on a large scale, in my opinion water that has once been contaminated by sewage ought not afterwards to be used for domestic purposes.

6244. Then are we to understand you to say that no amount of filtration would render those waters fitted for the supply of the metropolis?—As I have stated, no process of filtration that has hitherto been devised will remove choleraic dejections from water; and inasmuch as it is generally believed that the noxious matter of sewage exists there in the form of minute germs which are probably smaller than blood globules, I do not believe that even filtration through a considerable stratum of chalk could be relied upon to free the water perfectly from such germs.

6246. Do I correctly gather from your evidence that you think that no water that had passed over or through any cultivated district would be proper for the supply of the metropolis or other large towns?—I do think that that water is not safe for human consumption afterwards.

6247. That being your idea, would not it follow that no water could be supplied to the metropolis in a wholesome state from the Thames basin, because the whole of the Thames basin is as we all know very considerably cultivated?—Yes, I think it is very likely that that would be so; and inasmuch as the chalk water from shallow chalk wells exhibits this previous sewage contamination, I should infer that the springs feeding the Thames would also exhibit that contamination; but that does not necessarily follow, because it is stated that the deep chalk wells furnish a water free from nitrates and ammonia, or very nearly so, and consequently they are not so contaminated.

6248. Do you think then that there is a point below which the sewage matter would not get down?—At all events there is a point apparently below which the skeleton of the sewage no longer finds its way, it is either consumed by some living organisms and converted into other forms of matter, or it is absorbed by the strata themselves through which it passes. I have not myself analysed the waters of the deep chalk wells, but Mr. Dugald Campbell has done so, and he states that they are free from nitrates.

6278. Apart from the degree of hardness, in searching for water for the supply of a town, what should you be most careful in avoiding, having reference to the health of the population?—In avoiding a water which had ever been contaminated with sewage or manure matter.

6279. You stated, did you not, just now that the previous contamination, so far as it had ended in the formation of nitrates and nitrites, was of no importance?—That portion of the sewage which has been converted into nitrates and nitrites is of no importance.

6280. Therefore generally that might be left out of the question also?—Yes, so far as that itself is concerned.

6281. Apart from those two elements of consideration, what should you consider the substance to avoid?—In any water nitrogenous organic matter would be a substance to avoid.

6292. You conclude that it is very difficult to get rid of sewage matter by running water?—I do. That portion of it which remains undecomposed after its passage through the sewers oxydizes with extreme slowness. About four-fifths of the nitrogenous matter contained in fresh sewage, which has just been produced, as it enters the sewer is decomposed before the sewage, after a run of two or three miles, emerges into the river, and the remainder, I believe, as far as my experiments teach me, is decomposed with extreme slowness afterwards.

6296. Reverting to this particular question of the presence of organic nitrogen in those waters, what do you consider to be the effect upon water of the presence of organic nitrogen, whether derived from an animal or vegetable source?—As far as we know, the presence of organic nitrogen in the form of vegetable organic matter, such as peaty matter, is innocuous, unless contained in a considerable quantity in the water; but when contained in the water in the form of sewage matter it is believed to be noxious.

6297. Did I rightly understand you to say that you cannot distinguish in those cases whether it be derived from vegetable matter or from animal matter?—I have said that until recently it had been impossible to distinguish between the two, but that now I considered that the proportion between the carbon and the nitrogen in the two cases afforded a basis from which we could in many instances, decide.

6298. That is only an indirect method?—Yes, because the analysis itself gives no difference between the nitrogen from the two sources.

6328. It would seem that you could not very well refer the presence of nitrates and nitrites in all waters exclusively to previous sewage contamination. Without contesting that that may in many cases be so, are there other causes in operation which may have produced the same result?—There are, undoubtedly, causes which will produce a result of that kind to a certain extent. We have the presence of those materials, as I have already mentioned, in rain water, and it is conceivable that rain water falling upon a very dry sandy district, and evaporating there mostly from the surface, might leave those nitrates behind, and they might accumulate there to some extent from that source, and they may also be produced by the decay of purely vegetable matter. This strict analysis of water for nitrates is comparatively a new thing, and it is possible that we may find sources of those nitrates which we are at the present moment not aware of. But it is a remarkable circumstance that waters which it is well known cannot be contaminated by manure or by sewage never do contain those nitrates in a proportion bringing them near to the point of contamination.

6372. Then you do not accept the theory that sewage discharged at point A, and travelling down the river, is so oxydized as it passes a distance of six or seven miles, and is so entirely destroyed that its original elements are not to be found, but it is converted into some other substance or substances which are not detrimental to human health?—I believe that that is by no means a generally true proposition. I believe that under favourable circumstances, that is, when the water is warm, and there is a large volume of water, and the water is a good deal agitated in its course, that effect may be produced so far as regards the dead organic matter in the sewage, but not at all as regards the living germs that may be present in that sewage.

6382. And with regard to that which you do say is injurious [the unoxydized portion of sewage], you are hardly able to detect it?—Only rarely. Those waters are examined only on 12 days out of the 365, that is one point that must be taken into consideration. And I have only, in the case of the entire water supply, been able to get evidence which I consider anything like conclusive on this one occasion to which I have already alluded, namely, last month, on the 21st of January, when those waters contained this large proportion of organic nitrogen as compared with the organic carbon which they contained.

6383. That case to which you refer in January was quite exceptional, as I gather from your report of the 31st of January?—Yes; during the whole of the three years that I have examined these waters I have never found them in so bad a condition as upon that occasion, or in a condition approaching to that, but I may say that this condition of things having once set in lasted the greater part of a month.

6384. In this report of the 31st January you again repeat the words which I have just quoted; after giving the amount of sewage contamination in the water of the Chelsea Water Company, you say: "By gradual "oxydation, partly in the pores of the soil, partly in the Thames and its tributaries, and partly in the reser- "voirs, filters, and conduits of the company, this sewage contamination had been converted into comparatively "innocuous organic compounds before its delivery to consumers," and I think I find that almost word for word in all your weekly reports?—It is copied, in fact, from one to the other; it goes through the whole of them.

6385. Would that not rather lead the public to take it that your view was that this water was perfectly wholesome, or as nearly as possible perfectly wholesome?—I think it would, and that was the impression which I intended to convey, so long as I had not actually detected the presence of sewage matter unoxydized in the water; at all events I was very anxious not to convey the impression that analysis had discovered anything actually injurious in the water.

6386. Do you agree with those remarks of your friend Dr. Odling, which are separate from your report, "Although London is at present provided with an agreeable and in my opinion perfectly wholesome water," &c.?—No, I do not consider it a perfectly wholesome water, I did not at the time this was written, and that, I believe, caused my colleague to give a separate postscript to this report.

6389. In the month of January this year in your report you say: "The waters delivered in London during "the latter part of January by the Chelsea and especially by the Southwark and Lambeth companies, were "in such a muddy condition as to render them totally unfit for domestic use." On that point, filtration properly carried out would have met, would it not, that part of your objection as to the water being muddy? —Yes, certainly.

6390. From that we may gather, may we not, that your view would be that the question of the proper filtration of the waters is one of vital importance?—I think it is a very important point.

6391. You also state in your annual report: "The New River Company stands alone in the perfection of "its filtering apparatus. On no occasion during the past year has this company's water exhibited the slightest "turbidity, thus proving that perfect filtration is compatible with the largest daily supply furnished by any "one company in London." Do you see any reason why every company should not give out their water in the same perfect state that you here describe the New River Company does?—I see no reason whatever why the other companies should not.

6392. And do you consider that it would be a desirable thing in case of necessity that such a delivery of water in a pure state should be enforced by legislative enactment?—I do; in fact, it is so enforced at the present moment.

6426. What should you consider the essential conditions of a good drinking water?—The essential conditions of a good drinking water I should take to be, first, coolness and aëration; secondly, freedom from animal organic matter of all kinds; thirdly, that it should never have been contaminated by sewage or manure in any form; and, fourthly, that it should be soft water, not over five degrees in hardness.

Dr. Odling, Professor of Chemistry at the Royal Institution and at St. Bartholomew's Hospital:—

6447. You have examined the Thames water from time to time, have you not?—I have examined it fully.

6448. Have you found in those examinations of the Thames water the presence of sewage not decomposed? —I have not.

6451. Has your attention been directed to the important principle of the self-purifying process which is going on in rivers running at a given velocity?—Yes, it has. There may be great differences of opinion as to the degree to which that self-purification takes place, but that it does take place to a very considerable extent I think is undeniable.

6452. You will understand my question as not referring to sluggish waters, but to rivers where the body of water would become exposed to the action of the atmosphere as it passes along?—You may see in many rivers, even sluggish rivers, having sewage discharged into them, that for a mile or two the appearance of the river is affected by the sewage, but beyond a certain distance there is no recognizable effect at all, the weeds are perfectly clean and perfectly healthy.

6453. Do you know Leicester at all?—Yes.

6454. Do you know the condition of the river there?—Yes, I do.

6455. Near to the town it was in a very bad condition, and the water quite black, was it not, when you saw it, from the refuse of manufactories and the discharge of sewage?—Yes.

6456. Did you observe the condition of that river three miles from the town?—Yes, and from its appearance you could not tell that it had been contaminated, it was running clear, with fish swimming in it, and the weeds were clean.

6457. And that simply from the process of self-purification?—Quite so.

6459. You have not detected any of the skeleton forms which Dr. Frankland has given utterance to?—That is a point on which I am a little at issue with Dr. Frankland with regard to the interpretation to be put upon the presence of nitrates in water. It is admitted that the presence of nitrates says nothing for the present condition of water at all, and I rather dispute that it says anything very important for its history. There is no doubt that a very large quantity of sewage, or the equivalent of sewage, is discharged into the river Thames above the source of the present water supply, and I do not mean to say that Dr. Frankland exaggerates that proportion at all—I do not know whether he does or does not—but I contend that the estimation of the nitrates in a water does not give any ground on which to estimate its proportion of sewage.

6460. But when found are they in your judgment injurious to the water?—In such quantities as are found in the river supply of London they are, in my opinion, perfectly innocuous.

6461. Still less, I suppose, if found in chalk?—Yes, quite innocuous if found in chalk.

6462. Is it your opinion that those which have been found in chalk are due to sewage?—It is a point upon which there is no positive evidence, but I am inclined to think that it is not so, for we find them distributed so irregularly. For instance, the deep well water at Trafalgar Square, and the deep well water from the greensand, and lower chalk all over London, is nearly free from nitrates and nitrites; whereas the water of equally deep wells elsewhere in the chalk is found to contain very considerable quantities of nitrates. The deep well water from nearly all formations has been found to contain nitrates. Then, moreover, a proportion of the nitrates which the sewage itself undoubtedly does furnish, in one case is destroyed and in another case is not; and so far as the history of the water is concerned, in the one case where the nitrates are destroyed, that water may show but a very small amount of previous sewage contamination, whereas it might have had a much larger amount than the other.

6463. Apart from the question of sewage, is it your opinion that the condition of the Thames basin is such as to render it an unfit gathering ground of water for domestic purposes?—I do not think it at all unfit.

6467. Do you agree with Dr. Frankland, that supposing a system of perfect filtration were adopted (and he appears to consider that the New River Company has a perfect system of filtration), and if all the companies were to use the same process, we should have a water perfectly wholesome for domestic purposes?—Certainly I do.

6472. The presence of nitrates, if not in excess, is a comparatively unimportant element?—It is an unimportant element as to its state, and I believe it to be in many cases an unimportant element as to its history.

6473. You have heard the questions that were put to Dr. Frankland with regard to the probable origin of nitrates. Are you of opinion that their origin may be traced to several sources?—I am quite of that opinion.

6474. With regard to the presence of nitrates in the deep chalk wells of the Kent Company that have been referred to, they show a quantity of nitrates present as large or larger as in the Thames water; but it does not follow, does it, that they are necessarily derived from the same source?—Certainly not.

6477. What do you consider to be an essential quality of good water for drinking purposes?—It should be bright, colourless, and brisk, and it should not contain any considerable amount of nitrogenous matter.

6479. Do you think that there is no risk in using for drinking purposes waters which are derived from rivers the population on the banks of which is constantly increasing?—Of course it is conceivable that the amount of impurity discharged into the river may exceed the power of the river to purify itself, or approximate so nearly to that power as to leave a balance that it would not be safe to rely upon.

This gentleman also makes the following remarks in his report (Appendix D.) on the analysis on the Welsh and Cumberland waters:—

Although London is at present provided with an agreeable, and in my opinion perfectly wholesome water, still it is evident that for general town supply a soft water such as that of Wales or Cumberland is upon the whole more suitable than a somewhat hard water such as that of the Thames and Lee; and, further, that a water which neither contains nor has received sewage impurity is at any rate preferable to a water which certainly has received, even though it does not actually contain any such impurity.

Sir Benjamin Brodie, Professor of Chemistry in the University of Oxford:—

6986. It has been stated in evidence before this Commission that in the case of sewage discharged at Windsor into the river, and flowing down the stream six or seven miles, or rather more, at that point they have failed to detect the presence of the sewage, that from oxydization or the breaking up of the elements it is in such a condition that they have found nothing which in the judgment of the witness would be prejudicial to human health. Have you made any observation bearing upon that point?—I have not myself made any observations on that point, and indeed I do not know how such an examination could be satisfactorily conducted.

6988. Have you formed any opinion as to the probable effect of the flow of seven miles upon water contaminated with sewage, whether at the end of that distance or any other distance it would be fit for human use, or could be considered to be a safe water?—The sewage would be during its course to a certain extent oxydized and destroyed, and resolved into other compounds, but how shall we say that all the sewage is resolved and destroyed so that the water should be safe. To do that we must be able to apply some extremely sensitive test to the water which would enable us to ascertain the presence or the absence of sewage in it, and I want to know what the test is which we are so to apply. There are causes operating, as we all know, to destroy the sewage which, to a certain extent, will effect that end, but the question, as I understand it, is whether those causes are really adequate to destroy the sewage not partially, but absolutely and entirely, during a given course of the river.

6991. You have been supplied with a copy of the medical evidence which has been laid before the Commission, and no doubt you have observed that we have evidence on both sides, one party alleging that water impregnated with sewage will be purified by the action of the air and oxydization in its course a few miles down the river, but, on the contrary, Dr. Frankland states very distinctly, that water once contaminated with sewage is unfit for human use, and that you will still find what he calls the skeleton of sewage present, although it may have travelled 100 miles and been exposed to filtration?—I think what is asserted by Dr. Frankland is true, that there are no known causes in operation on which we can adequately rely to remove the sewage from the water. That causes are in operation which partially remove that sewage and diminish its injurious effects is true, but the question is whether those causes, as I said before, are adequate to produce a complete result; that is to say, whether they will take out of the water all the injurious matter which is contained in it, so as to render it fit for drinking. I do not think it possible, in the present state of our knowledge, to pronounce an absolute opinion upon that point. But if you ask whether it is wise to drink water into which you have put sewage, knowing that you have no positive means of getting that sewage out of it, that is a question which anyone can answer for himself, assuming always the injurious character of sewage. I am not now pronouncing any opinion upon that point, or saying in what degree sewage is injurious; that does not appear to me to be a chemical question. I think that is a question of very great importance, but which is much more likely to be solved by other agencies than by chemical experiments. Medical statistics will tell you more about the injurious or non-injurious character of sewage water than any analysis would do. It does not seem to me that we have, as I before said, any accurate chemical measure of the sewage in the water, at all events I do not know what that measure is. I have read the evidence which has been given by Dr. Frankland and one or two other witnesses also before this Commission, but I still hold to my opinion that we have no accurate measure of the sewage matter in the water, or even of the previous sewage in the water.

7004. In all those analyses a certain value is ascribed to previous contamination, as determined by the presence of nitrates and nitrites in the water; will you give your opinion whether the presence of nitrates and nitrites is to be ascribed to that one source alone, or may it be ascribed to several sources?—I think the probability would be that the presence of a large quantity of nitrates and nitrites would indicate the previous presence of organic matter in the water; but I do not know that you could take that nitrogen, in the shape of nitrates, as an absolute measure of that organic matter, which is a different thing.

7006. But is it not possible that in many cases such salts may be derived from other sources than that of previous sewage contamination, using that term in its common acceptation; may they not arise from other matters in the soil, and therefore is their presence a fair indication of previous sewage contamination?—I believe that nitrates may occur from other causes, but I cannot speak from positive experience.

7009. Dr. Franklin considers that this organic nitrogen in the London water is of a different value from that in the lake waters, because the proportion of organic carbon to the nitrogen in the waters is different?—Yes. This appears to me a very important fact, and may really indicate that the organic matter in the water had, in two cases, a different origin.

7011. You think that the tests of the greatest delicacy are yet insufficient to determine the point at which sewage ceases to be present?—I may take a case which really is an absolutely analogous case to the case of water, namely, the case of the atmosphere. You may look at the atmosphere as really a great ocean. Gases from drains are being discharged into this gaseous ocean just as the water from the drains is going into the river. Those gases are so diluted when they get into the atmosphere that chemical analysis is absolutely mpotent to reveal their presence in any given portion of the atmosphere. But nobody can doubt the njurious effect, under certain conditions, of the gases and other organic matters present in the atmosphere. Take the case of the Westminster drain, the opening of which is known to have occasioned a great outbreak of fever here. You say that you would not live in a house next it, nor at the end of the street, nor at the end of the next street; but where should you begin to live so as to be safe from the effluvia of that drain? We cannot answer that question. I suppose if I get to Oxford I am safe from that drain, but we have no chemical tests,—because that really is the only point at issue,—to apply to the air to say whether or not it contains injurious or poisonous organic matter from the drain. In the atmosphere just as in the water there are constant processes going on with great efficiency to destroy those noxious gases; and a person would argue, just as is done in the case of water, that you have sulphurous acid from the chimneys of London, you have the oxygen of the atmosphere, you have nitric acid, you have ozone in the atmosphere. All these agents, happily for us, are at work destroying those noxious gases from the drains and sewers and other places. But when is their work completely done? That is what we do not know. Another most important thing is this, that really there is no reason whatever to believe that the injurious character, either of sewage or of the gases from a drain, depends, fundamentally, upon the quantity of that sewage or of that gas; in all probability it far more depends upon the quality of the sewage, namely, what it consists of. Now what is the nature of the poisonous matter in the atmosphere or in the sewage? We do not know that at all. Therefore how can you possibly say when that poisonous matter is got rid of from the water or from the air. It is a question that with the means at our disposal it is absolutely impossible to answer; and I say as I said before, that I think you have a much better chance of getting at these relations through accurate statistics properly applied, than you have through chemical analysis, because chemical analysis is one of the poorest things possible to reach those delicate quantities. You cannot get at those small quantities at all. Chemical analysis must be limited by our power of weighing and measuring; we can only do those two things. We can weigh and we can measure, and we can do that with a certain accuracy, and there we stop; but that accuracy is not capable of being multiplied *ad infinitum*. It may go on to a certain point, but we cannot go beyond that point. I think that it is impossible absolutely to answer those questions, for we have not the data; but the question arises, as I said before, whether a prudent person likes to drink water which contains a certain quantity of nitrates and nitrites, or that when analysed is found to contain a certain quantity of organic carbon and nitrogen, water into which you have deliberately put cartloads of sewage at some time or other in its course.

7014. Oxydization is constantly going on in the soil and in the river, and therefore there must be some point at whichcthe perfect destruction or oxydization of this animal matter must take place?—What I think is muh more important still is another point, namely, the great dilution of the material, and I should rely upon the dilution quite as much and more than upon the destruction of the injurious matter. Supposing the sewage of a large town such as Oxford pouring into the river, there are numerous feeders and tributary streams to the river which effectually dilute the sewage. The sewage is gradually getting proportionately less and less, and therefore its noxious character diminishes and ultimately disappears.

7028. It is a perfectly possible and conceivable thing that a very minute proportion indeed of sewage in the water might be most extremely injurious to health. I say that partly from general experience, and partly because I have had occasion myself very frequently to observe the vast importance in chemical changes of what people so frequently pass by as inappreciable quantities of matter. Indeed, I have occasion to see more and more every day that minute portions of matter, which previously were not suspected at all to exist, exercise important influences on chemical transformations.

7041. If water is supplied to a town from a river which in a part of its course has received previous sewage contamination, and if that water is used on a large scale by that town and produces no ill results, and chemical analysis fails to detect anything unusual in its character, is it not a fair presumption that such water is wholesome and good water for the use of a town supply?—If it be used without injury to the inhabitants, really chemical analysis is altogether superfluous. But the question is whether it can be always and permanently so used. That seems to me to be the real point at issue. We should have found out long ago the injurious effects even of small quantities of sewage if the sewage were always injurious; but that is not asserted. It is only supposed that, under certain exceptional conditions, even sewage may become very injurious. The injurious character of a water impregnated with sewage matter might not be discovered for years. You might long go on using it, for years, and it might not be discovered, and yet you might have some outbreak of disease in the place which, nevertheless, might be connected with the use of that sewage water.

7043. You consider then that with regard to the effect of water upon the health of the inhabitants, it is rather a question for the medical observer than for chemical analysis?—I really think so. I think that chemical analysis is not yet sufficiently advanced (whether it ever will be I do not know) to pronounce a decision upon the matter, and that you have a better chance of getting at the real connexion between the injurious matters in the water and diseases generated by those matters through statistical observations carried on upon a large scale than through chemical analysis. Statistics elicit relations of cause and effect on which you cannot deliberately experiment.

Dr. Miller, Professor of Chemistry in King's College, London:—

7066. What was [in 1859] the state of the water at that part of the river above Teddington lock where the water companies are now taking their supply?—Above Teddington lock the water was very good, even at that time when there was but a scanty supply of water in the river.

7068. Did you detect in the water taken from above Teddington lock the presence of sewage?—There was organic matter, but I should not have called it sewage.

7069. Did you then form an opinion that it was traceable to sewage or partially traceable to sewage or to some other cause?—I did not specially determine whether it was sewage matter or what the origin of the organic matter was.

7070. Would there be a difficulty in determining whether the nitrates were due to one source or partly to one source and partly to another; for instance, the drainage of land, the manuring of farms upon the watershed, and the washing of the remains of the sewage into the river?—I do not think there is any means of determining what proportion of the nitrates is due to the natural supply from the chalk springs, and what is due to the oxydized sewage. In fact there is no means of determining that. They exist exactly in the same condition in the water, and therefore a proportion of the nitrates may be due partially to the one cause and partially to the other, the proportions varying with accidental circumstances.

7072. You have seen the evidence of Dr. Frankland in which he refers to the presence of sewage in the form of skeleton; if the view which he takes is a correct one would the presence of that skeleton be injurious to health do you think?—I understand that merely as a figurative expression showing the existence of nitrates and ammonia in the water. Neither of those things in themselves in small quantities is in the least degree injurious. I am speaking now simply of them after they have been completely converted into that condition of nitrates or of ammonia.

7074. You are aware Dr. Frankland takes a very strong view of the presence of that skeleton of sewage, because, in referring to certain wells used by the Kent Waterworks Company, where the water is pumped from a depth of 250 feet through the chalk, notwithstanding the filtration at that depth he still detects the presence of those skeletons of sewage?—That is to say, he finds nitric acid or nitrates, and he assumes what I think he is not justified in assuming, namely, that those nitrates are the result of the putrefaction, or rather of the decomposition of sewage matter. No doubt they are formed by that operation in a great number of cases, but to say that they are always formed so would be, I think, far beyond what the facts warrant.

7077. I do not deny or doubt that in a great number of cases the presence of nitrates does indicate the previous existence of some organic contamination. The only difference between Dr. Frankland's view and mine is this, that he assumes, apparently in all cases, at least if I read his evidence aright, that nitrates invariably point to previous sewage contamination. I think that that is not justified by other observations. The experiments of M. Boussingault and others show distinctly that the formation of nitrates does occur where there can be no suspicion of previous sewage contamination.

7082. Are you of opinion that water once contaminated with sewage can never be considered a safe water afterwards?—I think experience is quite against that. I think it is safe; evidence shows that it is safe in the majority of instances. There may be cases in which danger is produced.

7088. Have you made any experiments upon the power of water, in a given course, to oxydize organic matter?—I ascertained a remarkable result in the course of the summer of 1859 upon the river. I took specimens of the water at Kingston, at Hammersmith, at Somerset House, at Greenwich, at Woolwich, and at Erith on the same day, and I examined the quantity of oxygen which the water contained at all those different points. I found that the quantity of oxygen at Kingston was the ordinary or normal proportion; at Somerset House it was much diminished; at Greenwich the whole of the oxygen had disappeared; at Woolwich it was much in the same condition, and at Erith the water was very much improved, showing that this diminution of oxygen had been produced by its action upon the water contaminated with the sewage of the London district, and that as it passed lower down the oxygen was again absorbed from the air, and again it became diluted with a large volume of water from below, from other sources, the Lee, the Ravensbourne, and other tributaries, and in this manner the water had again become oxydized. I look upon this as a direct proof of the effect of oxygen in destroying those organic contaminations which are thrown into the river.

7099. You consider, do you not, that in small quantities the presence of such nitrates would be innocuous?—Yes; the presence of large proportions of nitrates would no doubt indicate communication with some source of animal refuse. Well waters in towns very commonly contain large quantities of nitrates, especially in the neighbourhood of graveyards.

7100. But they contain very unusual quantities?—Yes, quite large quantities; sometimes I have seen as much as 20 grains in a gallon.

7101. Have you had occasion to analyse any waters which you have reason to believe are removed from the possibility of previous sewage contamination, and yet found nitrates present in them?—Yes, the waters from Watford, which come from chalk wells, where there can be no suspicion of previous sewage contamination, always contain nitrates.

7104. Organic nitrogen, I presume, is the substance the presence of which in any excessive quantity is to be avoided?—The presence of organic nitrogen may be derived from substances which are quite harmless, or it may be derived from substances which are very injurious, and we have no means of distinguishing between the two. Nitrogen is always present in such combination, not as nitrates, and not as ammonia; but the presence of nitrates is always a suspicious circumstance in water, and the greater the quantity of nitrates the more suspicious is the nature of the water and the more reluctant one would be to use such a water as a source of supply.

Dr. Robert Angus Smith, Government Inspector of Alkali Works:—

7184. Have you directed your attention to the quality of waters supplied for domestic purposes?—Yes, I have.

7185. Have you made any analyses which you can refer to as giving information on that point?—I have made a great many analyses, but I have not brought any with me. I only intended to speak here on general principles, and especially about the organic matter which seems to have raised a discussion of more importance than, I think, any other subject in connexion with water.

7186. Will you be good enough to state your views upon the subject?—Some time ago, in studying the organic matter of water, I divided it into many parts. It had been common in analyses of water to write down the organic matter as if it had some special quality. Afterwards, however, I found it necessary to consider organic matter as a very complex substance, and instead of putting it down under one head I have put it down under at least eight heads, and some of those heads have subdivisions. The first head which I think it would be worth attending to is organic matter, which is putrefied. This would include the gases and vapours arising from putrefaction, and this is the thing which strikes one more especially on coming in contact with water which is impure; for example, in drinking it would be offensive to the smell, and generally it will give those characteristics that were found in the Thames some two or three years ago. I examine this part by means of permanganate of potash. It is very readily done.

7187. As I understand it, although you break up that which is usually designated organic matter into eight parts, still those eight parts form but one matter that is called organic?—It is so; it is one of the great divisions.

7188. None of those eight parts would have reference to anything except the original matter which is called usually by chemists organic matter?—No; but they will be as different in their properties as, I may say, organic or inorganic matter are—so widely apart are they in quality. It is difficult for one to give exactly all the particulars, but I will first say how I examine the gases of putrefaction. I use generally permanganate of potash for that purpose; that was the plan adopted by Professor Vorckhammer, of Copenhagen, some years ago, for organic matter generally, and it has been adopted by several chemists since, and rejected by several others as of no value. I find that it is of value. . . . .
I may say what I found in the Thames. Above Reading very little impurity was found in the Thames, but below Reading it was very marked indeed, and it never disappeared in any part below Reading.

7198. For what distance down?—Any part. I went down to London Bridge, and it was visible in any part below Reading.

7199. Did you detect the presence of sewage from every sample that you took below Reading to London Bridge?—Yes, what I believe to be caused by sewage; it was organic matter, which in its decomposition showed a great deal of animalcular life, and which I believe to indicate so much organic matter of a very active kind, probably dangerous.

7200. Supposing there had been no source of contamination below Reading, would you then have been able to detect the presence of sewage in the river, because, as you are aware, down the river there are fresh sources of contamination going on?—Yes, I think there would have been a little. I may say that above Oxford I considered the water extremely pure, but below Oxford and I might say down to Pangbourne, it was, perhaps, a little less pure, but very little. I considered at that time that it was not proper to take water from any source below Pangbourne at any rate. Perhaps I might be inclined to go higher now, but that was my view at the time when I examined the water for the Metropolitan Sanitary Commission, which is now 20 years ago nearly.

7201. Are you of opinion that a water once affected with sewage contamination is never after a safe water for domestic purposes?—I think it may be quite safe. It is so in some cases, in others not.

7202. Under what condition?—Supposing it were very impure indeed, the first thing that would occur would be putrefaction; that gives out a number of nauseous gases, and the most prominent to the senses is, perhaps, sulphuretted hydrogen. After the putrefaction had finished a great deal of the organic matter would be removed. If any remained, and it were exposed to oxydation nitrates would be formed. Those nitrates are, I consider, so far offensive as they indicate very bad company, but in small quantities I am not aware that they can be considered hurtful. On the contrary, to some extent they are a very valuable accompaniment of organic matter. They themselves are disinfectant and prevent processes going forward which would be unpleasant. . . . . If the germs pass into rivers we do not know how far they may be carried; on the other hand, we do not know that they ever can be carried in pure water; the dissolved oxygen may destroy them, as it unquestionably does putrescent matters. A positive proof of their transmission in otherwise pure water is wanting. We might ask if a cholera germ in the water at Oxford would produce disease in London; and we might answer by asking if one cholera germ passing into the air at Woolwich would produce disease in Pimlico. This we do not know; but it seems probable that disease cannot be carried far by pure air or by water with much oxygen in it, which is equal to pure air. We are informed that the atmosphere is full of germs; but the evidence seems to be that it requires an unusual excess to attack us successfully. It seems to be a question of quantity. Still there is the sentiment remaining; we do not like that any sewage should enter the water that we drink. I am disposed to think it well to listen to this sentiment, so far as large towns are concerned, although even then we must remember distance and quantity; but so far as villages and ordinary agricultural drainage is concerned, I am not aware of any experiments showing sufficient room for fear.

7242. Are we to understand you that you would be guided as to the objectionable quantity of organic matter in water rather by the results showing the development of animalculæ than by the results of chemical analysis?—I think that one of the most important experiments that can be made, although I would not neglect the others. I have seen some very striking instances indeed, in which an enormous number of animalcules have been found in water which at first appeared perfectly pure, and quite a contrary result has taken place in water which I thought to be inferior.

7244. I understand you also to say that if you give the water a sufficient length of flow this organic matter will be oxydized more or less completely?—Yes, that is always the case. It is a question of length of flow, or length of storage, or depth of drainage; those are the three most important points.

7247. The nitrates are what I have called old organic matter. There is no doubt that by the oxydation of nitrogen compounds nitric acid is formed. I imitated this process long ago, using chiefly yeast, and so produced nitrates from yeast or vegetable matter. The nitrate comes from animal and vegetable albumenoids indifferently. When estimating the London sewage we may readily refer most, if not all of it, to animal matter or sewage. In the river above London some of the nitrates come I do not doubt from vegetable matter. I have not estimated how much comes from one and how much from the others. I am inclined to think that nitrates coming down may be divided into the animal and vegetable nitrates, and measured. Albumen, &c., would produce nitrates without being used by animals. When nitrates are caused by matter from animals there is always a corresponding amount of common salt. Men take from 200 to 300 grains at least of common salt every day, and it is given out every day. This is the most unchangeable accompaniment of sewage.

7253. In most cases where there is danger to be apprehended from the presence of nitrates have you not been able to detect the presence of chlorides ?—Always. Whenever chlorine is high in the water it is necessary to look for nitrates derived from sewage, and, as a rule, it is so constant that there is scarcely any exception. When we find much more than the average quantity of chlorine in a well water, nitrates are found also, and if the water in a district is pretty well known, that is to say, if the amount of chlorine in water from any district is pretty well known, and a specimen of that water should indicate rather more chlorides than usual, you may conclude with almost certainty that it is from sewage.

Messrs. Letheby, Odling, and Abel, in the analyses for the metropolitan water companies, given in Appendix AH, add the following remarks :—

With reference to the second part of your letter, in which you request us to report on the system pursued by Dr. Frankland in obtaining and recording his analytical results, we have to offer the following few remarks.

Without discussing the question of the general applicability of Dr. Frankland's method of water analysis, which are at present we believe almost exclusively employed by him, we must express our dissent from one of the inferences which he founds upon his analytical results. In particular, we contend that the proportion of nitrogen discovered in water, in the forms of nitric acid, ammonia, &c., is not a trustworthy measure of the extent to which that water has, at some time or other, been contaminated by sewage, inasmuch as the nitrogen compounds existing in a water may, on the one hand, greatly exceed, and, on the other, equally fall short of those which would be furnished by the addition to the water of a given proportion of sewage (using the latter term in the broad sense in which it has been applied by Dr. Frankland), thus, for example, we cannot accept as a correct representation of the relative condition of the East London water (from the river Lee), and that supplied by the Kent Company from deep wells in the chalk, the statement of Dr. Frankland in the Registrar General's Weekly Return for May last (No. 22, page 179) that the former contains 0 parts of previous sewage contamination (estimated) in 100,000 parts of water, while the latter exhibits 3,540 parts of previous sewage contamination in the same amount of water.

It scarcely need be pointed out by us, that the apparently higher results which Dr. Frankland's published analyses record, as to the solid constituents generally existing in water, when compared with those given in the reports of other analyses, are simply ascribable to the circumstance that they are calculated on 100,000 parts of water instead of on the imperial gallon of 70,000 parts, as is the general custom.

In conclusion, we have to express our opinion that no useful results, but the reverse, can be attained by expressing in large multiples, as in tons (see Registrar General's weekly returns), the small proportions of mineral or other constituents, which analysis discovers in potable waters, and by designating as *impurities* perfectly harmless substances which exist, in varying proportions, as normal constituents of nearly all natural waters.

Engineers and others.

185. The Rev. J. C. Clutterbuck :—

1805. You are well acquainted, are you not, with the surface condition of the watershed of the Thames for some hundred miles up ?—Yes, all the way.

1806. Is it highly cultivated ?—It is highly cultivated, decidedly.

1807. And what, in your judgment, would be the effect upon the water in the rainfall passing through a soil so cultivated ?—With reference to the chalk surface, I do not conceive that there would be any great amount of effect produced by cultivation on the water percolating that part of the country, because it would sink through so very much soil.

1810. Looking at that general condition of the surface and at its geological formation, is there in your judgment any objection to that gathering area for water for the purposes of domestic use ?—No, I think not, I cannot say that I see any.

Mr. Hawksley :—

2553. The great complaint of London water at present is not the quality of the water itself so much as the polluted district through which it passes ?—That, I think, there is the greatest possible amount of misconception upon ; there is a great deal of prejudice, not unnatural at all, but still amounting to prejudice, upon that question. I believe, in fact I know, that the water of the Thames at Hampton is very excellent water, very pure, very free from organic matter, and that what little organic matter it does contain is of a very innoxious character.

5076. What quantity of water, as compared with the volume of sewage, is necessary for the purpose of breaking up into its original elements the sewage which has been discharged into it ?—Generally about 20 to 1. If the water flows rapidly and is very much disturbed, so as to be continually receiving fresh oxygen, a smaller quantity, even 12 to 1, will effect the process ; if it proceeds very tardily it may take a little more ; but usually 20 to 1 is perfectly abundant. I could give you very remarkable instances. Take Sheffield : nothing can be fouler probably than the state of the water at Sheffield, whereas if you go down to Doncaster the water is supplied by the waterworks, and is actually drunk in the town. I do not, however, say that it is a desirable thing.

5077. How many miles is Doncaster below Sheffield ?—About 20 miles.

5078. Is it a rapid running stream ?—No, it is not rapid in summer. In point of fact it is controlled by the weirs set up for the navigation. But take the river Irwell leaving Manchester, receiving the Irk, the Matlock, and all the refuse of the manufacturing population for a great many miles ; when it travels down only eight or nine miles to Warrington it is perfectly changed, it ceases, or nearly ceases, in that short distance to be an offensive river. I do not say that it has become all that it ought to be by any means, because the distance is not sufficient, and the flow is not rapid enough. The river is canalized, which prevents its flowing with all the rapidity it ought to have.

5079. You remember, do you not, the original condition of the river at Leicester after receiving all the sewage of the town into it?—Yes, perfectly well. I happened to be the engineer at Loughborough and also at Leicester. I made the waterworks at Leicester, and I advised the sewage works at Loughborough, and I also was called in to design waterworks for Loughborough, and I had on those occasions to take particular notice of the state of the river at all times, both at Leicester and at Loughborough, Loughborough being about 12 miles below Leicester. At Leicester the water was as black as this ink. I do not mean to say that it was absolutely so thick, but looking at it in a mass it was as black as ink—nothing would live in it, and the smell was abominable,—but by the time it got to Loughborough it was entirely restored to its pristine condition. You could stand on the bridge there and see the fish swimming amongst the beautiful reedy and other plants growing in the water just as in the purest stream. You could see every pebble at the bottom. That is an instance of the effect of oxydization.

5080. The water has symptoms of returning purity, has it not, within four miles of Leicester?—Yes, but not to the same extent as at Loughborough. The water was perceptibly impure at the driest period of the year down as far as Barrow. It could be just perceived there, but at Loughborough it was perfectly restored.

5083. Having regard to the capacity of the Thames watershed to yield a sufficient supply for the metropolis, (and when this system or purification is completed, whether for the sake of removing prejudice or any other purpose, to get rid of filth at all events the water must be improved,) you are of opinion that there is no necessity to seek a supply of water from a distance from the metropolis?—Certainly not. You have very fine water surrounding London in all directions, and it only wants utilizing.

Mr. Beardmore, Engineer to the River Lee:—

3329. What is your opinion as to the quality of the water supplied from those sources for the uses of the public generally for sanitary and domestic purposes?—I think that with proper arrangement of reservoirs the quality may be faultless, always excepting the carbonate of lime, which I regret to see published every week as so many grains of impurity, being merely a solution of pure chalk in the water. It is called in the papers impurity, but setting aside that carbonate of lime you will never get a purer water. In fact the New River is as pure as Loch Katrine now very generally, and with reasonable arrangements you may have the water still purer.

Mr. Leach, Engineer to the Thames Conservancy Board:—

4289. It would of course greatly improve the river if that sewage and other contaminating matter were diverted?—It would improve the condition of the river, but I think that the contamination has been very much exaggerated. In those country towns there is no regular system of sewage generally. The majority of the houses drain into cesspools; and really there is no very large outfall in any case except at Windsor; there a more perfect system of drainage has been carried out, and there is a most offensive outfall.

4290. Still there must be a very large amount of ammonia flowing into the river notwithstanding the cesspools, because of the overflow which you must necessarily catch in the river. A cesspool is very soon filled, and though not filled with solid excreta still there is an overflow, and that must find its way into the river ultimately?—The ground absorbs a good deal of that. I have noticed the outfalls of some of the larger towns, such as Abingdon and Wallingford, and although they are unquestionably offensive, still there is not that volume which would be the case with a similar population in London.

4291. Is the volume of water in the river sufficient to deodorize it?—Yes, it very soon loses any contamination.

4292. Take Windsor for example, where there is a discharge of a considerable amount of sewage out of their drains, have you observed the condition of the river at the point of discharge and also a few miles down?—Yes, I have.

4293. How soon in your observation is the effect of sewage destroyed by its flow and admixture with the water?—At Windsor it is discharged into a most unfavourable point in the river, where there is little or no stream at ordinary times. At times of flood of course there is more stream, but usually there is very little stream there, and the matter which is passed out of the drain floats about in the river there to a very great and very disgusting extent.

4294. Is there an eddy there, or what?—No, there is a weir just immediately below, which deadens the stream sufficiently to deprive it of the force required to take what is floating away. Two miles or even a mile below that I could see no traces whatever of the sewage.

4295. Was it all broken up and destroyed?—Yes, and taken by fish, and so on.

4296. Is it the habit of fish to take up matters of that kind?—Yes, you generally see persons fishing close to the outlet of a drain. I think that the operation of the Act of 1866, which prohibits the discharge of sewage into the river, will have a very beneficial effect. If some such provision had not been passed I can quite understand that as the system of waterclosets was extended and a more perfect system of drainage was carried out, the river would rapidly become much more contaminated; but the powers contained in that Act will, I hope, put an effectual stop to the pollution of the river.

Mr. Simpson:—

4625. With regard to the effect of the London water, which your companies supply, upon the health of the population, do you consider it an unwholesome water?—No, decidedly not. I believe the water to be as wholesome as any water that we can obtain.

4627. Are we to understand that you have heard nothing or seen any returns that would lead you to believe that the water supplied to London is bad in quality and injurious to health?—I certainly have not. I believe that a great deal of what has been stated upon that point is merely assertion without inquiry. I have been in the habit of being consulted by towns not only in England but on the Continent, and I doubt whether any city in Europe is better supplied than the metropolis either in quantity or quality.

Mr. Quick:—

6009. The quality of the water you say is good?—It is very good indeed for all purposes, not only for domestic purposes but for manufacturing purposes. Brewers and tanners, and those people who use large quantities of water for trade, all prefer the Thames water to any other water that they can get.

The following remarks by Mr. Pole (Appendix O.) also bear on this question :—

Below Lechlade the Thames is canalized, the water being held up by locks, weirs, and sluices at intervals, forming successive ponds.

There appears to be no traffic worth speaking of in a large portion of this navigation; but the weirs have, I have no doubt, a very beneficial influence on the quality of the water, as its flow over them causes great agitation and aëration, and so must promote considerably the breaking up and oxydation of the organic matter. This fact I think ought to receive more consideration than hitherto in the discussion of the general economy of the river.

The towns of Cirencester, Cricklade, Lechlade, Fairford, Northleach, Swindon, Highworth, and some other small places, lie in the basin above this point, but as no systematic drainage by sewers (except to a small extent at Cirencester) is carried out in any of them, I think it may be said that the only contamination of importance received by the water is from the tilled land. And from the absorbent nature of the ground over nearly the whole of the district, this will naturally be much less than in places where the waters flow over retentive soils.

Analyses of the Waters of the Thames and its Tributaries made for the Commission.

186. The analyses, by Drs. Frankland and Odling, of the samples collected by Mr. Pole (see Appendices O, and A X 1 and 2) show the difference in the quality of the water of the Thames, in different parts of its course, and of its principal tributaries, together with the character of the water of some of the main springs feeding these rivers. The facts obtained are important, although we see reason to differ from some of the conclusions which one of the chemists has drawn from them.

Dr. Frankland adds to these analyses the following remarks of his own :—

The conclusions arrived at from the foregoing investigation of the waters of the Thames basin may be thus summarised :—

1. The head waters of the Thames and the waters from chalk wells and springs in the Thames valley contain but a very small proportion of organic matter, which is, however, highly nitrogenized. They are very hard, and, with one exception (the Caterham well water), exhibit a high previous sewage contamination. Although markedly superior to the river waters at present supplied for domestic purposes to the metropolis, they are much inferior to the Welsh and Cumberland samples.

2. All the feeders of the Thames (exclusive of the head waters) which have been examined, are, without exception, ill adapted if not utterly unfit for domestic purposes. They are all decidedly inferior to the Thames itself at Hampton, and consequently none of them could be substituted with advantage for any portion of the present metropolitan supply.

3. The head waters of the Thames are polluted by sewage or manure matters soon after leaving their sources, and on reaching Lechlade are contaminated even to a greater extent than the Thames water delivered in London.

4. The precise effect of the flow of a stream, in purifying the water from sewage or manure matters, cannot be clearly ascertained from the foregoing investigation ; but the analytical results demonstrate that at no part of its course does the Thames become freed from the soluble animal organic matters with which it is contaminated, although the total amount of these matters becomes diminished as the stream pursues its course.

5. After leaving its head springs, the water of the Thames is purer and better adapted for domestic purposes at Hampton than at any other point in its course.

6. Irrigation, properly carried out, purifies sewage to a great extent, but not sufficiently to render it admissible into potable water without danger ; the risk arising not only from the considerable amount of animal organic matters which the effluent water still retains in solution, but also from the absence of any guarantee for the removal of the germs or other noxious suspended matters which are frequently present in sewage.

Dr. Odling adds as follows :—

It may assist the Commission, in interpreting the results of our analyses, to have their attention drawn to the following points :—

1. That unoxydized nitrogen, or nitrogen in the forms of organic substance and ammonia, is the characteristic constituent of animal excretions ; and that if the entire daily excretions of the 800,000 persons living above the Thames at Hampton were added at once to 800,000,000 gallons of water, or the daily quantity of water flowing past Hampton (*i.e.*, if the excretions of one average person were added to 1,000 gallons of water), they would give to the filtered water a proportion of unoxydized nitrogen amounting to ·3 part in 100,000 parts.

2. That whereas, in fresh animal excretions almost the whole of the nitrogen exists in the form of organic substance, and but a minute proportion in the form of ammonia, in ordinary town sewage about four-fifths of the dissolved nitrogen has become changed into ammonia, only one-fifth remaining in the form of organic substance ; so that if the sewage of 800,000 persons were included at once in 800,000,000 gallons of water, it would give to the filtered water a proportion of nitrogen in the form of ammonia amounting to ·24 part, and a proportion of nitrogen in the form of organic substance amounting to ·06 part in 100,000 parts.

3. That according to the tables of results, the excess of unoxydized nitrogen in Thames water at Hampton, above that in the Head Springs water, is ·015 part, and the entire amount of unoxydized nitrogen in the water at Hampton, but ·024 part in 100,000, the two waters being alike free from ammonia ; whilst, of feeders, &c., of the Thames draining sparsely populated districts, the quantity of unoxydized nitrogen amounts in the Kennet above Hungerford, to ·034 part, including ·003 of ammonia ; in the Thames below Lechlade, to ·036 part, including ·003 of ammonia ; in the stream from Bagshot sands, to ·046 part, including ·003 of ammonia ; in the Wey above Godalming, to ·066 part, including ·001 of ammonia ; and in the Thame, to ·073 part, including ·001 of ammonia, in 100,000 parts of water.

187. An examination of these analyses shows:—

	Parts.
1. That the solid residue in 100,000 parts of the *waters of the Thames* and of its *tributaries* in the Oolitic and Chalk area varies from - - - - -	25·58 to 32·95
And from its *tributaries* flowing through or from the Bagshot and Lower Greensand districts from - - - - - - - - - - -	7·05 to 18·10
2. That the proportion of *lime* (as carbonate of lime chiefly) in this residue varies in the one case from - - - - - - - - - -	11· to 15·03
And in the other from - - - - - - - - - -	·68 to 5·73
3. That the *springs* in the Chalk and Oolitic districts contain of solid residue from -	28·25 to 32·36
4. That the *lime* in these different springs is in nearly equal quantities, varying only from	14·00 to 14·50
5. That the quantity of sulphuric acid (in combination chiefly as *sulphate of lime*) varies in the tributaries of the Chalk district from - - - - - - -	·49 to ·54
Ditto, ditto, Oolitic limestone district from - - - - - - -	1·62 to ?
Ditto, ditto, clay and mixed districts from - - - - - - -	3·68 to 4·28

Of other inorganic substances the quantities are small.

In the whole course of the Thames, from Lechlade to Hampton, the only resulting difference in the quantity of solid residue is ·56, showing a decrease of from 28·63 to 27·87. Part of the lime present in the springs is precipitated, apparently by exposure to river flow, both in the Thames and the Lee, showing a reduction of from about 14·25 to about 11·50 in the 100,000 parts of water.

188. There are great anomalies in the quantities of nitrites and nitrates present in the springs and in the rivers in different parts of their course. All the springs hitherto examined, whether in the chalk or oolitic districts, contain more of these salts than the river waters do, as estimated by the quantity of nitrogen in combination with them, which varies from ·358 to ·422. From ·358, which is the quantity in the head springs of the Thames, it decreases rapidly to ·157 at Lechlade. It rises again to ·277 below Oxford, decreases to ·245 at Abingdon; is ·205 above and ·211 below Windsor, and falls to ·196 at Hampton. Some effect is no doubt partly due to the addition of sewage matter as the river passes these towns, and we had hoped to obtain a measure of the extent of conversion of organic matter into innocuous nitrates and nitrites by the plan adopted of testing the water before and after it had passed the principal towns on the banks of the river; but the change effected by other causes, especially by the influx of the tributaries, is so much greater, that it becomes difficult, or rather impossible, at present to apportion effects to the relative causes. Thus the high figure below Oxford is in greater part accounted for by that of the Cherwell, which, two miles above Oxford, gave ·264, while again the Thames proper had risen from ·157 at Lechlade to ·218 above Oxford, influenced possibly by the smaller tributaries it had received in its 27 miles flow. At Caversham, above Reading, the quantity had again increased to ·286, whereas just below Reading, after receiving the drainage of this town, it fell to ·148; this arises evidently from the influx of the Kennet, which a little above Reading contains only ·029, while nearer its supply springs above Hungerford this tributary gives ·113. The Thame—the hardest and worst of the tributary waters—contained only the small amount of ·080 of nitrates. Again, the Thames at Hampton is affected on the one hand by the Colne with ·302, and the Wey with only ·090.

It would appear, therefore, that the effect produced by the drainage of towns into the Thames is quite subordinate to the changes produced by the flow of the river, the effects of vegetation, and probably by the action of the mud and silt, which in some of the tributaries, where there is a larger proportion of argillaceous matter present, may have a more efficient action in separating the bases of the nitrates and nitrites. The Thame flows chiefly over argillaceous strata, and the Kennet just before reaching Reading receives the several small streams draining the London clay and Bagshot sands of the district. The Wey has a portion of its drainage from the same formations. The fluctuations in the quantity of nitrates seems to us inexplicable upon the hypothesis of their immediate dependence upon recent organic matter. We should be more disposed, looking at the exceptional quantity present above Reading, in the Colne and at other places where the rivers have been largely fed by springs from the chalk, to refer much of it to supplies furnished by these springs. This, however, requires investigation.

189. The organic matter in solution in the waters of the Thames through its 140 miles course exhibits the same general persistence, accompanied by similar though not parallel fluctuations to those of the inorganic matter and the nitrates. In this case, however, the conditions at starting are very different. The quantity of organic nitrogen, taking that as the test of undecomposed organic matter present in the springs, is at its minimum instead of the maximum shown by the nitrates. The following table shows some of the

results of the analyses made for the Commission by Dr. Frankland which bear on this point:

——	Organic Nitrogen.	Organic Carbon.
Amwell Well (taking this water to represent the springs of the Lee) - - - -	·009	·076
Otter Spring, the Colne, near Watford - - - - - - - - -	·012	·026
Croydon Well (taking this to represent the spring water of the Wandle) - - -	·007	·040
Syreford and other large springs, forming the main sources of the Thames - -	·009	·014
By the time the Thames has reached Lechlade these quantities have increased to -	·033	·133
And subject to a number of fluctuations they stand on the river reaching Hampton at -	·024	·260

190. The effects of town drainage, and the diminution of the quantity of organic matter brought about by the flow of the river, are more apparent in these experiments, but are still far from striking. Thus the quantity of organic nitrogen has decreased from ·033 at Lechlade to ·028 in the Thames above Oxford: after passing Oxford it still stands at ·028, but that is accounted for by the junction of the Cherwell with only ·025 of organic nitrogen; at Abingdon it falls to ·026, rises to ·032 at Caversham, increases to ·049 just below Reading, decreases, 5 miles lower, to ·032, decreases to ·028 above Windsor, rises at Windsor to ·029, and then falls to ·027.

191. In a supplementary report, Dr. Frankland and Dr. Odling call attention to the important fact that "the Thames is chemically purer at Hampton than at any other part "of its course." They account for the reduced quantity of mineral constituents by the influx of the Wey at Weybridge, which, draining a tract of Lower Greensand, Bagshot sands, and London clay, brings down less carbonate of lime, as is rendered clear by the results of their analyses, which show the solid residue in each to be—

Thames at Staines.	Colne.	Wey.	Thames at Hampton.
31·40	32·14	18·10	29·90

of which the lime is in the proportion of—

12·63	13·78	5·73	11·85

The nitrates in the same way give a mean result. They remark, however, that the marked reduction of ·003 part of organic carbon and ·044 part of organic nitrogen in the Thames between Staines and Hampton finds no explanation from this series of analyses, and they attribute it to some exceptional cause, such, possibly, as the precipitation of organic matter, which they show may take place when calcareous waters—such as that of the Colne—are mixed with peaty water like that of the Wey. We would, however, observe that the diminution in the quantity of organic nitrogen in the Thames in the five miles below Reading by ordinary oxidation (for there is no influx of any tributary) is ·017 part, while the ·072 part in the Thame water at Dorchester leaves the Thames water at Caversham, after a flow of about 18 miles, at ·032.

192. The fluctuations in the quantity of nitrogenized organic matter, in summer and winter, which their analyses show to take place, are, however, more remarkable, and need further investigation. They are as follows:

——	Filtered Thames Water just below the Weir at Staines.		Filtered Thames Water at Hampton.	
	May 2d.	Oct. 28th.	May 4th.	Oct. 28th.
Organic substances in 100,000 parts of each water:				
Organic nitrogen - - - - - - - -	·027	·097	·024	·057
" carbon - - - - - - - -	·304	·304	·260	·263

Compared to these the slight changes in the quantities of organic nitrogen noted in the Thames water in different parts of its course, from samples taken during the months of April and May, are comparatively insignificant.

193. Although these analyses of the Thames waters will require repetition and extension before the exact value of all the facts can be determined, yet as they relate to the river at one season they may be accepted as relatively correct, and they are sufficient to show at least not only the absence of any increase of objectionable matter in the river from

Lechlade to Hampton, but that the variations in the quality which commence at Lechlade, after showing several temporary changes in many parts of the river's course, fall at Hampton in general to a point as low as at Lechlade, and in one respect, viz., the organic nitrogen, to a point even lower.

It is necessary to remark that the river waters were filtered before analysis, but not the spring waters, which were only left to subside. This must be taken into consideration, as the effect of filtration on organic matter, to which reference is made elsewhere, is of great importance.

194. We cannot conclude this part of our Report without making a few observations on some of the inferences attached to the chemical analyses made for the Commission, as well as on some of the same character accompanying the monthly reports of the Registrar General, as they have been much disputed in the evidence, and as the authority these Reports carry is necessarily great. We refer especially to the interpretation put upon the presence of certain salts as indicating what has been termed "original sewage contamination," and on what are really impurities in water.

It is well known that decomposing organic matter is constantly giving rise to alkaline nitrites and nitrates. Dr. Frankland refers them, not simply to organic matter taken generally, but to sewage or manure matter especially; and the quantity of these salts is made the measure of the estimated "previous sewage contamination" of the different waters, for which a separate column is given. This seems to be an inference which can hardly be accepted. It would be perfectly correct if all the nitrogenized matter supplied to the Thames or other waters was, after conversion into nitrates or nitrites, retained in the water, and if also all these salts could be referred to sewage and manure matter solely. But such is not the case. All the analyses show how variable the quantity of these salts is in different parts of the river's course, and that the quantity present at any place is not so much dependent upon the sewage received as upon the removal which has been effected by vegetation and other causes, by the interference of tributaries, and by the addition from springs; so that, even supposing them to originate solely from animal origin, the residue affords no comparative results as to the amount of original contamination. The interfering causes are too numerous to allow us to assign any value to the remainder. We find it therefore difficult to understand the value of the meaning to be attached to "previous sewage contamination" if by that term it is supposed that we are able to recognize the amount of contamination produced in a river by the addition of the sewage of the towns by which it passes.

If the quantity also of nitrates varied in the inverse ratio of the organic nitrogen some more definite conclusion might be formed; but that is not generally the case. It appears that the sources most free from probable contamination, such as the springs forming the head waters of the Thames, contain in 100,000 parts of water, 3·260 parts of nitrates, whereas the Thames just below Lechlade contains only 1·270, and after experiencing various fluctuations as it flows by Oxford, Reading, and Windsor, still contains at Hampton only 1·640 or only one-half of that in the head springs of the river. The Kennet above Hungerford contains ·830, while just above Reading the quantity is 0. The chalk springs at Amwell give 3·740, while the East London Company's water at London shows 1·077. The water in Croydon well has 5·200, and the Wandle at Mitcham 3·704. The excess in the springs has been referred to manured lands, but this seems offered rather in explanation than as an ascertained fact.

Here the sources most free from possible contamination show the larger skeletons, whilst, after the known large additions of sewage matter made to the Thames at Oxford, Reading, Windsor, Henley, and other places, the proportional quantity of nitrates present in the river at Staines is no greater than at Oxford; so that without an *à priori* knowledge of the facts of the case, the analysis would have failed to indicate them. The Kennet, after flowing through Hungerford and Newbury, would seem by the column of "previous sewage contamination" to be as pure as the waters of Loch Katrine or Bala Lake; the river Lee, to become purer the nearer it comes to London; and the river Wandle, so far from suffering from the addition of the Croydon sewage from the Beddington meadows, would show to more advantage than the water at its source.

Nitrogenous compounds are, in fact, not peculiar to animal substances. They are present in a great number of plants. Their decomposition in either case may give rise to alkaline nitrates, and in the latter lead naturally to their introduction into the surface soil. Nitrites and nitrates are not only the result of the decomposition of sewage and other animal matter, but they are also constantly present in the soil and in springs. M. Boussingault, the distinguished French chemist, in his work on "Chimie Agricole," states that he tested for these salts in soils which were never manured, as in the soil of forests, as well as in soils which were slightly and much manured; that one kilogram of earth from ground never manured, as for example that of the pine forest on the summit of the Liebfrauenberg hills, contained 0·0041 gramme of nitrates, another pine forest gave 0·0014, and the forest of Fontainbleau 0·0020; whilst a vineyard at Liebfrauenberg gave only 0·007, and a hop ground at Sauer 0·0018, both the latter being highly manured lands. Other cultivated lands gave larger quantities,—some very large. Much depends upon the fall of rain. The same able chemist shows also that nitrates are occasionally found in chalk, in some marls, faluns, and in gypsum, while springs equally free from known sources of contamination give very variable results. In lakes he generally found the quantity small. In some wells, on the other hand, he found as much as from half to one gramme per litre.

We cannot help therefore concluding that considerable sewage contamination may take place without indication of its presence by nitrites and nitrates, whilst in other cases these salts may be derived from vegetable matter and from springs which cannot be suspected of having been contaminated with true sewage matter. Their presence in moderate quantity does not indicate with certainty the presence of old sewage matter, nor does their absence prove freedom from such matter. At the same time, where an excess of these salts occurs, as in some wells, they should be regarded with suspicion, and form cause for immediate inquiry; for that they are generated largely by town sewage is indisputable.

Nor can we agree with some eminent authorities in looking at river water in a solely chemical point of view, and speaking of the presence of the 10 to 20 grains of mineral matter in the gallon as *impurities*. So, chemically speaking, they are, but as this seems to be almost a normal condition of river waters, we should not be disposed to consider this term an appropriate one to be applied to substances so constantly present in natural springs and streams.

And further, we cannot but consider it unphilosophical when, in addition to treating as "impurities" substances perfectly harmless even in much larger quantities, the minute quantities present in a gallon, or any other small measure of water, are multiplied by taking masses of water, such as the individual never has to deal with, and given to the public in figures so large as to tend to cause misconception, and perhaps unnecessary alarm in the minds of those not conversant with all the conditions of the case. It would be as just to speak of the small proportion of carbonic acid present in the atmosphere, equally in populous cities and in the Alps, as an impurity, and to startle those unacquainted with the subject by giving in some large figures the total quantity of that gas present in the atmosphere of London.

The question of main and vital importance is not the presence of a moderate quantity of mineral matter, which is of secondary importance, but refers to the presence of organic matter of an objectionable quality. Few waters are free from organic matter, but all organic matter is not objectionable in small quantities.

It is contended, and no doubt with truth, knowing beforehand the probabilities of the case, that although the soft waters of the mountainous districts of England and Wales contain as much organic matter as the Thames water, there is an essential difference in its quality. Still the evidence is by no means conclusive even on this point. Whilst on the one hand there is clearly far less objectionable matter introduced into the former, on the other hand the remarkable power of oxydation possessed by running water, admitted more or less by all chemists, so destroys and removes organic matter that the water regains in a great measure its original purity, either unassisted or else further aided by filtration. It is possible also that the deposition of carbonate of lime, which is known to take place in rivers where the saturation has been in excess of a given quantity, may carry down with it, as it does in Clark's process, a certain quantity of organic matter. The singular fact also noticed by Dr. Frankland and Dr. Odling, of the precipitation of nitrogenous organic matter by the influx of a more peaty water into the Thames is of great interest.

Where a minute quantity only of organic matter escapes destruction, it would seem that chemistry is not yet sufficiently advanced to pronounce authoritatively as to its exact quality and value, and with microscopic living organisms, especially, chemistry is incompetent to deal, and other modes of examination are needed.

Where the organic matter is present in quantities sufficient to diminish the free oxygen in the water, or to tend to putrefactive decomposition, danger is to be apprehended, and considering the nature and scale of the experiment now about to be made with respect to the disposal of the sewage of towns, too much care and watchfulness cannot be exercised in face of the risk which any neglect or oversight might give rise to.

Whatever may be our difference of opinion with respect to some of the conclusions, we cannot place too high a value on the independent analyses of the water supplied to London, published monthly in the comprehensive and important Reports of the Registrar General.

B.—ON THE FUTURE INFLUENCES LIKELY TO AFFECT THE QUALITY OF THE WATER FROM THE BASIN OF THE THAMES.

195. We must look forward to the prospect of a probable increase of the quantity of sewage coming from the towns, and which if allowed to be poured into the river and its tributaries, would no doubt have a serious effect on the quality of the London supply.

The Chemical Commission of 1851 say:—

"The contamination by sewerage, however, cannot fail to become considerable and offensive with the increase of population, and the more efficient and general drainage of towns. And it appears to be only a question of time, when the sense of this violation of the river purity will decide the public mind to the entire abandonment of the Thames as a source of supply, unless indeed artificial means of purification be devised in the meantime and applied."

And again:—

"The removal of the nuisance complained of, however, can never be complete, but only partial. The contamination from navigation and the river population must be increasing rather than otherwise; while gas-works and other indispensable chemical manufactories, which at present pour their refuse products directly into the river, would necessarily continue to do so, as these products are often of a kind not admissible into ordinary sewers."

196. This question, however, has been grappled with by the Rivers Pollution Commission, who in their report on the Thames, March 1866, have treated at considerable length the subject of the purification of the river, not only from house and town sewage, but also from the refuse of manufactories and other pollutions.

In regard to the former they came to a conclusion expressed as follows:—

"That from experiments conducted under the Sewage Commission, and evidence taken on the subject of sewage utilization, and also from our own inspections and investigations, and from the evidence appended to this report, we believe that town and house sewage may be so utilized on land as to preserve the river from the danger of pollution."

They proposed certain changes in the governing body in whom was vested the conservancy of the river, and added the following recommendations:—

"That, after the lapse of a period to be allowed for the alteration of existing arrangements, it be made unlawful for any sewage, unless the same has been passed over land so as to become purified, or for any injurious refuse from paper-mills, tanneries, and other works, to be cast into the Thames between Cricklade and the commencement of the metropolitan sewerage system, and that any person offending in this respect be made liable to penalties to be recovered summarily.

"That it be made incumbent upon the conservators to see to the enforcement of the above prohibitions against pollution of the river, and that for this purpose power be given to them to visit and inspect works, and, after due notice, to close the outlets of sewers, drains, and discharge-pipes into the river within the limits described in the last preceding recommendation.

"That, subject to proper safeguards to prevent abuse, powers be given to local authorities to take land compulsorily for the purpose of sewage irrigation, to an extent not exceeding one acre for every 50 persons whose sewage is to be applied.

"That the conservators be empowered to levy upon all waterworks, taking water for domestic or trade purposes from the River Thames, a rental in proportion to the volume abstracted; the maximum of such rental to be named by Parliament."

197. In consequence of these recommendations an Act was passed in August of the same year (29 & 30 Vict. cap. 89), intituled "An Act for vesting in the Conservators of "the River Thames the Conservancy of the Thames and Isis from Staines, in the county "of Middlesex, to Cricklade, in the county of Wilts, and for other purposes connected "therewith." It altered the constitution of the existing Conservancy Board of the Thames, and considerably enlarged their powers and the extent of their jurisdiction.

The following clauses relate to the improvements affecting the quality of the water of the river:—

"52. The Conservators shall cause the surface of the Thames to be (as far as is reasonably practicable) effectually scavenged, in order to the removal therefrom of substances liable to putrefaction.

"63. From and after the passing of this Act it shall not be lawful for any person to do any of the following things, namely,—

"(1.) To open into the Thames any sewer, drain, pipe, or channel with intent or in order thereby to provide for the flow or passage of sewage, or of any other offensive or injurious matter:

"(2.) To cause or, without lawful excuse, (the proof whereof shall lie on the person accused,) to suffer any sewage or any matter aforesaid to flow or pass into the Thames down or through any sewer, drain, pipe, or channel not at the passing of this Act used for that purpose:

"(3.) To open into any river, stream, cut, dock, canal, or watercourse communicating with the Thames at any point within three miles of the Thames, measured in a direct line therefrom, any sewer, drain, pipe, or channel with intent or in order thereby to provide for the flow or passage of sewage or of any matter aforesaid in such manner that the same will be carried or be likely to be carried by, through, or out of that river, stream, cut, dock, canal, or watercourse into the Thames:

'(4.) To cause or, without lawful excuse, (the proof whereof shall lie on the person accused,) to suffer any sewage or any matter aforesaid to flow or pass into any such river, stream, cut, dock, canal, or watercourse at any point within the distance aforesaid down or through any sewer, drain, pipe, or channel not at the passing of this Act used for that purpose, in such manner that the same will be carried or be likely to be carried by, through, or out of that river, stream, cut, dock, canal, or watercourse into the Thames:

"If any person does any act or thing in contravention of this enactment he shall for every such offence be liable on summary conviction to a penalty not exceeding one hundred pounds, and to a further penalty not exceeding fifty pounds for every day during which the offence is continued after the day on which the first penalty is incurred.

"64. Whenever any sewage or any other offensive or injurious matter is caused or suffered to flow or pass into the Thames, or is caused or suffered to flow or pass into any river, stream, cut, dock, canal, or watercourse communicating with the Thames, at any point within three miles of the Thames, measured in a direct line therefrom, in such manner that the same is carried or is likely to be carried into the Thames, then and in every such case, whether any such sewage or other matter aforesaid had or had not been so caused or suffered to flow or pass before the passing of this Act, the Conservators within a reasonable time after knowledge of the fact shall and they are hereby required to give notice in writing under their common seal to the person or body causing or suffering the same so to flow or pass, to the effect that they require him or them to discontinue the flow or passage thereof as aforesaid within a time to be specified in the notice, not being in any case less than twelve months or more than three years; provided that the Conservators may, if they think fit, at any time and from time to time extend the time specified in the notice by another notice in writing under their common seal; but nothing in this section shall authorize the Conservators, until the expiration of six months after the passing of this Act, to give to the owner or occupier of any mill or work a notice requiring him to discontinue the flow or passage as aforesaid of any liquid matter produced or used in the manufacture of paper or in any process incidental thereto."

"65. Subject to the provisions of this Act, any person to whom any such notice is given by the Conservators shall, notwithstanding anything in any other Act, within the time allowed by the notice, discontinue the flow or passage of the sewage or other offensive or injurious matter to which the notice refers, and if any person fails to do so he shall be guilty of a misdemeanor, and shall be liable, on summary conviction thereof before two or more justices, or on conviction thereof on indictment, to a penalty not exceeding one hundred pounds, and to a further penalty not exceeding fifty pounds for every day during which the offence is continued after the day on which the first penalty is incurred."

In consideration of the improved quality of the water which it was assumed would result from these measures, the five metropolitan water companies drawing water from the river agreed and were bound by clauses 59 to 61 of the Act to pay to the Conservancy Board, each the sum of 1,000*l.* per annum, in addition to certain sums previously agreed to be paid by some of them.

198. We have had before us the chairman, Mr. Thorpe, the secretary, Captain Burstal, and the engineer, Mr. Leach, of the Conservancy Board, and we learn from them that they have served the notices required by the Act, on all the local authorities, from Oxford downwards, to discontinue discharging their sewage into the river.

We are not aware what the result of these notices has been; probably sufficient time has not elapsed to carry out the works necessary, but we presume we may take it for granted that the provisions of the Act will be duly enforced, and that if any difficulties should arise in doing so the subject will receive the attention of the Legislature.

199. Presuming, therefore, the sewage to be used upon the land, it only remains to inquire what amount of benefit may be expected from this measure. It must be borne in mind that the use of liquid sewage for irrigation does not entirely intercept it; for after deducting a certain loss by evaporation and absorption during the irrigation process, the remainder must still flow off into the streams; and hence the question becomes, to what extent will this latter portion be improved in quality over its original state of simple sewage?

200. This question presented itself to the Conservancy Board, and they referred it to three eminent chemists, Drs. Letheby, Frankland, and Odling, desiring them to report— 6851 et seq.

"Whether fluid which has been mixed with sewage can be so purified as to be admissible into the river Thames, and if so, in what manner it may be done; and to fix a standard of purity."

The report given in answer to this question is printed in Captain Burstal's second evidence. The referees examined carefully the application of the sewage irrigation systems in use at Croydon, Rugby, Carlisle, Worthing, Leicester, and Hertford, and give their opinion that if the process is performed under certain conditions, the defæcated fluid is remarkably improved in quality and may be safely discharged into any running stream. Dr. Frankland, however, adds an opinion as follows:—

"P.S.—The conditions under which fluid which has been contaminated with sewage may be admitted into the Thames, as prescribed in the foregoing report, will, I have every reason to believe, preserve the river from being offensive to the inhabitants upon its banks; but, whilst thus far agreeing with my colleagues, I wish it to be distinctly understood that, in my opinion, such fluid can only be safely admissible into the Thames on condition that the water is not afterwards used for domestic purposes. Neither by the processes of purification mentioned above, nor by any others of a practical nature, at present known, can water which has once been contaminated with sewage be, in my opinion, again rendered safe for human use."

The Board referred Dr. Frankland's opinion to the two other chemists, who expressed their dissent from it.

Dr. Letheby says:—

"In reply to your letter of the 5th instant, I have to state that I cannot at all agree with Dr. Frankland that the water of the Thames, after receiving defæcated sewage water, is unfit for domestic use; for after a large practical acquaintance with the subject as it is observed in the principal streams and rivers of England, I have arrived at a very decided conclusion that sewage when it is mixed with about 20 times its volume of running water and has flowed a distance of 10 or 12 miles, is absolutely destroyed; the agents of destruction being infusorial animals, aquatic plants and fish, and chemical oxydation.

"I have stated this in evidence before Parliamentary Committees and Royal Commissions, and I am satisfied that the opinion is well founded."

Dr. Odling says:—

"From many considerations, and especially from the fact that the undefæcated sewage, &c., discharged into the Thames above the source of the present water supply is not recognizable in the water at present supplied, I am decidedly of opinion that the water of the Thames will not be rendered unfit for human use by receiving sewage matter defæcated in the manner described, unless the proportion of such defæcated sewage should become much larger than there is any reason to anticipate."

201. Many able witnesses have given us evidence on this subject.

Mr. Simon says:—

2817. But assuming that the powers given to the Commissioners of the River Thames Conservancy are fully carried out, which amount to an absolute prohibition as to the towns drawing their sewage directly into the Thames, would not that, in your opinion, be an immense advantage in purifying the present supply of London, which is taken now above Teddington lock?—Yes, it would be a very great gain.

2818. Supposing that the prohibition were extended to all sewage going directly into the river at any part of it, and that under the powers which are given to the Thames Conservancy Board, they compelled the towns to distribute their sewage for the purposes of irrigating the land, and consequently that all the water falling on the surface merely came into the river after having passed through the soil, do you think that in that case the Thames water taken above Teddington lock would still be polluted, or should you consider it to be practically free from pollution?—Assuming a sufficient thickness of soil, I should so consider it.

2819. Can you form any opinion at all in that case as to whether the water taken above Teddington lock would still be impure and unwholesome, supposing, for instance, it had travelled exposed to the atmosphere for 15 or 20 miles of river?—I should think it quite a safe water as regards the danger that we are speaking of.

2839. Supposing that those upper towns are driven to deodorize their sewage, or to apply it for irrigation to the land, would the water that must pass off ultimately into the river be sufficiently purified, do you think, so as not to affect the river prejudicially?—A speculative answer is not worth much upon this subject, and I can only give a speculative answer at present. I think it very likely that the water would be harmless, but possibly the result might show that the water could not be deemed quite safe.

Dr. Parkes says:—

3230. Assuming that under the powers of the Act of last session all that sewage will be diverted in the first instance from the Thames and used upon land, would you not consider that the result would be that it would be very much purified beyond what it is at the present moment?—I have no doubt of that at all, but it is impossible to say what the amount of purification would be, because I do not know what the conditions would be of the irrigation of land in proximity to the river, or the amount of water which would pass through the land.

3231. All that would be laid upon the chalk and oolites would be almost entirely absorbed by the land, would it not?—Yes.

3232. But where the sewage is laid upon the clay it would come off more rapidly?—Yes.

3233. Do you think that if that plan were carried out there would be still an impurity in that water sufficient for you to say that it ought not to be used?—I should feel very great difficulty in answering that question.

3234. You seem to say now that from Dr. Frankland's analysis it is what you would call a suspicious water?—I should say so, because there has been certainly organic matter in it derived from sewage, and though that has been oxydized to a considerable extent, still, as showing previous impregnation, and as indicating that there might be a further passage of sewage into the water, and the possibility of a less degree of oxydation at certain times, I should call it a suspicious water.

3235. Then until that purification has taken place which is now in progress, and the water is analysed afterwards, you think that no opinion could be formed upon that point?—I should like to know whether it would be effectual or not in completely diverting the sewage from the Thames, and I should hardly think it possible to form any opinion upon that point.

Dr. Letheby says:—

3891. "I think that none of the sewage discharged into the Thames can at the present moment be discovered at Hampton, but nevertheless it is very possible that there may be a still further improvement of the Thames water by the adoption of these measures. Certainly there will be an improvement in this manner, that if the discharge of the sewage into the Thames were to go on increasing during the next 20 or 30 years, as it has been during the last 20 or 30, we should then probably have such an excess of sewage in the water of the Thames as would render it very unwholesome."

Dr. Frankland gives evidence as follows:—

6376. Supposing the sewage were diverted from the Thames in pursuance of the existing law as carried out by the Thames Conservancy Board, would your objections be removed with regard to the Thames water being suitable for the supply of London?—They would be removed so far as the actual sewage was concerned. I should still object, although in a mitigated degree, to the drainage from cultivated land flowing into the Thames. But in speaking of the diversion of the sewage from such towns as Oxford and Windsor, the mere diversion of that sewage so as to throw it upon land, and then allow it to drain or to make its way into the Thames, would not overcome my objection to the water on the ground of the sewage, because I do not think that sewage which has been merely passed over land, or even through land, can be safely allowed to mix with water that is to be employed for domestic use.

6377. Then your gathering ground for the supply of large towns must necessarily be very limited if that view prevailed, that it should pass over no cultivated land, and that the smallest particle of sewage makes it unsuitable for domestic purposes?—If you have no choice of water, of course it would be much preferable to drink water that was contaminated only from the drainage from manured land, as compared with that which was contaminated directly by sewage. But sewage that has been allowed to flow over land, and which perhaps does not sink into the land at all, would, I should think, be much more objectionable than the water drainage from cultivated land, and which is manured principally from animal as distinguished from human manure.

6378. In the case of the 250 acres of land at Croydon upon which the sewage of that town is spread, the water running off into the Wandle is to the eye perfectly pure; have you ever examined any of that water to ascertain whether there is still held in solution that which is prejudicial to human health?—I have examined that particular water which you have mentioned, and also a number of other similar waters running off land upon which sewage has been placed. Those examinations have been recently made by Dr. Odling and Dr. Letheby and myself for the Board of Conservators of the Thames, and I may say that the substantial result, at least what I myself would say was the substantial result, of those examinations is, that about four-fifths of the sewage matter is destroyed under favourable circumstances, but that is all you can calculate upon. So that if you were to have all the sewage which is at present poured in an unmitigated form into the Thames distributed over the land as it is done at Croydon, you would reduce the amount of contamination of the Thames to one-fifth of what it is at present. In other words, if the population increased to five times its present amount, in the Thames basin the contamination would be as great as it is at the present day, after the sewage had passed over the land.

6396. Assuming that the Act of Parliament which was passed last session for preventing the pollution of the river Thames is efficiently carried out, and that no sewage is directly discharged into the river, and assuming also that those companies adopt proper modes of filtration, would not this specially objectionable case be to a great extent met?—With regard to the muddiness of the water, it would completely, but not with regard to the wholesomeness completely. The unwholesomeness of the water would doubtless be mitigated by otherwise disposing of the sewage, or rather, I should say, by passing the sewage over the land before its admission into the Thames; but I do not think that even after that such a proportion of sewage would be innocuous when admitted into the Thames.

Dr. Odling says:—

6443. But are you of opinion that, supposing the Act of last year were faithfully carried out, and the sewage were intercepted from the river Thames, the water on the whole would be a suitable water for the supply of London for domestic purposes?—Yes, I am.

Sir Benjamin Brodie says:—

6992. Are you prepared to express an opinion on the result of the application of sewage to the land, the water being afterwards discharged into a river, whether it would or would not be injurious to health after its filtration through the soil?—No; I think here again the same obscurity prevails, only to a less extent. I think it is certain that the sewage water must be benefited very materially indeed by being filtered through the land, and I have that opinion because I know that in the porous material of the land the processes of oxydization which destroy the injurious sewage matter go on much more rapidly and efficiently than they do otherwise, and not only that, but that the land operates as a filter and stops, mechanically, a large portion of the solid injurious matter of the sewage; but if you ask me whether the water that runs out from the land, although it may be bright and clear, is a good beverage, I do not know how we are to answer that question except by giving the water to human beings to drink, and by long observation of its effects.

6993. Then, although the process of filtration may catch and retain all that is held in mechanical suspension, still in your judgment there may be elements passing off in solution that might be injurious to health?—I think there may be, certainly, and not only in solution, but even not in solution; I mean by that that there may be even solid matters, organic germs, which would be so small that they would pass through the filtering material employed.

6994. And which might be unobservable to the eye?—Unobservable altogether to the senses, and yet which might be extremely detrimental to the health; but here again you cannot say that they are detrimental to the health, you can only say that they may be so.

7039. What course do you consider the most efficacious one to get rid of sewage contamination from the towns on the river?—The best is not to put the sewage with the river at all, that is the best answer I can give, and, indeed, that is really the only course by which you can be certain that you have not got it in. I certainly do think it a very good thing to employ the processes used for the filtration and destruction of sewage, and they are *pro tanto* beneficial. They really help the matter a good deal, but I do not think that they are entirely effectual. There is no known process that I am aware of for, on a large, scale destroying the injurious qualities of sewage.

7040. By throwing it upon the land you absolutely get rid of a large portion of the sewage, and what is left is somewhat improved?—Very greatly improved, but I should not like to take a glass of water and drink it from just the spot where it went into the river, still less to make it one's daily and habitual beverage.

Dr. Angus Smith says:—

7204. Is it your opinion that after the application of sewage to the land the water filtered off and running into the river would be harmless?—If the land or the filter is not overburdened with sewage, that is to say, if no more is allowed to pass through than can be properly oxydized, then complete purification must take place.

7206. Then, as a rule, are you of opinion that it would be safe to apply sewage to land and allow the water to run off into a river which is the main source of supply to a town for domestic purposes?—It is certainly safe to apply some. I am not able at this moment to say how much. I am not able to say, considering the new plans of irrigation proposed, that it would be proper to load the neighbourhood of a large town with sewage, and collect the water from it and use it for the town. I am inclined to think that it would not be safe; but in a thinly populated agricultural country I think we have no reason to believe that any danger can occur. . . . . . . I therefore conclude that it is a question of quantity, how much sewage can be put upon the land.

Mr. Hawksley says:—

5074. Are you aware that the Thames Conservancy Board are now clothed with power to call upon all the local authorities on the banks of the river, up to and including Oxford, to divert their sewage and other polluting matter from finding its way into the river?—Yes.

5075. Of course the river would be greatly improved if that principle were adopted uniformly up the river?—The river would be very much improved near the towns themselves, but at considerable distances from the towns it would have no effect whatever, because all those matters are exceedingly decomposable in the presence of oxygen and become decomposed entirely by oxydization. There is no such thing as a particle of fæcal matter put into the Thames at Oxford finding its way down to Hampton Court. It is all burnt up in fact by the combustion set up by the oxygen.

Mr. Greaves says:—

5169. Have you seen the report which has just been issued out from the River Pollution Commissioners?—Yes, I have.

5170. They recommend that the same course should be followed in the Lee as had been adopted by Act of Parliament with regard to the Thames, but giving power to a new body to prevent the pollution of the Lee for the future. If that were carried out do you think it would add to the good quality of your water?—I have not the least doubt that it would.

202. During the inquiry our attention had been called to the improvement made in the water of the river Wandle by the sewage irrigation practised at Croydon, and as this example of the process was so accessible, we requested Mr. Pole, when collecting the samples of water from various parts of the Thames basin, to visit these works and to take specimens of the sewage before and after defæcation, and to submit them to Drs. Frankland and Odling for analysis. Mr. Pole's report will be found in Appendix O; he gives a general description of the process, and adds—

When I saw the system at work on the 11th May, although the sewage was foul and dirty when it went on to the land, the water running off was quite bright and clear, without any appearance of foul deposit in the channel. I noticed several fine trout in the river, near the point of discharge, as well as in other places farther down.

It is worthy of remark that the plan here adopted, of allowing the sewage to travel slowly over the land, in constant agitation among the blades and stalks of the vegetation, appears to me peculiarly favourable for the oxydation of the impurities by the action of the atmosphere, which I have no doubt powerfully aids the purifying action by vegetable absorption.

The report of the chemists will be found in Appendices A. X. (1 and 2); it shows that in the diluted condition in which the Croydon sewage is applied to the land, it contains only 11·6 grains more of solid matter (or 43·6 parts in 100,000 parts evaporated to dryness) than the well water of Croydon. In this undecomposed sewage water the ammonia has increased from ·001 to 2·191, and the organic nitrogen from ·007 to 1·156, whilst the nitrogen, as nitrites and nitrates, stands at ·000, whereas the Croydon well water contains ·551. After flowing off the land, the sewage contains only 34·4 parts per 100,000 of total solid residue, the ammonia being reduced to ·002, and the organic nitrogen to ·037, and the nitrogen, as nitrites and nitrates, has increased to ·317. At Mitcham, one mile lower down, the water of the Wandle contains only 31·0 parts of solid residue, or one part less than the Croydon well water, the ammonia has disappeared, the organic nitrogen has decreased to the extent of ·007, and the nitrogen, as nitrites and nitrates, has further increased to ·403. Dr. Frankland considers this amount of purification exceptional, as the quantity of solid impurity in the sewage water, as it flows off the land into the Wandle, would appear to vary according to the rainfall and the season of the year.

According to chemical analysis, the Wandle at Mitcham will contrast fairly with other river waters. The amount of contamination effected by the Croydon sewage, which, however, is weaker than London sewage, almost disappears after the river flow of three furlongs, and a mile lower down all excess of solid impurity has disappeared, the organic nitrogen only being in excess of the quantity existing in the Croydon well water. On the other hand it has to be observed that, notwithstanding the large and constant introduction of town sewage at Beddington, the nitrates and nitrites in the Wandle at Mitcham are present in less quantities than in the Croydon well water, or than in many of the oolitic and chalk spring waters of the Thames basin. The following table gives some of the comparative results obtained by some of the analyses made for the Commission. It shows the condition of the Wandle $1\frac{1}{2}$ mile below the place where it receives the Croydon sewage, as contrasted with the waters of the Thames and the Lee in places free from town sewage. The quantities are given for 100,000 parts of water.

———	River Wandle at Mitcham.	Lee above Hertford.	Thames above Reading.
Total solid residuum	31·0	25·88	32·7
Ammonia	·000	·000	·001
Nitrogen as nitrates	·403	·246	·286
Organic nitrogen	·024	·025	·032
„ carbon	·099	·125	·291
Hardness before boiling	21·1	19·9	21·
Do. do. by Clark's test	14·8	13·9	14·7
Hardness after boiling	9·7	2·1	8·2
Do. do. by Clark's test	6·8	1·5	5·7

WATER FROM THE LEE VALLEY.

203. Our remarks hitherto have been directed principally to the quality of the water from the main stream of the Thames, but they apply also very generally to that from the River Lee.

204. The Rivers Pollution Commission, in their report on the Lee, dated May 1867, point out that the river, above the lowest intake of the water companies, is polluted by the sewage of Luton, Hertford, Ware, Bishop-Stortford, and many other places, as well as by manufacturing refuse of several kinds. In some towns attempts have been made to purify the sewage by different processes before its discharge into the river.

The New River are in the best position as to quality, as they escape the sewage of Hertford, Ware, and all below, and have moreover in their supply a large proportion of pure water received directly from the chalk.

The East London Company's intake is considerably lower, but still their supply is considered wholesome by the Rivers Commission, who report on it as follows:—

"With regard to the quality of the water, the water drawn at Ponder's End is not of course so pure as that taken by the New River Company higher up the stream, because the river in its course over the intervening space has received additional impurities from towns and places, as already detailed under the head of pollution, but this difference is greatly diminished by the fact that between Hertford and Ponder's End the Lee has been reinforced by a large accession of fresh water from the land springs which break out from the chalk into the bed of the river. The result is, as the analyses show, that the East London Waterworks Company are able to obtain a fair wholesome water. The company have gone to great expense to improve the water before it passes to their filter beds, by the construction (under statutory powers) of Catchwater Dyke to intercept sewage of certain towns above the intake, and to deliver it at a point below. In a bill now before Parliament the East London Waterworks Company proposed an extension of this system of intercepting sewers."

The Commission, however, came to the conclusion "that it is expedient that more "stringent measures be adopted to protect from pollution that portion of the metropolitan "water supply which is derived from the river Lee," and they made recommendations with that object.

205. In 1867 the Board of Trade directed an inquiry to be made, through Captain Tyler, into the severe outbreak of cholera which had taken place in 1866 in the east of London, and which had been ascribed principally, if not solely, to the bad quality of water supplied by the East London Waterworks Company. This case has been frequently mentioned in evidence before us, and it appears that by some faulty arrangements at the East London Works the foul waters of the lower part of the river Lee were admitted into the company's reservoirs.

The conclusions arrived at by Captain Tyler are expressed in the following extract from his Report:—

"The disease was, undoubtedly, very fatal during the visitation of last autumn in the metropolis, in the East London Company's field of water supply, and especially in the districts which drew principally from the Old Ford reservoir. There were, on the other hand, other localities, chiefly on high ground and of a better class, such as Stamford Hill, Leytonstone, Wanstead, Woodford, Buckhurst Hill, and Walthamstow, parts of which are supplied exclusively from that reservoir, which were nearly or quite free from it. Silvertown and North Woolwich were exceptions, the former in the early part, the latter throughout the epidemic. All the houses in these latter places are on constant supply from the North London Company; and the disease was very fatal in certain localities near the East London Company's field of supply, where no water that they supplied could have been an exciting cause. The want of better drainage had, no doubt, much to do with the intensity and duration of the epidemic; but the mortality declined from the 1st and still more from the 9th of August; while the Metropolitan Board of Works commenced their pumping operations to divert sewage from the River Lee and the Limehouse Cut into the northern outfall sewer only on the 24th of August. The Lee must have been contaminated at Old Ford at an early period of the epidemic. The covered reservoirs at Old Ford may have received from the river at different times, as they were partially emptied, some of the poison; and the water supply of some of the districts drawn from those reservoirs may thus at different times have been to some extent infected. Considering this possibility of infection, and looking to the effects which were only too apparent in the general field of supply from Old Ford, a case of grave suspicion exists against the water supplied by the East London Company from Old Ford, and that proximity to absolute proof at which I hinted in commencing this subject has thus been nearly reached. But any poison so distributed would have been in a condition, if it were soluble in water, of considerable dilution, and I am not prepared on that account, as well as in consideration of the deplorable state in other respects of their district, to go so far as the memorialists in asserting that this water was 'the principal if not the sole cause of the fearful mortality from cholera.' I believe, however, that if, as is possible, choleraic poison did find its way into the company's mains, it must have passed directly from the River Lee into the closed reservoirs and I have no reason to believe that it was distributed in the water which was so improperly supplied to the district from the open reservoir."

But whatever may have been the connexion of the East London water with this outbreak of disease, it is clear that the evil arose from an accidental circumstance, and therefore affords no argument against the quality of the Lee water when taken under proper conditions, at the upper part of the river.

206. The House of Commons Committee of 1867, who devoted considerable attention to the Lee, state:—

"Your Committee having received scientific evidence of the present quality of the water supplied by the New River Company and the East London Company, are satisfied that, as far as chemical or other science affords the means of judging, the water is not only wholesome, but compares favourably with that supplied to other places."

The Committee noticed the pollution of the river, and after making some suggestions in addition to the conclusions of the Rivers Pollution Commission, they recommended that a bill should be introduced into Parliament to provide remedial measures.

207. This was done, and on the 31st July 1868 there was passed "An Act to make better "provision for the preservation and improvement of the River Lee and its tributaries, "and for other purposes" (31 & 32 Vict. cap. 154).

The provisions of this Act for excluding sewage and other contamination from the river are generally of the same nature as those enacted for the Thames; making, however, a special exception of the town of Luton, which is allowed to use a chemical purifying process instead of applying the sewage to the land.

WATER OF THE KENT COMPANY.

208. The water of this company is about four or five degrees harder than that of the Thames or the Lee, but in other respects it is fully equal to them, if not superior, on account of its smaller quantity of organic matter. Objection has been taken to the large quantity of nitrates and nitrites in this water, but we have already pointed out that this is not an unusual feature in the water of springs far removed from sources of pollution, as in those of the oolite at the head of the Thames valley, and the chalk.

FILTRATION.

209. It is absolutely essential to the good quality of the Thames water that it be effectually filtered. The Chemical Commission remarked in 1851 that the effect of ordinary filtration through sand was very decided on Thames water, as it appeared to be upon chalk waters in general. The river water, they remarked, could thus be easily obtained, under usual circumstances, entirely free from suspended solid matter or mechanical impurities. More modern experience seems to lead to the belief that filtration also acts, though probably in a way less understood, in improving the quality generally. The analyses in Appendix AG, by Messrs. Letheby, Odling, and Abel, which give the comparative qualities of filtered and unfiltered water, clearly show the advantage gained, as will be seen by the following extract:—

General Results.	Thames Companies.		New River.		East London.	
	Unfiltered.	Filtered.	Unfiltered.	Filtered.	Unfiltered.	Filtered.
	Grains.	Grains.	Grains.	Grains.	Grains.	Grains.
Dissolved matter, per gallon	20·825	19·479	22·402	21·550	24·940	24·360
Of which organic and other volatile matter	1·261	0·976	0·702	0·567	0·915	0·300
Suspended matter, per gallon	0·830	0·034	0·241	0·095	0·561	0·047
Of which organic and other volatile matter	0·173	0·005	0·033	0·014	0·045	0·023
Hardness before boiling (degrees)	14·4	13·3	15·5	13·5	14·4	14·0
„ after „ „	5·3	4·6	4·2	4·0	5·0	5·0
Dissolved gases, per gallon (cubic inches)	13·77	13·85	13·95	12·75	12·51	13·75
Dissolved oxygen, „ (grains)	0·796	0·825	0·906	0·906	0·891	0·752
Oxygen required to oxydise organic and other matter (grains)	0·146	0·134	0·115	0·069	0·090	0·095
Ammonia, per gallon (grains)	0·003	0·002	0·001	0·001	0·004	0·003

Mr. Wanklyn's letter, Appendix AK, says,—

"The water of the Thames at Hampton Court, where the companies draw their supply of water, is not very good, as it exists in the river; but after the filtration effected by *some* (but not all) of the companies, it becomes excellent, and in point of purity from organic nitrogenous matter is then fully equal to the water supplied to Manchester, Edinburgh, or Glasgow."

All chemists agree on the importance of filtration.

210. Filtration was made compulsory by the fourth clause of the Metropolis Water Act, which runs as follows:—

"IV. From and after the 31st day of December 1855, every company shall effectually filter all water supplied by them within the metropolis for domestic use before the same shall pass into the pipes for distribution, excepting any water which may be pumped from wells into a covered reservoir or aqueduct without exposure to the atmosphere, and which shall not be afterwards mixed with unfiltered water."

211. All the companies profess to comply with this provision, but the evidence shows that the filtration has been imperfectly carried out. In the Registrar General's annual summary for 1867 occurs this passage:—

"It is much to be regretted that the London waters are not more effectively filtered before distribution. Only on one occasion during the whole year have I obtained a transparent sample of water from the Southwark Company's main. The Grand Junction and Kent Company's waters were turbid four times out of 12, the Chelsea thrice, and the West Middlesex, Lambeth, and East London twice out of the 12 occasions when the samples were drawn for analysis."

In every succeeding monthly report the same complaint has arisen.

212. We call special attention to this neglect to comply with the provisions of the Act. The process of filtration presents no difficulties, all that is wanted being a sufficient area of filtering surface. There seems to be no efficient means of enforcing an observance of this provision of the Act, and the neglect of the companies to comply with it, notwithstanding the repeated attention drawn to the imperfect filtration, shows the necessity for some change in the system of supervision to which the supply of the metropolis is subjected.

GENERAL REMARKS BY THE COMMISSION ON THE QUALITY OF THE WATER FROM THE THAMES BASIN.

213. The evidence before us leads us to the conclusion that the Thames water has many good qualities which render it peculiarly suitable for the supply of the metropolis, and which give it, in some respects, a superiority over the soft waters usually obtained from high gathering grounds. When properly filtered it is clear, bright, colourless, agreeable, and palatable, and the amount and nature of its saline constituents are considered by many to contribute to its general acceptability for drinking. It is well aërated, has good keeping qualities, and is unusually safe as regards action on lead and iron.

On the Organic Impurities.

214. The evidence we have collected on this subject presents great diversities of opinion; but there is one result which, we think, is clearly deducible from the facts before us, namely, that in the present state of chemical science, analysis fails to discover,

in properly filtered Thames water, anything positively deleterious to health. Whatever may be the difference of opinion with respect to the time required for removal of all the objectionable organic matter, all the chemists agree that in Thames water taken from the present source and properly filtered, all such matter has disappeared, and that the resulting compounds, such as nitrates, &c., remaining therein are innocuous and harmless.

Having carefully considered all the information we have been able to collect, we see no evidence to lead us to believe that the water now supplied by the companies is not generally good and wholesome.

215. The only point raised against the Thames water on the ground of organic contamination is of a less positive character; it is said that water which has been once contaminated with sewage may still contain undecomposed organic matter, which, though inappreciable by the most delicate chemical tests, may still exercise prejudicial effects on the human system.

The strongest form of this objection has reference to some opinions now prevalent, that certain forms of disease, such as cholera and typhoid fever, are propagated by germs contained in excremental matter; and it is conceived possible that when matter of this kind once gets into streams, these germs may escape destruction and long preserve their dangerous character. It is said that no process is known by which such noxious material can be removed from water, and therefore it is argued that water which has at any time been contaminated by sewage is thenceforth unsuitable for domestic use.

These opinions have been advanced by many eminent men of science; they are worthy of respectful attention, and ought to operate as a constant stimulus to the most searching examination of the state of the water; to the improvement of the modes and means of scientific analysis; and to the diligent collection of medical data as to the effect of the waters upon the public health. But we cannot admit them as sufficiently well established to form any conclusive argument for abandoning an otherwise unobjectionable source of water supply.

216. We may also expect that the state of the Thames and the Lee will be very much improved by the exclusion from them of all sewage and other offensive matter, in accordance with the provisions of the Acts of 1866 and 1868. And it is worthy of consideration whether these provisions should not be extended higher up the tributary streams, so as to exclude all possible sources of noxious pollution.

217. We are of opinion that, when efficient measures are adopted for excluding the sewage and other pollutions from the Thames and the Lee, and their tributaries, and for ensuring perfect filtration, water taken from the present sources will be perfectly wholesome, and of suitable quality for the supply of the metropolis.

218. The analyses made specially for us of the waters in the various parts of the Thames basin are, we conceive, of great interest and value, and will be very useful as data for comparisons of the state of the river at future times. The result shown by them that the present point of intake is the best that could be chosen in the whole course of the river, is peculiarly important and satisfactory.

PART V.

REMARKS ON VARIOUS POINTS BEARING GENERALLY ON THE SUBJECT OF THE METROPOLITAN WATER SUPPLY.

SECTION I.

ON THE QUANTITY OF WATER LIKELY TO BE HEREAFTER REQUIRED FOR THE SUPPLY OF THE METROPOLIS.

219. The quantity of water that is likely to be hereafter required for the metropolis forms a prominent element in the consideration of any plans of supply, and we propose to devote a few remarks to the elucidation of this subject.

This quantity will obviously depend on two elements—

(*a.*) *The estimated future population, and*
(*b.*) *The quantity to be allowed for each individual.*

(*a.*) AS TO THE ESTIMATED FUTURE POPULATION TO BE PROVIDED FOR.

220. The population of London embraced within the limits of the Registrar General's district (see map Appendix AW.), was given for the middle of the year 1867 at 3,082,372 persons.

The number of persons estimated to have been supplied by the companies in that year, as given in the table in Part III. of our Report, amounts to 3,100,000. The districts supplied have a somewhat wider range than that of the Registrar General, as they extend farther into the suburbs; but on the other hand, it is probable that some portions of the population may not be included within the companies' returns.

221. In reasoning upon the probable number of persons to be hereafter provided for, Mr. Bateman states as follows:—

"Will you give us, in the first place, the population of the metropolis in the year 1861?—According to the population returns for that year the population within the district of the Metropolitan Board of Works was 2,803,034 persons. 3-4.

"What is the present population?—The present population, taking the rate of increase at which the metropolis in recent years has been increasing, is upwards of 3,000,000 by estimate. Dr. Letheby, in December 1866, gives the population at 3,067,000 in round numbers. The rate of population has been as follows: it has trebled since the beginning of this century, it has doubled itself in the last 40 years, and it is now half as large again as it was 20 years ago; therefore, at the same rate of increase, in 20 years, it will be half as large again as it is now, and will amount to 4,500,000 persons. I believe that that will scarcely represent the whole population which may be expected to reside in the immediate neighbourhood of London at that time, because the suburbs of London beyond the area included in the district of the Metropolitan Board of Works are so rapidly increasing that they may be taken as forming a part of the metropolis, and ought to be considered with reference to any supply of water."

He gives further explanations of his views on this point, and adds:—

"In 1856 the supply was at the rate of 28 gallons per head per day, in 1866 it was at the rate of 31 gallons per head per day, and in 1867 it was at the rate of 32 gallons per head per day. If you take 32 gallons per head per day as the consumption, and estimate the population in 1877, nine years from the present time, at 3,650,000 persons, which it would amount to at the rate of 1·73 per cent., you will want 117,000,000 gallons a day. If you take the increase at the rate of 2½ per cent., you will want 127,000,000 gallons a day at that time; and if you take it at 3 per cent., which with all deference I think ought to be what you should take it at, you will want in nine years from the present time 132,500,000 gallons a day. Judging from the experience of all the places that I know, I think that is about the right amount to take, and my own belief is that when you get water which can be supplied by gravitation, when you include everybody as you ought to do upon the principle which I have laid down, and compel them to pay for water, and therefore give them an inducement to take it and use more than they have done, when you have converted every privy into a water-closet, and when you have water of the softness of Welsh water, in which case you would sell as much again for trade purposes as you do now, that is an under-calculation instead of an over-calculation, and my belief is that before nine years are over you will want more than 130,000,000 gallons a day. However, I have assumed 130,000,000 gallons, because that happens to be the scale on which I devised these works when I first laid them before the Commission, and that seems to me to be the quantity which may be required about the time at which they could now be executed." 6583-6.

In about 12 or 13 years from the present time he estimates that 170,000,000 gallons will be required, and ultimately 230,000,000 gallons; but he extends his estimates to the provision of 300,000,000. 6632-54.

Mr. Hawksley, on the other hand, does not agree to the probability of the increase continuing at such a rapid rate. He says:

502. "Of course you must add to the present population, and that is a very difficult question, because it is quite impossible to take it that London should increase at the rate it has recently done; we know indeed by the census tables of this kingdom as well as of others that the rate of increase is declining. In all countries the rate of increase attains a certain maximum and after that it declines. Put it as it was in England at the period of the greatest increase; the increase I think was a little over 2 per cent. per annum throughout the kingdom in general. Then it declines and it will go down to 1¾ per cent. Then in future periods it will be 1½ per cent., and so on till it comes down to a more moderate rate of increase. In England we have had a wonderful stimulus by the inventions which have been made; the introduction of the steam engine and railways in particular, and the enormous development of our manufacturing power, contributed for a certain period to a most rapid increase of the population, but the increase will not, in my opinion, continue at the same rate; nor is the supposition warranted by the statistical facts gathered in England itself and in other countries as well."

The Government Commissioners, Captain Galton, Mr. Simpson, and Mr. Blackwell, who reported in 1857 on the Metropolitan Main Drainage, considered the question of the probable increase of population for which sewage should be provided, and they estimated the prospective population in the metropolitan districts at 3,578,000 as compared with 2,362,000 in 1851. They also added 401,000 for a suburban area beyond the limits, making a total prospective population of nearly 4,000,000 for which the sewage plan should be laid out.

222. With the view of aiding in the elucidation of this subject, we have had prepared, from the Census Returns, the four diagrams marked Appendices AL, Nos. 1, 2, 3, and 4 respectively.

Diagram AL (1) shows the increase of the population of the metropolis from 1801 to 1861, distinguishing the increase from excess of births over deaths, and that due to immigration. Diagram AL (2) shows the manner in which the increase of the metropolis has been distributed among the persons of different occupations in life. It will be seen that the increase due to immigration is very much the larger, being in the 60 years 1,287,200 as compared with 557,920. It appears somewhat doubtful whether this source of increase will go on as fast as heretofore; it has already diminished from 17¾ per cent. in the first 10 years of the period to 8 per cent. in the last 10 years; and if it should decrease further it will prevent the continuance of the increase of the metropolis in its former ratio. The diminished immigration, which probably consisted largely of bread-winning adults, exhibits a check to the increasing means of employment; and this is also borne out by the diminished rate of increase among the industrial classes, which was between 1841 and 1851 nearly 51 per cent., but was little over 11 per cent. between 1851 and 1861. This does not lead us to anticipate an increase in the population of London similar to that of past years.

Diagram AL (3) shows the increase as distributed among the districts of the various water companies, and AL (4) among the various metropolitan districts. This last diagram also gives the population *per square mile* of area in the different districts and parishes. It must be considered, that with the present great accommodation of suburban railways, which will doubtless further extend, the population will be likely to increase principally in the districts lying within a few miles of London, and it will undoubtedly be necessary, as Mr. Bateman suggests, that these districts should be properly provided for as a part of the system of the metropolitan supply. We believe all the companies are alive to this prospect, and have been arranging their plans to meet the wants of these districts as they gradually arise.

223. It is impossible to calculate with any exactness to what extent this increase will go on in any given number of years; but from the whole of the above data we have endeavoured to estimate what increase would be probable, and we are inclined to think that Mr. Bateman's estimate of 4½ millions as the future population to be considered is reasonable, although we should allow more time than he does for this population being attained. In our calculations of quantity, we shall, to be on the safe side, assume an ultimate future population of 5,000,000.

(*b.*) Quantity of Water to be allowed for each Individual.

4058. 224. The quantity of water, per individual, necessary to be supplied in any particular town appears to be very difficult to reduce to any definite rule. It is found that on an average about 10 gallons per head per day are sufficient for ordinary domestic requirements, including waterclosets; but to this have to be added large supplies for street watering, flushing sewers, &c. &c., and for trade purposes and other large consumption, which in the case of London have been estimated at another 10 gallons. Then in addition to these there is considerable waste, often amounting to, or even exceeding, the whole domestic supply.

225. The following is a resumé of the evidence we have received on this point:—

Mr. Bateman states that the quantity varies very much, according to the character of the place and the class of inhabitants; it varies from 15 to 16 gallons a head a day to 50 gallons. Hence each town and city ought to be taken with reference to its own existing circumstances, and what the probabilities are of the supply being greater or stationary.

He takes the present London supply as equal to about 36 gallons per head per day, and 6–20. he thinks that this, or even 40 gallons (looking to the constantly growing consumption App. E. of water), ought to be the least taken in any estimate of supply for the metropolis.

He states that in Glasgow the consumption is 50 gallons, including, however, a very large waste; and that in Manchester the gross quantity supplied is 21 or 22 gallons per head, of which about one-third is for trade purposes; but as baths and waterclosets are very sparingly used there, this does not afford a safe criterion.

Mr. Duncan states that for a large town, where sufficient care is taken to prevent 2365–74. waste, 30 gallons per head per day would be about the right quantity; but he thinks it will go on increasing in future to probably about 45 gallons, which he would take as the measure of a future supply.

Mr. Hawksley says that in his view 25 gallons would be safe; but if this were 2502. extended to 30 gallons he thinks there is no doubt whatever that that would be a superabundant quantity. He considers that 30 gallons per head would be quite a safe calcu- 5088–92. lation for the probable necessity of a population like London—more than enough; including all trades, all waterclosets, stables, incidental causes of consumption, and all household consumption and street watering.

Mr. Simpson estimates that, looking forward to a few years to come, about 30 gallons 4718–21. per head would be a sufficient provision for the population of London, including all public sewers.

Mr. Hassard states that the Dublin Waterworks are estimated to supply 40 gallons 551–62. per head, with provisions for a larger quantity if required. He considers that the estimate 865. for London ought to be 50 gallons.

Mr. Rawlinson is of opinion that half the water now supplied in London is wasted, 1408–11. *i.e.*, is not used for any useful purpose. Allowing for waste, he conceives 30 gallons a head is sufficient.

Mr. Muir, after much investigation, has found that 10 gallons a day are ample for 4058–64. ordinary domestic purposes, and 20, including all other requirements, for such a city as London. The difference between this and 30 gallons, the present consumption, is due entirely to waste. But he adds,—

"I think a great deal more might be done than is done now for the prevention of waste. The companies, and the New River Company I may say especially, have attempted to check waste to some extent for the sake of the consumers, (for the waste of one set of consumers is very injurious to another, who may be upon a higher level,) and they have succeeded in some measure in reducing waste, without in the least degree stinting the proper supply of their tenants."

Mr. Greaves gives an account of some special investigations on this point which lead 5143–54. him to the belief that the whole population of London ought to be very well satisfied with 24 gallons per head. The results are as follows:—

"Can you give the Commission the result of that?—I can give 15 cases of streets. One street averaged 306 gallons per house per day; the number of inhabitants I do not know; I have taken it per house. Those quantities were determined by the insertion of meters on the supply pipe of the street without any particular information or instruction to the people that they were being metered, but merely as a source of information for ourselves.

"What would you take as the average population of each house?—7½ I should think. No. 1 street comes out at 306 gallons per day; No. 2 at 329 gallons; No. 3 at 283 gallons; No. 4 at 132 gallons; No. 5 at 90 gallons; No. 6 at 96 gallons; No. 7 at 148 gallons; No. 8 at 45 gallons; No. 9 at 87 gallons; No. 10 at 194 gallons; No. 11 at 78 gallons; No. 12 at 358 gallons; No. 13 at 146 gallons; No. 14 at 73 gallons; and No. 15 at 37 gallons."

The average of the whole was 160 gallons per house, or 21 gallons per head.

Mr. Beardmore considers that, including waste, which is enormous, the quantity 3326–7. required for London per head, including trade and public supplies, would not be less than 35 gallons per head per day.

Mr. Dale allows 30 gallons per head for all purposes. The supply at Hull is 32 1095–6. gallons.

927-30. 943-5. Dr. Letheby considers 20 gallons per head for all purposes a good and sufficient supply. All beyond is wasted.

226. We have endeavoured to collect data as to the supplies in different towns, and Mr. Bateman and Mr. Simpson have communicated to us the particulars given in the tables printed in Appendix AM. It will be seen, however, that the quantities per head for the total supplies vary enormously in the different cases, from 14½ gallons at Norwich to 53 at Glasgow, showing that every case must be judged by its own circumstances.

We conceive, therefore, that the only way to arrive at an estimate for the metropolis which shall have any pretensions to be relied on, is to reason from the present experience, making such alterations as may seem to be necessary for the future.

227. The quantity of water supplied per head in any town may be estimated in two ways; *i.e.*, by dividing the total quantity either among the whole population, or among that portion of them only who take the water, the latter number of inhabitants being frequently much less than the former. In the following table we have endeavoured to give the quantity according to both these methods:—

QUANTITY of WATER supplied to the Metropolis at different dates.

	1829.	1849.	1856.	1867.
Average daily quantity of water supplied - - -	29,000,000	44,383,129	73,376,860	98,600,248
Number of houses and tenements supplied by the companies	177,000	267,305	319,213	441,442
Estimated number of inhabitants therein - - - (N.B.—Where this item is not given in the returns it is obtained by assuming seven inhabitants to each tenement supplied.)	1,239,000	1,871,135	2,234,491	3,100,000
Daily supply per head to inhabitants taking water from the companies - - - - - - -	23·3	23·6	33	31·8
Total population of the metropolis - - - (N.B.—This has been filled in by proportionate interpolation from the decennial census returns.)	1,572,000	2,280,000	2,583,000	3,082,372
Proportion of whole population supplied with water -	79	82	86	100
Daily supply per head on the whole population - -	18·3	19·4	28·5	32

It will be seen that in 1828 only about 79 per cent. of the inhabitants were supplied by the companies, the remainder procuring their supplies by shallow wells and pumps from the superficial gravel on which London stands. As this source has become worse, by the increasing contamination of the water from underground pollutions, it has been gradually abandoned, and the proportion of persons taking water from the companies has been gradually rising to the present time. It must be remembered, however, that the number of inhabitants in each tenement is merely an estimate, and the districts included extend in some cases beyond the limits of the census returns.

As regards the quantity supplied per head, the table shows that, estimated on the whole population it has increased from about 18 gallons in 1828 to 32 gallons in 1867;—while estimated by the number of persons actually taking water from the companies, it has increased from about 23 to 32 gallons.

228. This is no doubt a considerable increase, but we think it may be accounted for in a way that will not warrant the expectation of its continuance to any considerable extent. During the last 20 or 30 years very great advances have been made in sanitary arrangements; the introduction of waterclosets into houses, the much more frequent use of private baths, and a general advance in domestic cleanliness, have all tended largely to increase the quantity demanded. The companies have met the demand liberally, and all the upper and the middle classes of London may be said to be at present so plentifully supplied with water that further augmentation would be only waste. In regard to the lower classes, there is, no doubt, much sanitary improvement still to be effected, and much more useful application of water still to be promoted; but it is probable

that the improvement will have a tendency rather to check the waste than to increase the supply.

We are not aware that the requirements of trade, or the quantities used for municipal purposes, are likely materially to increase in a larger proportion than the increase of population, so that no variation on this ground need be taken into account.

The only remaining element of change likely to occur would be the introduction of the system of constant service. This would probably not materially affect the quantity of water actually used, but it would have a considerable influence on the quantity supplied, by affecting the amount of waste.

It has been found that where the system could be carried out perfectly, with suitable 2561.
house arrangements and under efficient control, so far from wasting water it has considerably economized it; but considering the great difficulties that must be encountered in making the change under such disadvantages as will be experienced in London, there is reason to fear that, with every precaution, a considerably increased loss of water will at first be suffered. It is impossible to foretell to what extent this loss may go, or how long it will be before it can be subdued; all will depend on the caution with which the change is made, and the efficiency of the control exercised. But it is to be hoped that before many years after the constant service is commenced, the supply may be brought down again to its normal quantity. And it must be recollected that as the population extends, all new supplies, being adapted (as they ought to be even now) for the new system, will be on the most economical plan. And looking forward further still to the time when long experience shall have been gained of the plan, ample time allowed for making all improvements and changes, and a rigid supervision introduced, it would not be too much to expect that a considerable reduction of the present waste may be effected, and the supply be brought down much nearer than at present to the quantity beneficially used.

Estimate of Quantity.

229. If these views are correct, we may give the following as an approximate estimate of the quantity to be provided :—

	Gallons per day.
The present supply is, say, for 3,000,000 of population, at $33\frac{1}{3}$ gallons per head, equal to - - - - - - -	100,000,000
Assume the population to have increased to 4,000,000, and at the same time the additional waste due to the new introduction of the constant service to have increased the supply to 40 gallons per head, equal to -	160,000,000
By the time the population has increased to 5,000,000 we may hope that the allowance may be reduced again to 35 gallons, which would give - - - - - - - - -	175,000,000
Or for the maximum summer consumption, say - - -	200,000,000

which we consider the highest demand that need be reasonably looked forward to for the metropolitan supply.

Section II.

PROVISIONS AND PROSPECTS OF THE VARIOUS COMPANIES FOR THE FUTURE.

230. Having thus arrived at an estimate of the future quantity of water which may be required for the metropolis, we have thought it right to inquire what provisions the various companies have made for increasing their supplies as the increasing demands arise. We had previously addressed, to the five companies now drawing water from the Thames, a letter on this subject, which is printed, with the answers to it, in Appendix L.; to these have been added further information given by the engineers of the various companies at our request; and the following statements will, we believe, express the companies' own estimates of their positions and prospective capabilities.

231. The *New River Company* state that from their present sources, and with their App. BF.
existing works, they can obtain the following quantities of water:—

	Gallons per diem.
Average flow of the Chadwell Spring - - - - - - - -	3,500,000
Quantity which the New River Company are authorized to take at all times from the River Lee, through their gauge at Hertford - - - - -	22,500,000
Additional supply from gathering ground at Cheshunt, &c. - - - -	500,000
Quantity obtainable from six existing deep chalk wells, upwards of - - -	8,000,000
Water collected in ponds at Hampstead and Highgate, and distributed through separate mains for watering roads and other non-domestic purposes - - -	500,000
Total - - -	35,000,000

In addition to this, there is the produce of a new well now in preparation at Wormley, and also the quantity of unfiltered water that might be drawn from the Thames through separate mains for street watering, &c.

The company are further entitled, by the "River Lee Water Act" of 1855, to increase their supply from that river by storing flood waters, and they believe that under these powers a considerable further addition may be obtained, the New River being capable of conveying twice its present flow. But they have not thought it necessary to mature any plan for this purpose.

The *East London Company* have felt the necessity of largely increasing their powers of supply. They have, like the New River Company, power to store flood water in the River Lee, and in 1867 they obtained an Act to make a considerable increase in their present reservoirs; but they have preferred, as a larger and more certain measure, to go also to the Thames, and they obtained, in the same year, an Act (30 & 31 Vict. c. 148), enabling them to draw from this source a quantity of 10,000,000 gallons per day.

The works authorized under this Act are now in course of construction. The water will be taken from the Thames at Sunbury, about a mile and a half above the intake of the other companies at Hampton, and from this point the water will be lifted to a station at Hanworth, where it will be filtered. It will then be pumped through an iron main, 18 miles long and 36 inches diameter, into a service reservoir on high ground at Hornsey Wood Hill, and thence delivered either into the district for use or to replenish the increased storage in the valley of the Lee.

It is expected the works will be finished in 1871, and that they will cost, under the two Acts, about 450,000*l*. The capabilities of this company may then be estimated at about 30,000,000 gallons per day.

The *Chelsea Company* are empowered to draw from the Thames a quantity of 20,000,000 gallons per day; and they state (Appendix L.) they could pump, filter, and store this quantity without materially adding to their present capital. As, however, their present supply is only half this, we presume so great an increase might overtax the safe and efficient capabilities of the works, unless further mains and pumping and filtering power were provided.

The *West Middlesex Company* have also power to take 20,000,000 of gallons from the Thames. The pumping engines there are already calculated to pump 12,000,000, or more, if worked to their full power; but when this quantity is much exceeded duplicate engines would be required. A new main is already under construction from Hampton to Barnes, which, when finished, will with the present one convey the full quantity. The present reservoirs, filters, and distributing engines are equal to about 15,000,000, but land is provided for the necessary extensions. The mains from Hammersmith to the store reservoirs are of the full capacity.

The *Grand Junction Company* have power to take 20,000,000 of gallons. The present works are calculated to deliver 13,000,000, but are laid out so as easily to admit of extension. A large new covered store reservoir, to hold 10,000,000 of gallons, is now being constructed at Camden Hill.

The *Lambeth Company* are empowered to take 20,000,000 of gallons. They are now duplicating their main from the Thames to Brixton, which, with the former one, will safely deliver this quantity; and the additional pumping, filtering, and reservoir power will be added as required. The works have been laid out, and land provided, with a view to a still larger increase.

The *Southwark and Vauxhall Company* have power to take 20,000,000 of gallons. The works already in operation are capable of supplying about 15,000,000 gallons, but the company are now constructing additional engines at Hampton, with large new reservoirs and filter beds, and are laying down a new line of 30-inch main; and when these works are finished, the whole quantity of 20,000,000 gallons may be delivered when required.

The *Kent Company* state that their present wells will supply 14,000,000 of gallons per day, and that with their present machinery they could raise 10,000,000. One of the wells at Charlton is a duplicate, not yet used. They are now sinking another well and erecting new engines at Deptford, where more water is wanted. 6141.

Summary.

232. It appears from the above data that the various companies represent themselves as being prepared, with their present legal powers, and with only moderate additions to their present engineering means, to supply the following quantities of water:

	Gallons per day.
New River - - - - - -	35,000,000
East London - - - - - -	30,000,000
Chelsea - - - - - - -	20,000,000
West Middlesex - - - - - -	20,000,000
Grand Junction - - - - - -	20,000,000
Southwark and Vauxhall - - - - -	20,000,000
Lambeth - - - - - - -	20,000,000
Kent - - - - - - say	15,000,000
Total - - -	180,000,000

Which is very little short of the quantity we have estimated as the highest demand that need be reasonably looked forward to for the metropolis, but which is still far below the limit of the quantity capable of being furnished from the Thames basin.

Section III.

ON THE SYSTEM OF CONSTANT SERVICE AT HIGH PRESSURE.

233. We have explained in Part III. of our Report that in the distribution of water in London, the water is not constantly laid on to the mains serving the houses, but is only supplied to them during an hour or two each day; this is what is called the "intermittent service" system, in contradistinction to that of "constant service," in which the service pipes are always charged under pressure, and the water may be drawn from them at all times by simply turning the taps in the houses.

234. This constant service system is now adopted in many country towns, and it has obviously many advantages over the other plan. It allows the water to be drawn always fresh from the main, free from the pollution often acquired in dirty receptacles (an evil of great magnitude among the poorer classes), and it ensures supplies at all times independent of cistern storage. It is also a great advantage to have the mains always charged in case of fire, without waiting for the intervention of the turncock, as on the intermittent plan.

Independently, however, of the advantages to the consumers, the constant service plan would seem to be so much more simple and easy to work than the intermittent (which requires much complexity of construction, and trouble of management), that one would think the companies would have adopted it for their own sakes, were there not good reasons to the contrary. In the various discussions that have taken place on the metropolitan water supply, the adoption of the system has been strongly urged; but the proposition has been met by statements of the causes which have led to the adoption of the intermittent plan, and of the difficulties that would arise in attempting to introduce the rival one.

235. In order to make the subject clear we may state at once what these difficulties are; and as far as we can learn, they appear to be five in number.

1. In the first place it is alleged that there is great leakage from the fittings in the houses, producing a waste of water which, though it can be met when it lasts only an hour or two a day, yet if allowed to go on for the whole 24 hours would amount to such an enormous quantity that the supply could not be kept up with the present means or at the present cost. This leakage always takes place to some extent even in the better class of houses, by inattention to the state of ball-cocks, watercloset apparatus, &c.; but it is in the poorer districts, where through carelessness and dishonesty it is impossible to keep the fittings in a respectable condition, that the chief difficulties arise.

2. It is also alleged that assuming all the fittings to be in good order, their strength, particularly that of the lead pipe, though suitable for the small pressure of the intermittent supply, would not be sufficient for the greater strain necessarily induced by constant service at high pressure.

3. The habits of domestic establishments lead the inmates to draw their larger supplies of water at one particular time of the day. During the morning hours the consumption is double the average. Now on the intermittent system this variable draught comes upon the store cisterns, and does not interfere with the power of distributing the quantity pumped uniformly over the day; but under the constant system it would come directly on the mains, and the increased draught at a particular time would lead to much inconvenience. For such of the companies as have no store reservoirs, but are obliged to supply entirely by pumping, the increased draught would require a much greater pumping power to be in readiness, a large portion of it, however, being used only for a short time in the day.

4. This greater draught at a particular time, when it occurred at low levels, would further have the effect of reducing the pressure in the mains and services to such an extent as to render them incapable of supplying at the same time the higher parts of the districts. The leakage also would powerfully contribute to this effect, and thus it would become necessary generally to increase the dimensions of the mains and service pipes throughout the entire metropolis. It is a part of the present system, enforced on the companies by Act of Parliament, to supply the better class of houses up to their highest floors; and as many of these houses are of great height, and stand on elevated ground, a great pressure is required for this purpose. Under the intermittent system this can easily be arranged, but under the constant system these high services would be entirely at the mercy of the draught going on at lower levels. And even in the same building no water could be had on an upper story while lower ones were drawing.

5. In case of any repairs or alterations to the mains, or of any accident whatever interrupting the flow in them (instances of which are said to be of almost daily occurrence in some parts of London), the whole district served by those mains must under the constant system be deprived of water, whereas under the intermittent plan the house cisterns keep up the supply. For this reason it is urged that it is advisable to retain the cisterns, even where constant supply is given, whereby one of the advantages alleged in its favour is done away.

236. Before remarking on the weight to be attached to these objections, we may review what has already been done in the matter, and state the evidence given before us thereon.

Nearly a quarter of a century ago it seems to have been established that on public grounds the system of constant service was the right one, for at the time of the passing of the "Waterworks Clauses Consolidation Act" in 1847 (10 Vict. cap. 17) the following provision was introduced:—

"XXXV. The undertakers shall provide and keep in the pipes to be laid down by them a supply of pure and wholesome water, sufficient for the domestic use of all the inhabitants of the town or district within the limits of the Special Act, who, as herein-after provided, shall be entitled to demand a supply, and shall be willing to pay water rate for the same; and such supply shall be constantly laid on at such a pressure as will make the water reach the top story of the highest houses within the said limits, unless it be provided by the Special Act that the water to be supplied by the undertakers need not be constantly laid on under pressure."

This Act was intended to be incorporated into all Waterworks Bills thenceforth introduced, and it became therefore the law of the land that the constant service system should be applied in all new works, unless special reasons could be shown for its inapplicability.

237. The Board of Health, in their report of 1850, strongly urged that the metropolis should be brought under this system, putting on record the following opinions on the point:—

"That the practice of intermittent distribution occasions, in the case of the better description of houses, the retention of the water in cisterns and butts; and in that of the poorest classes, in tubs, pitchers, and such other vessels as can be obtained; and as a consequence of such retention the water imbibes soot and dirt, and absorbs the polluted air of the town, and of the offensively close, crowded, and unhealthy localities and rooms in which the poor reside."

"That the annual cost of the construction and maintenance in repair of cisterns, and their supports and connected apparatus, in the houses of the middle and wealthier classes, often exceeds the annual water rate."

They also add the following remarks:—

Many practical difficulties have been urged against the substitution of the constant for the intermittent system of water supply in the metropolis, we have particularly examined into the working of the constant system in towns where it is established, and in some of which it has been in operation for 15 and 20 years, and we find—

That the waste of water is so far less, instead of greater, under the system of constant supply, that although the inhabitants have unlimited command of water, and use what they please, though the actual use of water by the inhabitants is greater, the quantity delivered by the companies is less, frequently less by one half, in consequence of there being less waste from the more perfect delivery.

That the water under the system of constant supply is delivered purer and fresher, of a lower temperature in summer, and that it is less subject to frost in winter.

That the inconveniences apprehended from the interruption of supply during repairs and alterations are never experienced, the work being executed under such simple precautions that no complaint has ever been known to have been made on this account.

That the interruptions of supply which are so constantly experienced on the intermittent system from the waste in the lower districts, from the neglect of turncocks, from limitation of quantity, from inadequate or leaky butts and cisterns, or from deranged ball-cocks, are scarcely ever known on the constant system.

That the system of constant supply admits of great economy in pipes, as they may, under that system, for the most part, be considerably smaller, and, not being subject to the violent hydraulic jerks of the intermittent system, are less liable to burst.

That the pipes for the house service may not only be considerably smaller and cheaper, but that the cisterns and apparatus connected therewith, which in the smaller class of houses now cost more than the whole public portion of the works, may be entirely dispensed with.

238. The subject was warmly discussed before the Committees on the Waterworks Bills in the Sessions of 1851 and 1852. The Government wished to carry out the constant service system, but were met by arguments urged by the companies against it, and the result was a sort of compromise, by the introduction into the Act of 1852 of a clause compelling the companies to give a constant service to any district when required by four-fifths of the inhabitants, on its being shown that the pipes and fittings in the houses were in a proper condition to receive such supply. The following is the clause:—

"XV. After the expiration of five years from the passing of this Act, every company shall, subject to the provisions of the Special Act relating to such company, provide and keep, in the district mains already laid down or hereafter to be laid by them, a constant supply of pure and wholesome water sufficient for the domestic use of the inhabitants of all houses supplied by such company, at such pressure as will make the water reach the top story of the highest of such houses, but not exceeding the level prescribed by the Special Act of such company: provided that no company shall be bound to provide a constant supply of water to any district main until four-fifths of the owners or occupiers of the houses on such main shall by writing under their hands have required such company to provide such supply, nor even upon such requisition, in case it can be shown by any company objecting to the same that more than one-fifth of the houses on such main are not supplied with pipes, cocks, cisterns, machinery, and arrangements of all kinds for the reception and distribution of water, constructed according to the regulations prescribed by the Special Act or by this Act, or which any company, with the approval of the Board of Trade, may from time to time make in that behalf; and after any such requisition as aforesaid shall have been delivered to the company, it shall be lawful for the surveyor, or any other person acting under the authority of the company, between the hours of nine of the clock in the forenoon and four of the clock in the afternoon, to enter into any house or houses on such district main, in order to ascertain whether the pipes, cocks, cisterns, and machinery of such house and houses are so constructed as aforesaid; and provided also, that any company may, with the consent of the Board of Trade, suspend the giving of such constant supply, or give the same in succession to the several districts of such company or to any parts of such districts as may be found to be convenient; and provided that it shall be lawful for the company, after due notice, to abstain from supplying, or to cut off the communication pipes, and withdraw the supply of water from any house whereof the pipes, cocks, cisterns, machinery, or arrangements as aforesaid shall not be in conformity with such regulations; provided that neither the Kent Waterworks Company nor the Hampstead Waterworks Company shall be required to give such supply at any height exceeding one hundred and eighty feet above Trinity high-water mark, nor the East London Waterworks Company be required to give such supply at any height exceeding forty feet above the level of the pavement nearest the point at which such supply shall be required."

It would appear that the companies convinced Parliament of the validity of the fifth objection we have given, namely, as to the necessity for the retention of the cisterns under the constant service system, for the following provision was added in clause 22:—

"Whenever water shall be constantly laid on under pressure in any district main, every person supplied with water under pressure by any company through such main shall, when required by the company, provide a proper cistern or other receptacle for the water with which he shall be so supplied."

And then follow provisions as to ball-cocks and fittings, and prevention of waste, &c. We believe that cisterns are retained to a considerable extent in Manchester and many other towns where constant service is given.

239. The House of Commons Committee of 1867 devoted particular attention to this subject, and as they took a large mass of evidence, embodying the most recent experience on both sides, it may be useful to present at length the conclusions at which they arrived, as set forth in their report:—

67. The Act of 1852 is so framed that the introduction of any constant supply depends upon its provisions relating to the preparation of plans, and the proceedings consequent thereon, but these provisions have been too difficult of application to be carried into effect in a complete or satisfactory manner. With some trifling exceptions, therefore, the metropolis is now supplied by the water being turned on for a short time in each day, except Sundays, when no supply is given to the larger part of the metropolis. The occupiers are left to obtain and store as much of the supply as they may desire, or as the condition of their houses will admit.

68. The use of cisterns for the purpose of storing water for consumption is probably a more fertile cause of impurity than any pollution of the river from which the water is drawn. Decaying animal or vegetable bodies, or other impure matter, may easily find their way into a cistern, and are more likely to engender disease than any impurity existing in the water before it flows into the cistern. In well-regulated houses the cisterns are of course constantly drawn dry, and properly cared for; but as cleanliness decreases, it is found that the cisterns are allowed to become more foul until the lowest state is reached, when the water is stored in tubs and otherwise, under the most disgusting conditions, which cannot but be injurious to health, and a cause of the diseases which are found to prevail in the worst regulated parts of London. On the other hand, an intermittent supply of water without cisterns not only deprives the inhabitants of the supply they ought to receive, but from the want of adequate storage it is kept in pails and other small receptacles, in rooms and places where it is liable to much contamination.

69. For these and other reasons, which will be found in the Evidence, and in the paper of Dr. Farr, No. 7 in the Appendix, and the report of Captain Tyler, which are full of interest, your Committee have come to the conclusion that the Act of 1852 has failed to secure for the inhabitants the advantage which they ought to have long since enjoyed of a well-regulated supply of water in their houses for domestic purposes; your Committee therefore recommend that the Act should be amended by providing that every company should afford a constant supply of water to each house, so that the water may be drawn direct from the company's pipes at all times during the 24 hours, with the exceptions herein-after mentioned.

70. It is right, however, to observe that this recommendation cannot be carried into effect unless adequate provisions are also made to prevent the waste of water which may arise from its being constantly laid on in every house. To determine how far water may be and is in fact now wasted in the metropolis, much evidence has been given which is deserving of notice.

The Committee go on to investigate this matter, and come to the conclusion that out of 78½ millions of gallons supplied daily, about 17 millions are wasted. They then remark:—

75. From experiments made on several occasions in the metropolis, it has been found that where the supply was suddenly changed from the present intermittent system to a constant supply, without any alteration of the arrangements in the houses, there was an enormous waste of water. The experience derived from changes made from an intermittent to a constant supply in other towns, without suitable arrangements within the houses, leads to the same result.

76. Your Committee have therefore endeavoured to ascertain the precise causes of this waste, and the means by which it may be obviated.

77. With regard to the constant direct supply of water to a tap in the house, it appears that no waste is likely to occur if it be so placed and arranged that waste cannot take place without producing inconvenience, which will be immediately felt by the person permitting the waste, and that there are no real difficulties in fulfilling these conditions.

78. All other modes of supply afford opportunities of waste, which it is not so easy to prevent. The ordinary cistern is so liable to occasion waste, that it has been found requisite in other places to lead the waste-pipe into some exposed position, where any flow from it can be immediately detected. It would no doubt be necessary to make this alteration when a cistern is maintained, but as it would be easy to substitute a direct service, without the intervention of a cistern, except for hot-water services or closets, no difficulty need be apprehended on this account.

79. But with regard to the supply of waterclosets, it has been shown that in consequence of the practice of allowing the water to flow through them uninterruptedly for long periods, instead of merely flushing them, they are a frequent cause of great waste, which cannot be detected; there appears, however, to be no difficulty in guarding against this by making such arrangements for flushing, that the water cannot flow on continuously for an unlimited period.

80. It has indeed been objected by some of the witnesses, that it will be found impracticable to maintain any flushing apparatus in proper order in houses frequented by the most negligent people, and that it would be better in these cases to leave them to draw water and flush with a pail. If this were a question affecting the individuals only, such an arrangement might be tolerated, but the health of the public being greatly concerned in the rapid removal of all matters which may either engender the forms of disease, for the most part infectious, found in ill-regulated habitations, or may tend to spread such disorders when they arise from other causes, your Committee are of opinion that the introduction of a flushing apparatus where no water service now exists ought to be imposed on the owner of every house, without prejudice to his right to recover the cost from the tenant, if the latter be under an obligation to incur the expense.

81. The other special services provided with cisterns will be of a limited character, under conditions where the waste is not likely to be considerable, and it will be sufficiently guarded against by the arrangements recommended.

82. It has also been objected by some of the witnesses that there is no remedy for one of the chief causes of waste in certain localities, which is to be found in the tendency of evil-disposed persons to take away all fittings of brass or copper.

83. Your Committee have, however, been informed that it is not impossible to remove much of this temptation by reducing the present use of copper and brass in such fittings; but as the removal of the fittings undoubtedly causes great waste of water and loss to the companies, as well as great inconvenience and injury to the public, your Committee are of opinion that the unlawful removal of fittings should be made a specific offence, punishable summarily with imprisonment, and that the sale of such fittings, if marked with some certain initial letters, should be placed under the same restrictions as the sale of stores with the mark of the Crown on them, by which the unlawful traffic in such fittings would be repressed.

84. It has been further objected, that if the constant supply were laid on in each house, there would be great danger of the house pipes bursting in frosty weather; but it has been stated in reply, that this cause of danger may be easily obviated by the water being turned off at the stop-cock at night, and the house pipes being emptied by drawing the water off at the lowest tap in the house. This precaution is so simple as to render the objection undeserving of further consideration.

85. It has been urged by the water companies that a constant supply would endanger the pipes which have been laid down by the owners of houses between the house and the pipes of the company, called communication pipes; but as this would depend upon the arrangements which the company might think fit to make to regulate the pressure or height of the head of water supplied, which would involve much interference with the operations of the company, your Committee recommend that all the communication pipes under the

streets and pavements, up to and inclusive of the stop-cock, if any therein, should be vested in the company, and that all future communication pipes up to and including a stop-cock, should be laid down by the company at established rates of charge, at the expense of the owner, and then vested in the company, and that both those now and hereafter laid down should in future be kept in repair by the company; that it should be penal to use the stop-cock contrary to any rule of the company for cutting off the supply of water.

86. The companies would thus be left free to make their own arrangements so long as they deliver a sufficient supply of water for the upper storey of each house within the limits of height which are or may be prescribed.

87. It may be necessary to make an exception to meet the case of rows of houses of small value. It has been suggested by some of the witnesses that, for the sake of economy, these houses may be supplied by a small iron pipe, running through the houses, with a separate branch pipe and tap for each house. Your Committee recommend that in this case the companies should not be required to provide more than one communication pipe, with a stop-cock at the commencement of the through iron pipe; but it being impossible to define beforehand the occasions when this arrangement may be desirable, it should be left to the inspector to decide in each case in the event of disagreement between the owners or occupiers and the company.

88. Considering the improvements that are constantly taking place, both in economy and perfectness of construction in mechanical contrivances, and the difficulty of providing against inconvenience which may arise, your Committee do not think it desirable that any precise mode of effecting a constant house supply, or any particular kind of apparatus, should be enjoined in a statute, but that the companies should be required, in conjunction with the Metropolitan Board of Works, to frame rules, with power to alter them in like manner, for the purpose of prescribing the arrangements within the house to carry out the general principles above noticed, and that any violation of these rules should be penal.

89. To facilitate the application of these rules at the least possible expense and inconvenience to the owners and occupiers of houses, your Committee recommend that the companies should at the request of the owner or occupier provide all the fittings and apparatus required by their rules, and keep them in repair at established rates of charge, in estimating which due regard should be had to the fact that they would have to make a periodical inspection for their own protection at their own expense; and that when the fittings and apparatus are supplied by others, they should be put up in the prescribed manner, to the satisfaction of the water company, and that for this purpose standard patterns should be kept by the companies and by every local authority in the metropolis.

90. The constant supply of water to each house thus recommended will no doubt entail upon the companies a watchful supervision on the internal fittings and apparatus, for which sufficient powers are contained in the Acts above noticed; but as they will be relieved of the trouble and expense of turning on the water, which they now have to do under the intermittent system, your Committee do not consider that the companies have any valid objection or claim to indemnity on this account.

240. We may now give a summary of the evidence we have ourselves received on this point.

Mr. Hawksley says that the question of having a constant high level supply in London

Is a question of the magnitude of the pipes, and that only. The fact, as regards the piping and the constant supply, is this, that at certain periods of the day, generally between 9 o'clock and 11 in the morning, the quantity of water that is delivered is double the average quantity for the whole twenty-four hours, and consequently the main pipes must be made large enough for that purpose. Where the supply is given on the intermittent system the companies spread the delivery just as they think fit over a great number of hours, as much in one hour as in another, but on the system of constant supply they lose the command of the delivery entirely. 2257–63.

2558. What is your opinion with regard to the constant supply as compared with the intermittent system which is now in operation?—The constant supply is much more beneficial than the intermittent supply *per se*, the difficulty is in changing from the one to the other.

2559. Is that difficulty in the mechanical arrangement in the pipes and taps, and so on?—Chiefly so. Of course you must have a different organization from what you have now—in point of fact there is scarcely any organization—and people must submit to the inspection of their premises from time to time, but that need not be unpleasant nor need it be frequent.

2560. Under proper inspection, assuming always that the pipes are equal to the pressure and the taps properly formed for the constant supply, do you think that the health of the public would be promoted by having their supply of water constant instead of holding it in vessels that are unsuited to the purpose?—As regards the poor I have no doubt that it would be so, as regards the middle and upper classes I do not think there is anything in that point, because we all have in our own houses admirable receptacles for water; it is quite immaterial to us.

2561. Even under proper regulations is it not your opinion that there would be a waste of water with the constant as compared with the intermittent system?—No; that I can give the fullest answer to. On the contrary, where the constant supply is well managed the waste of water is less than upon the intermittent system. I can give you a very remarkable instance, one among a considerable number, but it is so remarkable in itself that it is worth mentioning to you. A few years ago the City of Norwich Waterworks were transferred from a very old-fashioned company to a new one, by whom the system of constant supply had been accepted under an Act of Parliament, that is to say, it was imposed upon them. They tried to work it upon the old principle, and the consequence was that in a very short time the delivery amounted to 40 gallons per head per diem, and that amount of consumption exhausted all their pumping power. They could do no more, and the consequence was that they were obliged to shut off the water at night, and the company fell into a state of ruin; all their efforts were insufficient to check the waste, and the work was very nearly being closed. I was called in amongst other persons, and they obtained a very good manager, and under my advice they applied for an additional Act of Parliament to enable them to correct the fittings. With some difficulty—for the bill was opposed, as is almost always the case, for there is great jealousy about internal inspection, and so on—the bill was carried and it was put into operation, and now and for many years past, although the constant supply has been unfailingly in use, the water is never shut off, and the consumption has descended to 15 gallons per head per diem as compared with 40 previously.

5100–5. Mr. Hawksley agrees that the poor ought to have an abundant and constant supply of water, but they ought to be prevented, by proper means, from wasting it. He says,—

A constant supply, with proper regulation and proper supervision, takes less water than an uncontrolled intermittent supply; but then you must have that regulation and supervision, and if the public will not submit to the expense and will not submit to the inspection, nothing can be done for them; but if the Legislature choose to empower the companies to make it compulsory upon the landlords, through some other authority, to put everything in a proper state of repair, and keep things in that proper state of repair, there is no reason at all why the constant supply should not be granted to-morrow. I do not think that there is any company in London that would think of resisting it; but they are all in a state of alarm now, because they know perfectly well that if they were to turn on the constant supply to-morrow, probably three-fourths of the houses in London would receive no water. I should not get any water myself, it would all be draughted off into the lower districts, and run away in waste. But that is not so in the towns where there is a constant supply, and where those powers are conceded and where they are properly acted upon.

2621–2. Mr. Simpson says the constant service would be a very difficult thing to apply, unless the companies have more power; in fact it must become a question of police, or he does not see how it can be applied. He adds,—

There is an immense difficulty in dealing with the supply of the poorer neighbourhoods, and one which I confess they have never been able to surmount. Some years ago I took great pains on behalf of the Chelsea Company, who were taunted with the want of supply to the inhabitants of Westminster, to lay down pipes from the mains and have water constantly on. Immediately that was done the middle men sold all the cisterns and leaden pipes, and in the next year they refused to pay the money. They said that their tenants had not the water and that they had a right to the water, and in the course of seven years the whole of that work was destroyed which cost the company 800*l*.

We have the greatest difficulty with those small properties. It is nobody's interest to preserve the fittings, at least nobody does interfere. It is a part of the pastime of the children to injure them, and the least thing that would fetch a penny they will steal. The stealing of anything in the nature of metal goes on constantly.

4699. There are such difficulties attending it, and I hear of them on all hands, that I think it is not only a large experiment to introduce, but it would require an amount of interference almost greater, I think, than we should carry out in the metropolis.

4699.
4717. He gives a long statement to show the great difficulties which have been found at New York and in Boston, through the waste of water; and further discusses the subject as will be seen in the evidence.

4055.
4065–76. Mr. Muir, being asked whether he sees any practical difficulties in the way of constant supply, says,—

In London there are no doubt great difficulties. In a town to be supplied for the first time I think everyone would admit the desirability of a constant supply, care being taken to have everything in reference to the fittings of the houses of a proper description, and means being taken to have such supervision as would keep everything in order. The difficulty in London will arise from the amount of change required to make *old* premises ready to receive the constant supply. The position of the New River Company has always been this, that if their consumers will only take the supply without waste there would be no objection to give it on the constant system, and the advantages of the constant system would be very great in the houses of the poor. I think that the one disadvantage of the intermittent system is its needing cisterns that are liable to become fouled; and in the houses of the poor it is a most difficult matter to have cisternage so placed as not to acquire some foulness by vitiated air or other contamination. The New River Company have repeatedly offered to furnish the houses of the poor with a constant supply if the landlords of such property would only take water in some way that would insure the company against waste.

Were a constant supply introduced it would be necessary to have very strict supervision indeed, for the purpose of preventing waste, and if that strict supervision could be borne by the inhabitants, and if the requisite power were granted to the companies or to local authorities to control the condition of things in houses, I think that the supply might be brought within more reasonable limits than it reaches to now.

You have been examined upon that point before Mr. Ayrton's committee, have you not?—I have.

Do you advocate the entire abolition of cisterns in the case of a constant supply?—Not at all. I think it would be a very inadvisable thing. I believe the whole question was gone into in the years 1851 and 1852 before Parliament, and the result come to then was that cisterns should in all cases be provided, and it is so arranged in the Metropolis Water Act of 1852. I think in all houses of a better description, where there is a possibility of putting cisterns in proper places, cisterns should still be required, and only in the houses of the very poor should cisterns be dispensed with, and water taken on the constant system through some waste-preventing apparatus.

Although you would retain the cisterns, you would still have a constant pressure upon your mains?—There would still be a constant pressure upon the mains, and a constant pressure upon all mains would be decidedly an advantage, especially for fire purposes. When I speak of mains under a constant system I mean all the companies' pipes, because at present a portion only of the companies' pipes are always charged, and they alone are called "mains" by the companies. Other portions (the branch pipes of the companies) are intermittently charged, and they are called "services." The effect of giving a constant supply to all those pipes would be to enable a direct fire supply by a hydrant to be taken from the "services" as well as from the "mains." But I still say that the difficulty arising out of the enormous expense which would be thrown upon the owners of house property in making houses fit to receive a constant supply would be so great in London, that a general adoption of the constant system here appears to be almost impracticable.

Of what could that expense chiefly consist?—It would chiefly consist in laying down new lead pipes for those at present in use. Many of the lead pipes in London are very old and very feeble, and the least increase of pressure would cause them to give way. The fittings are also of a very imperfect kind. Under the intermittent system those pipes are all saved from the night pressure. The pressure of water at night, when no one is drawing from the mains, is very much greater than the pressure during the day, and as houses are now served, those lead pipes are only subjected to pressure during the day and are saved therefore from the higher pressure of the night. Under the constant system they would come under that higher pressure, and in the great majority of cases they would give way.

If your view is correct that you could reduce the consumption per head from 30 gallons to 20, there would be a saving in that case of water to the water companies of 33 per cent.?—There would.

Would not that saving of 33 per cent. in the quantity of water that they supply enable the water companies to bear such an expense as would be involved in the alteration of the services to the houses?—I think not.

Would the system of constant supply entail a large expense upon the water companies?—To a certain extent. The New River Company has already incurred a very large expenditure in preparations for the constant supply. It was arranged by the Metropolis Water Act of 1852, that the companies should prepare themselves after an interval to give a constant supply, and that if four-fifths of the inhabitants on any district main should come to a company asking for a constant supply, and put themselves in order to receive it, the company should be bound to give it. Under those Acts of 1852, 1854, and 1857, which I mentioned, the New River Company laid out something like 800,000*l.* in the general improvement of their supply, providing filtering beds, laying down large new leading mains, and constructing high service covered reservoirs, all of which were in preparation for this improved constant supply. As yet no applications have been made for a constant supply, and a constant supply therefore has not as a general rule been given, though there are exceptional cases in the New River district where the supply is constantly on.

What do you understand by the householder putting himself in a position to receive the constant supply?—The lead pipes must be made of sufficient strength by him, that is, for his own sake. He must take the water for the watercloset use out of a service cistern with a double valve, so that there shall not be waste in the watercloset (one valve always being shut while the other is open). While the water is being drawn into the closet the water is prevented from coming from the main into the cistern, and so waste is effectually prevented. He would require to have all his ball-cocks and taps of the best description, and one thing which has been found almost always necessary in every house in which a constant supply has been given is to forbid overflow of waste-pipes from cisterns, so that consumers shall have a very good reason for taking care that ball-cocks are always in perfect working order.

What do you calculate the average to be per house for making those necessary alterations?—I have calculated that on the average, to do the thing properly, it would take something like 8*l.* per house all over London in order to put the houses in proper condition for receiving the constant supply.

That 8*l.* would lie between two extremes; what would it be for a small house, and what for a large one?—I think for a small house it might take 4*l.* or 5*l.*, and in larger houses a very great deal more.

Would you say 12*l.* or 14*l.*?—Yes. Where the pipes are built into the walls and have to be cut out and the decorations made good, the expense might be 20*l.* and upwards. In some cases it has been said and often felt, I believe, that the companies obstinately stand in the way of a constant supply. I do not think that at all to be the fact. If a constant supply could only be carried out here in London as it is said to have been carried out in some other places, with a great reduction in the quantity of water consumed, the companies should hail it; it would be a great matter to them to be able to dispense with the services of many turncocks, and save water at the same time.

Mr. Greaves says:— 5156–66.

I myself am rather an advocate for a constant supply on the whole. Of course claiming to have the privilege of putting a reduced orifice somewhere on the pipe so as to prevent inordinate waste, I find no difficulty in giving a constant supply in my district. I have now 25,000 houses out of 92,000 who are continuously from year's end to year's end on the constant supply system.

Will you explain what you mean by a reduced orifice?—Somewhere in the pipe between the pipe which belongs to the company and the cistern which belongs to the consumer, a disc with a small hole in it is inserted so as to prevent the water being drawn beyond a certain speed. That limits the draught of the system, and it saves us from inordinate loss which we know we should suffer, because notwithstanding that we have 25,000 tenants supplied in this way we cannot leave them unguarded, we are obliged to visit and inspect continuously over and over again.

That limits the size of the supply pipe to the cistern?—Yes.

What class of houses do you supply in this way?—We supply without distinction now.

But does that include any of the poorer class of houses?—Yes; in fact seven-eighths, perhaps nine-tenths, of all the houses that we are laying on now we are laying on upon the constant system.

And all upon that principle?—Yes, all upon that principle.

With regard to the poor people your experience would be, I presume, that it is of vital consequence to them to have a good supply of water?—Yes, it is. I advocate giving a complete and good supply to the poor on every possible ground, moral, social, and physical, with reference to the ordinary comforts of life. I think the absence of a proper supply of water to the poor is one of the grievances of the day.

When you do adopt that system and apply a contracted disc for the water to pass through you have of course to assume that you will allow them to have a certain supply in 24 hours?—Yes, certainly.

What do you assume in that case?—I assume, say 180 gallons in 24 hours per house, that is the maximum, that is to say, if they have no ball-cock nor any check upon it and they were to rob me to the utmost they could only take to the extent of 180 gallons a day. A pint a minute is 180 gallons a day.

Have you found that the constant supply to the poorer class of houses has led to any greater waste of water than under the intermittent supply?—I do not think it has.

He also describes some contrivances introduced by him to prevent waste. 5202–5.

Mr. Beardmore considers that under any system cisterns must be used. He says:— 3347 *et seq.*

I do not see any possibility of dealing with the general humanity, as you may say, without them. If you have such waste as you have in the low districts in London no pipes can furnish water constantly and with high pressure. You cannot deal with it. If you have a fraudulent or a careless man in one house he is wasting water away, and of course he is diminishing the head to the person next door, that is the difficulty you have got—to protect everybody and to give an equal pressure. At this moment I have the general advising and management of a small board of health town near London, and we profess to give a constant service, but it is perpetually breaking down; one wrongdoer opens a cock, and there is the whole thing at an end, and we have perpetual difficulties, and now I am dividing the services. At Enfield, I have reduced the pressure from 170 feet for the low district to about 35, and the landlords of the houses have already thanked us for doing it. The expense of keeping up the fittings was so great that they liked the low pressure better.

He instances the rigid supervision necessary in towns where constant supply is given, and thinks it would be impracticable in London.

Being asked whether the health of the inhabitants would be promoted by the constant supply system, he says:—

I cannot say that, because I think the real evil is the iniquitous state of the poorer class of houses. They have no sort of cistern at all, and if you made it absolutely requisite to have a very moderate amount of cistern, and proper arrangements for taking in the water, and could keep the people from stealing the apparatus, you will be as well supplied by the present system as by the constant system. At present, in the low parts of London, in the east of London, you cannot keep a tap on a pipe at all; everything goes.

He adds further remarks on the subject.

5587–686. Mr. McClean has adopted the constant service system extensively in waterworks in Staffordshire, and believes it is the proper system. He has found no difficulties in applying it.

3813–18. Dr. Letheby says:—

As an abstract question, there can be no doubt that the constant supply is a very advantageous thing to the public, chiefly because they would get their water cooler, more grateful, less liable to the pollution to which it is now subject after it is delivered by the water companies, and, if the question really turned upon poor people's houses, I should say that the constant supply to them, whether it be in a court by a standpipe, or whether it be in their own yards by a standpipe, would be a boon, the good of which is hardly to be calculated.

2720–25. Dr. Lyon Playfair expresses his opinion of the advantage of constant supply, which he says

Delivers the water always cool and in good condition; it obviates the necessity for a number of cisterns in badly ventilated houses, and especially in the houses of the working classes, and so prevents a great source of the danger of epidemics which arise from the solution of the polluted atmosphere in the water.

3162–8. Dr. Parkes prefers the system of constant supply as doing away with the evils of house storage. He says,—

"There are great sanitary advantages in a constant supply, namely, in doing away entirely with the house storage. The house storage entails a great chance of the water being impure, either from the cisterns being allowed to get filthy or from substances finding their way in from the overflow pipes communicating with sewers and drains, and gases forcing their way back through imperfect traps. All these evils the constant supply entirely does away with, but the disadvantages of the constant supply are certainly the very great quantity of water that is wasted, and the occasional failure at times when it is very important indeed to have a large supply of water. For example, last year, in Southampton, in the time of the cholera, when it was extremely important to have the drains well flushed, and everything carried out, we had rather a failure in the supply of water in the low parts of the town. The population in the higher part of the town being nearer the reservoir used a very large quantity of water owing to the dryness of the season, also their gardens required a large quantity of water, and this was taken from their constant supply. At the same time there happened to be also some alterations going on in the pipes and in the machinery, which also lessened the quantity. The consequence was that we were unable in the low parts of the town for several days during the prevalence of the cholera to ensure a proper quantity of water passing through to the sewers."

"Assuming that you have an ample supply for the whole population of a town, are you of opinion that the system of constant supply for all sanitary purposes is infinitely superior to that of an intermittent supply?—Quite so, if you can get over the practical difficulties and the enormous waste, but I think that if you have the constant supply it must be understood that there is to be no stint in the water in any part of the district at any time as there appears to be in some towns which are supplied with the constant service."

2771 *et seq.* Dr. Simon considers the system of intermittent supply to be a very bad one, for reasons he gives at considerable length.

"Do you consider the system of intermittent water supply to be a good or bad one?—A very bad one.

"What is the reason which induces you to consider it a bad one?—My opinions about it are substantially those which I expressed in 1849 and 1850, in the following passages of my reports then made. From report of 1849:—'I consider the system of intermittent water supply to be radically bad, not only because it is a system of stint in what ought to be lavishly bestowed, but also because of the necessity which it creates that large and extensive receptacles should be provided, and because of the liability to contamination incurred by water which has to be retained often during a considerable period. In inspecting the courts and alleys of the city, one constantly sees butts for the reception of water, either public or in open yards of the houses, or sometimes in their cellars, and these butts, dirty, mouldering, and coverless, receiving soot and all other impurities from the air, absorbing stench from the adjacent cesspool, inviting filth from insects, vermin, sparrows, cats, and children, their contents often augmented through a rainwater pipe by the washings of the roof, and every hour becoming fustier and more offensive. Nothing can be less like what water should be than the fluid obtained under such circumstances, and one hardly knows whether this arrangement can be considered preferable to the precarious chance of scuffling or dawdling at a standcock. It may be doubted, too, whether even in a far better class of houses the tenants' water supply can be pronounced good. The cisternage is better, and all arrangements connected with it are generally such as to protect it from the grosser impurities which defile the waterbutts of the poor, but the long retention of water in leaden cisterns impairs its fitness for drinking and the quantity which any modern cistern will contain is very generally insufficient for the legitimate requirements of the house during the intervals of supply. Everyone who is personally familiar with the working of this system of intermittent supply can testify to its inconvenience, and though its evils press with immeasurably greater severity on the poor than on the rich, yet the latter are by no means without experience on the subject.'"

He goes on to explain the large waste which takes place on the intermittent system, and which, he conceives, reduces the average available supply for domestic purposes within the city to only a quarter of its alleged quantity.

Mr. Holmes, the borough surveyor of Sheffield, says he does not see any advantage in substituting the constant for the intermittent supply except in case of fire; there must be a great waste in the former, going on by night as well as by day. He adds, however, that with pipes capable of withstanding the pressure, he would prefer a constant supply. 4884.

Mr. Dale is arranging a constant supply to Hull. He has found no inconvenience; on the contrary, the leakage is less when the constant supply is given. The inhabitants prefer the constant supply. He says in reply to the question— 1107-19.

"Have you experienced any inconvenience arising from the constant supply?—None at all; far from it; there is far less leakage I should say, and I have tested it in fact. I should say that on the eastern portion of the town there is a saving of 25 per cent., or say 20 per cent. to be on the safe side, in the leakage, compared to what there is on the other side of the town."

He explains how he tested the quantities supplied to each side of the town, and further adds—

"Have you had any complaint from the inhabitants with regard to the change of system?—The inhabitants are continually crying out for a constant supply, they prefer it to intermittent."

Mr. Quick gives evidence as follows in regard to constant service:—

"I think that in the poorer districts it might be an advantage, but I think that practically the better class houses have the best constant supply that they can have by having a good cistern in their houses, by means of which, in the event of any interruption from the breaking of a main, or a conflagration in the neighbourhood, or anything of that kind, they have a supply of water which will last them two or three days in there own cisterns; whereas if they merely depended upon a pipe passing into the house, the moment that there was any interruption to the flow in the main they would be deprived of that accommodation. 6014-92.

Then are we to infer that you are not in favour of the constant supply system?—I think that it has its evils. Perhaps in a poorer neighbourhood it might be an advantage, but I think where cisterns are properly taken care of and cleansed, and so on, that is the best constant supply that anyone can have. In fact, I do not know how the constant supply system is to be arranged in a house, where the kitchen boilers, for instance, require constant filling; and with regard to waterclosets, again, it would be an exceedingly inconvenient thing to have water absent from the house probably for 24 hours in the case of an accident to a main, or anything of that kind.

Are the accidents to the mains of which you speak frequent?—The large valves want repairing occasionally, and the mains will break now and then, and alterations are necessary, such as putting on new branches to a main, and when the main has to be cut out and a connexion made to it to go down a side street during the whole of that time, which may occupy several hours, if there were no storage the people would be deprived of water.

Mr. Quick gives a statement of 4,300 different works done in the Southwark and Vauxhall Company's district during the year 1866, in each of which cases it was found necessary to keep the stopcock on the main or service pipe shut for periods varying from one to twenty-four hours.

Being asked whether the expense of keeping the pipes and fittings in repair would prevent the system being carried out, he says—

We find great difficulty in getting the owners of small property to lay out a single sixpence for benefiting their tenants in any way, and I am quite sure that any representation that the companies could make would never induce them to do it unless there were some legislative power to compel them.

Has your attention been directed to the principle of a constant supply in regard to its effect upon the public health?—I think, as I have stated before, that in the poorer districts there would be a great advantage from the constant supply, but in the better class of property I cannot conceive that there would be any advantage at all in respect of health.

A constant supply would have its advantages for the purposes of fire, would it not?—I think there is a great question whether it would or not.

I mean under proper pressure?—That is the difficulty. If there are so many thousands of taps in connexion with the mains, there will be always a certain amount of draught passing into the district which will lower the pressure. At the present time the whole of the trunk mains or principal mains of the district are kept under the full pressure all night, and in case of fire they have only to open one of the side cocks and direct the water to the particular place where the fire may be burning, and all the pressure can be directed by merely opening these one or two cocks, whichever it may be.

But I wish you to direct your attention not to such a pressure as that the fires might be extinguished from the hydrants by application of the hose, but to such a pressure as would keep the pipes charged and the supply sufficiently full to be pumped by means of a separate fire engine.—That can always done by the mere opening of one of the side cocks leading from the trunk main.

The difficulty now is to find water, is it not, in case of a fire?—The water is always in the main.

A recent case occurred where water was not to be obtained in any quantity for useful purposes for more than 20 minutes after the fire, and the destruction was pretty well completed, how do you account for that?—I think that that arises principally from a want of understanding between the brigade and the water companies.

Being asked what it would cost to put the fittings into proper order to receive the constant supply, as required by the Act of 1852, he says:

It depends upon the class of house, in some cases it might cost 2*l.* or 3*l.*, and in others 10*l.* or 15*l.* per house.

In the present system of supply is it not one of the great objections to the cistern system that those cisterns are not kept clean by the owners of the houses themselves?—That is so.

And if they got the water direct from the pipes, they would get it, would they not, in a purer condition?—There is no doubt of that.

Your view perhaps would be that it would be a necessary thing to have a combination of cisterns and a supply direct from the pipes in the same house?—Yes.

Up to the present time the practical effect of the clauses in that Act of Parliament has been, has it not, that no company has been called upon by the inhabitants to give them a constant supply?—That is so.

Do you think that the water companies themselves would object to it if they were called upon by the inhabitants, and if the inhabitants were to do their part of the duty?—I do not think they would. Of course the water companies would have to lay out a very large sum of money to enable them to do it, and I had perhaps better explain why that would be so. It is on account of the undulations in the districts. In the Grand Junction district there is some portion of it but little above the level of the Thames, whereas other portions are nearly 200 feet above the level of the Thames, and it is constantly rising and falling; and of course if the water is allowed to run to waste in any way in the lower portions of the district, unless there is a division of the trunk mains the high portions would never get any water at all.

Still there would not be an objection on the part of the companies to that outlay?—I think not, if proper provisions were made.

And it would necessarily be attended with much greater stringency of supervision on the part of the water companies?—Yes.

Do not you think that the result would be great economy in the consumption of water per head?—There might be an economy in the quantity of water pumped, but the difference of cost to the companies would not be any very great deal. You would not reduce the expense of management, or labour, or anything of that kind; it would be the mere expense of pumping.

Still there would be economy in the actual consumption per head?—Yes; there is no doubt there would be less water used, supposing that all the fittings were put in a proper state to prevent waste.

Mr. Morris's evidence is as follows:—

6155–60. But you think that a constant supply would be a very good thing?—I do, if we could once prevent waste, or if we had power given to us to prevent it, or any mode were devised by which we could get rid of the enormous waste which is attendant upon a constant supply as carried out under the present system, we have no objection.

When you say if you could get power given you to do so, have you ever considered what powers would be satisfactory for preventing waste?—I think that the power which would be required must be vested in what we may call a water police; there should be a constant inspection, which I know that the public would not bear, but unless we had power to exert that, it is perfectly out of the question. I have made some experiments, and I know that people have wasted as much as 2,000 gallons a day per house for a twelvemonth together.

Having regard to a properly arranged system of supply, pipes of sufficient strength to resist the pressure, and an efficient supervision, you are of opinion in the first place that a constant supply would produce a great saving of water, and in the second place promote the health of the inhabitants?—I will confine myself to the saving of water. I have no doubt there would be a great saving of water, but the restrictions must be very stringent, otherwise it would completely absorb the whole of our power of supplying; you might pour water upon the sea beach with as little effect.

You think it necessary, if I understand you aright, to have some very stringent police regulations?—I do not say police, but something of that nature, persons armed with authority who could go into the houses and prevent waste.

6269. Dr. Frankland says:—

"With regard to the deterioration of the water by storage in cisterns and in tanks, I think that too strong an opinion can scarcely be expressed. In my own house, when I first went to it, I found that the waste pipe from the cistern which was to supply us with water was not furnished with a trap at all, but that there was free communication between the sewer and the interior of my house through this pipe, and sewer gases were brought just upon the surface of the water in the cistern, and I believe that is the condition of most of the houses around me at Haverstock Hill."

6589–6604. Mr. Bateman has given us a paper he wrote on this subject a short time ago, and which, as it is well worthy of attention, we have reprinted in Appendix I. He advocates the constant service system, but it will be seen that he is by no means insensible to the great difficulties that would be met with in making the change in London. He adds, in his evidence, remarks as follows:—

"I may state that my own opinion is that a constant water supply under high pressure in the existing state of the plumbing in London would be almost impossible, and that it is necessary that very stringent powers be given to the companies or to a corporation, if it had the administration of the water, to compel all the parties to put their water fittings into perfect order before the constant supply was given. Even the Welsh district would be almost insufficient to supply London under the constant system, as the fittings are now; but if proper care be taken that the fittings be all properly put in order, and a very strict supervision exercised, I find as a matter of experience that towns supplied under the constant system do not take more water than those which are supplied under the intermittent system. The consumption of water in Glasgow is 50 gallons per head per diem, where water fittings are as bad as they can be, as bad as they are in London (and that is about saying the worst thing for them), and the waste is very great indeed; I forewarned them against this, and for a time very active supervision reduced the waste after the introduction of the Loch Katrine water; but they consider that they have an inexhaustible supply and that it tends to sweeten the Clyde and flush out the sewers, and they allow the waste to go on, but all that might be corrected."

He further adds particulars as to the advantage of constant supply in cases of fire, as illustrated in Manchester. He says:—

'The per-centage of property destroyed from 1846 to 1850, before the introduction of the water, was 21·3 per cent. of the value of property attacked by fire. The amount saved out of such property was 78·6 per cent. From 1851 to 1855, Manchester, for half the time at least, not having advantage of high pressure, and for the latter two years of the time having it, and therefore it would be partly under the old system and partly under the new, the per-centage of property destroyed was 12·9 per cent., and of that saved 87 per cent. Then came the advantage of the constant supply and high pressure, with a full water supply, and from 1856 to 1860 the per-centage destroyed was only 7·7 per cent., being only one-third the amount which was destroyed before the introduction of the fresh water supply, and the amount saved was 92·2 per cent. From 1861 to 1865 the amount of property destroyed was 6·7 per cent., and the amount saved was 93·2 per cent."

He believes that the expense of alterations in the houses, to receive the constant service, has been much overrated as regards the better class of dwellings.

Mr. Rendle, a medical gentleman who has been very active in promoting sanitary improvements in Southwark, gives examples of the defects in the London supply, for which he believes constant service is the only remedy. 6749 *et seq.*

Mr. Heron, town clerk of Manchester, states that no difficulties of importance have been found in introducing the constant service into that city, and that in the small houses cisterns are dispensed with. There are, however, no waterclosets in the small houses. The arrangements for extinguishing fires are very complete and efficient. Cisterns are useful in cases of stoppage of the supply in the main, though such accidents seldom occur. 7330–41. 7349–53. 7367–70.

His impression is in favour of the economy of the constant supply, but the regulations to prevent waste must be very stringent. He says:— 7386–90.

"We have most ample powers with reference to fittings, and also for the purpose of inspection.

"7388. Would not a similar power be a matter of absolute necessity in the case of London being put upon the constant supply system?—I should think it absolutely necessary in any case. I think it is quite right that whoever is supplying water, whether it is a corporation or a company, should have ample power to see that the water is not being improperly wasted.

"7389. Do you find any complaints from owners of property of such supervision being at all inquisitorial? —Not at all; I never heard a complaint of the kind, and we have found it to be most necessary."

He gives, in answer to question 7390, a list of the regulations provided by Acts of Parliament for this purpose.

Remarks by the Commission.

241. We are of opinion that the mode of distribution is a most important point, particularly as bearing on the health and comfort of the poorer classes; and we agree with the conclusions arrived at on previous public inquiries, that earnest and prompt efforts ought to be made to introduce the constant service system to the farthest extent possible, in the supply of the metropolis.

242. The provisions of the Act of 1852 in this respect appear to have been ineffectual, and we are not unimpressed with the difficulties of the case, which we fear would be beyond the power of being successfully dealt with by the present companies. The legal powers they now possess would not be sufficient to enable them to control the house arrangements, or to check the enormous waste that would arise on the introduction of the new system. And we do not see our way to recommending that they should be invested with new powers which, if they are to be effectual, must be of too inquisitorial a character to allow of their exercise in private hands.

We cannot adopt the suggestions of the House of Commons' Committee of 1867 as to how the details of the arrangements should be carried out, believing that such technical details can only properly be dealt with by competent professional skill, and that they must be carefully determined under the guidance of the experience gained in the process of change. The same Committee recommend, among other things, that the companies should combine with a metropolitan public body to frame rules for controlling the house arrangements, any violation of such rules being penal; but we believe it would be difficult for any such complex arrangement to be made to work satisfactorily.

243. After mature consideration of this important question, we have come to the conclusion that the constant service system cannot be effectually carried out in London so long as the supply remains in the hands of private companies, and we have explained, in Section IV. of this part of our Report, in what manner we conceive the change may be effected.

In any case, however, such a change must be introduced very gradually, and with the greatest precautions, particularly in the poorer and lower districts; and even with all possible care preparations must be made for meeting considerable loss of water in the earlier periods of the alteration.

COMPULSORY SUPPLY TO THE POOR.

244. Connected intimately with this subject is that of furnishing a compulsory supply to the poorer districts.

It has been established by law that the supply of water, being a necessary of life, must not be left optional; for though every arrangement may be made for affording a proper supply wherever it is demanded, experience has shown that it is necessary in many cases to enforce its reception.

We have reason to believe that the companies honestly do their best to supply the poor, and are inclined to be liberal in their arrangements for this purpose; but they complain of the great difficulties they have to encounter.

The Committee of 1867, after reciting the legislative provisions applicable to this purpose, say:—

"These various provisions of the law would seem to be ample for the purpose of ensuring a due supply of water for all purposes for the inhabitants of the metropolis in every house, but your Committee regret to state that they have hitherto failed to effect this desirable object, more especially in the cases where a proper supply of water is most essential."

They recommend an improved system of inspection, under the auspices of a metropolitan public body, and certain alterations in the manner of levying the rates; but we are of opinion that in this case also, the same complete change is called for as in the case of the constant supply.

Section IV.

GENERAL CONTROL OF THE WATER SUPPLY.

245. In a matter of such vital importance to the health of a large population, we consider that it becomes a serious question in what hands the control of the water supply should be placed.

246. The duty of supplying the inhabitants of a city with water has from a very early period been regarded as a peculiarly municipal function; and the supercession of the municipalities by joint-stock companies is a comparatively modern innovation, assuming the New River Company to be the earliest case in point.

Since this case the private companies have very generally exercised the functions in question; but of late years many towns in England have come to the conclusion that the new practice was a fundamental error, and have resumed the ancient principle by taking the control of the water supply again into their own hands. Manchester, Glasgow, Liverpool, Dublin, Bolton, Bradford, Halifax, Leeds, Rochdale, Preston, and many other towns, are instances where this has been done.

247. We have had Mr. Heron, the town clerk of Manchester, before us, and he has given evidence as to the circumstances under which the water supply was taken into the hands of the corporation. The following are extracts:—

7270. "In 1845 the attention of the corporation was more especially directed to this subject; we were in a most lamentable condition, and it was quite clear that some complete change was necessary. Perhaps I may be allowed to state that about that time the second report of the Health of Towns Commission was published—a commission over which the Duke of Buccleuch presided—and which I have no doubt is familiar to this Commission, for in that report it seems to me the subject is almost exhausted; we found it stated that 'the importance of an ample supply of good water, accessible at a price within the reach of the poorer classes of society, and in far greater quantities than have hitherto been furnished, is a subject worthy of the greatest attention.'"

7276. The report states: "It appears to be generally admitted by witnesses examined before us, who, being "themselves connected with existing water companies, have had every opportunity of observing the effect "of the opposing interests of the companies and their customers, that a copious supply of pure water cannot "be secured to the poorer classes of the community, unless the duty of providing it is placed under the "management of some independent body. It should be the duty of the local administrative body not only "to secure a sufficient supply for all the inhabitants, but, by contracting with or purchasing it of the water "companies, to ensure its regular distribution at a fair remunerating price." Another recommendation was—"With a view of ensuring a sufficient supply and proper distribution of water to all classes, we "recommend that it be rendered imperative on the local administrative body charged with the manage- "ment of the sewerage and drainage to procure a supply of water in sufficient quantities not only for the "domestic wants of the inhabitants, but also for cleansing the streets, scouring the sewers and drains, and "the extinction of fire. For this purpose we recommend that the said body have power to contract with "companies, or other parties, or make other necessary arrangements." A further recommendation was—"We "recommend that as soon as pipes are laid down, and a supply of water can be afforded to the inhabi- "tants, all dwelling houses capable of benefiting by such supply be rated in the same way as for sewerage "and other local purposes, and the owners of small tenements to be made liable to pay the rates for water, "as we already recommended in respect to drainage.' The corporation at that time felt so satisfied that it was desirable to carry out those recommendations within the city of Manchester, that we determined to go to Parliament to take power to purchase the works of the existing company, and to go for a large scheme which we believed would be sufficient for our present and prospective wants. But we determined also to go beyond those recommendations, because we determined, believing that it was only right and just, to introduce the principle of a public rate, and I believe it was the first time that the application was ever made to Parliament to obtain power to levy, in addition to a compulsory domestic water rate, a compulsory public rate, payable in respect of all property of every description within the city. We applied to Parliament in 1845, and then and by subsequent Acts obtained power to carry out a scheme which is not yet, I am sorry to say, completed. In 1848 we went for a second Act, which was simply to enlarge the scheme which was proposed by the Act of 1847 and since then we have had to go for other Acts of Parliament to obtain additional power, both with regard to the scheme itself, and also for carrying out in detail works within the city and the adjoining districts which we supply."

Mr. Heron remarks that one result of this has been that the corporation have been enabled to carry out a plan of water supply of such magnitude as could not have been accomplished by any private company. He says :—

"I feel perfectly satisfied that we should never have had such a scheme carried out unless we had 7314. undertaken to do it ourselves. Besides, the expenditure which we undertook was such an expenditure that it is quite certain no private company would ever have dreamt of encountering; nor was it one which they would have been justified in undertaking. A private company could not have acquired the money. If it had asked Parliament they would not have granted them the powers that we obtained; and it is only by the exercise of those powers that we have been enabled to incur such an expenditure, and to supply, as I think I can show you we do supply, water at a very low price to the inhabitants of the city."

He then goes on to speak of the advantages to the town:

"You are of opinion, are you not, that the supply of water and of gas to any large town should be in the 7316–8. hands of the municipal authorities?—I think the experience that we have had in Manchester has shown to us most clearly that the advantages are very great indeed of the supply being in the hands of the corporation.

"Are you now supplying water, not only more abundantly, but of a much purer quality, to the inhabitants of Manchester at a less cost than that at which they obtained their supply prior to 1845?—At a very much less cost, and we are giving them an unlimited supply of, as we have always thought, as pure water as is obtainable.

"Does that reduction in cost arise from your mode of spreading the burden of supply over all the rateable property as compared with the charge made by a private water company on domestic dwellings only?—In the first place the public rate goes necessarily in reduction of the charge that is to be made for the domestic supply within the city. That is the first important item, and which is obtained by the power which we possess to rate all property within the city. In the second place, no doubt as the question suggests, we can rate all dwelling houses, whether they take the water or not, (but they do take it, every house within the city takes it,) and this power diminishes considerably the amount which would otherwise have to be charged if you were only supplying, say, half or two-thirds or three-fourths of the houses; the cost is the same, the water is there, the water has been obtained, and it costs no more to supply the whole, assuming that we have got the water, which is the fact, than it would to supply three-fourths or one-half of the dwelling houses.

"I gather from your own experience in the case of Manchester that you are thoroughly convinced of the 7355. advisability of all corporations undertaking the water supply themselves?—I am perfectly convinced of it. I think the reasons are unanswerable, and one of the strongest reasons is, first of all, that they may obtain power to rate the inhabitants, which I do not suppose would be granted to any private company; they get power to rate everybody whether they take water or not, so as to spread the expense over the largest possible area, and they get that which after all is one of the objects of greatest importance, and I think so reasonable and so just—they get power to tax the whole of the property within the area with a public rate, which is in reduction of the expense of distributing water amongst the domestic consumers."

The corporation are stated to have the power of levying two rates, one a public or 7277–88. general rate on all property, which is fixed at 3*d.* in the pound, and secondly, a special or domestic rate upon all dwelling houses, which is 9*d.* in the pound, making in this second class of property 1*s.* in the pound on the rateable value, or about 10½*d.* on the gross rental. For the 3*d.* rate no water is specially supplied, but the rate is a contribution for the advantages secured to the whole community by their protection in case of fire, cleaning streets, flushing sewers, &c. The 9*d.* rate is for water actually supplied for 7395. domestic use. Water is further supplied for manufacturing and trade purposes at prices agreed upon with the corporation.

Mr. Duncan, the acting engineer to the Liverpool Corporation Waterworks, says that 2429. his experience is most decidedly in favour of the corporate bodies in large towns having the entire charge of the water supply. He considers the question is so mixed up with the general health of a town that it is almost impossible to separate it from that view of the subject. In all those towns in England where this has been done the tendency has been altogether in the direction of improvement. Corporations are more easily influenced than companies who have dividends to draw from their supply of water.

Mr. Hawksley, however, the consulting engineer to the same works, is not favourable 2564–6. to corporation management, public bodies being he thinks more under external influences, and less inclined to be liberal in their expenditure. He admits that a large scheme of improvement for such a city as London could not be carried out by divided companies, but he would prefer amalgamation.

Mr. Bateman, as we have noticed in our description of his scheme, relies on the assumption by the public of the water supply as the only possible means of carrying out any great measure of improvement. He suggests that for such a purpose London App. E. has only to follow the example of various towns, where of late the waterworks of companies have passed into the hands of corporations; and he instances Manchester and Glasgow as the two most prominent cases of success.

2838. 7127. Mr. Simon speaks of the great power which water companies hold in regard to the health of the populations supplied by them; and states that he feels very strongly that the public requires more protection than it yet has against their occasional malfeasances. He says:—

"This power of life and death in commercial hands is something for which, till recently, there has been no precedent in the world, and even yet the public seems but slightly awake to its importance."

248. The expediency and advantage of consolidating the water supply under public control are manifest on many grounds.

In the first place such a measure affords, we consider, the only effectual means of carrying out, in the metropolis, the system of constant supply. We have stated, under the last head, that we conceive the difficulties of introducing this system would be too great to be efficiently overcome by private companies; inasmuch as the great powers necessary for the purpose could only be confided to some public body who would be responsible for their proper application. The unity of action, and the extent of command that would be possessed by such a body, would enable the difficulties to be grappled with far more effectually than could be done by divided and private companies; the divisions of districts would disappear, and hence the store reservoirs and mains might be re-arranged with a special view to the new system of distribution; and the inhabitants would be much more likely to fall in with rules and arrangements established by a public body having no independent interests, than with those made by commercial companies.

Secondly, this measure would offer the best mode of ensuring a proper supply of water to the poor, which, as already stated, has been found impracticable under the present system. For a public control would involve compulsory rating, under which all difficulties of a financial nature, which are the only ones really formidable, would necessarily disappear.

Thirdly, we believe that the consolidation of the various present interests would tend largely to economy. The fusion of the districts; the more convenient re-arrangement of the distribution; the abolition of the several and widely dispersed centres of action; the uniformity of management; and many other beneficial effects of the measure, would all result in saving.

Fourthly, the transfer would tend to improve the quality of the supply, not only by checking the tendency to general abuses, but in particular by ensuring more effectual filtration, which is greatly needed, and which it appears difficult to enforce under the present system. We have already remarked on the neglect of the companies to comply with the provisions of the law in this respect, and may here add that this neglect calls either for more stringent control, or for a more effectual change. If the frequent examination and testing of the water, under public managemement, showed at any time that the filtration was inefficiently carried out, the public, instead of uselessly complaining, as heretofore, would have the remedy in their own hands.

Fifthly, the change of ownership would increase the probability of beneficial results from the measures already enacted, or any further ones to be enacted, for the purification of the Thames. It is possible there may be some difficulty in effectually carrying out these measures; and we believe that a public body having charge of the water supply would be far more likely to stimulate efficient action on this point than individual commercial companies, who have little power to interfere in the matter. And if, at a future time it should be found desirable to undertake any large and comprehensive measure for increasing the quantity of water, whether from the Thames basin or elsewhere, or for further improving its quality, such a measure could only be carried out by combined action, of which the consolidation under public control would be the most advantageous mode.

Sixthly, this measure would much facilitate the provision of water for all public and municipal purposes, and in particular for the important object of extinguishing fires. The documents we have printed in Appendix BL. furnish an appropriate illustration of the urgent necessity of some change in the latter particular.

249. But independently of these advantages, we believe the public management to be far more correct on general principles than the supply by joint-stock organization, which is obviously only applicable to those cases in which a fairly remunerative return may be anticipated for the capital expended. But a sufficiency of water supply is too important a matter to all classes of the community to be made dependent on the profits of an association.

We are hence led to the conclusion that future legislation should restore the ancient practice. The various important considerations above mentioned;—the increase in wealth and rateability of the great centres of population;—and the facility and advantage with which, in the cases brought to our notice where the requisite powers have been conferred, these powers have been exercised;—all point to such a solution of the problem.

250. Under this system it would be necessary to abolish the voluntary buying and selling arrangement now subsisting between the consumers and the companies, and to adopt the plan of compulsory rating as at Manchester, Glasgow, and elsewhere. Two rates should be enforced; one a special or domestic rate on all dwelling houses, the other a public or general rate upon all rateable property.

Such rates would assess all property much more equitably than the present tax upon consumers. The cost of the supply of water for extinguishing fires, and for general public objects, ought clearly to be borne rateably by all ratepayers; and to assess such burdens solely on the customers of the water companies is a manifest violation of all equitable commercial principles.

PART VI.

ON THE SUPPLY OF PROVINCIAL TOWNS.

251. Your Majesty's commands to us directed that, after reporting on the suitability, for the supply of the metropolis, of the sources of water in the high grounds of England and Wales, we should further report "how the supply from the remaining sources may "be most beneficially distributed among the principal towns."

252. In accordance with these instructions, we began to make inquiries as to the supply of some of the provincial towns, and as to the gathering grounds in various parts of the country generally available for water supply. But we soon found that such an inquiry must be one of great magnitude, involving a large amount of statistical and topographical investigation extending over the whole kingdom. We felt that it would be impossible for us to undertake this without further powers, while its prosecution would delay, probably for some years, the more important and pressing question as to the metropolitan supply. For this reason we resolved to complete our report on the latter subject, and to limit our recommendations on the former one to a few general principles.

To aid in these researches we have had prepared an elaborate map of the catchment basins of the various rivers in England and Wales; we have published this map in Appendix BN., and it will form, we believe, a useful groundwork for future investigations.

277. 253. We have received evidence from Mr. Bateman, as to the supply of Manchester and Glasgow, and he has also given us valuable data as to the supplies of a large number of towns in the Lancashire district, illustrating his remarks by the map, Appendix BO.

2097 et seq. We have also had much evidence about the supply of Liverpool, from Mr. Duncan and
2570–80. 4620. several other witnesses.

1381–407. Mr. Dale has given us some information as to the supply of Hull, and we have already
277–9. mentioned, in Part I., his proposal for bringing water from the Westmoreland lakes for
1061 et seq. the supply of various towns in Yorkshire and Lancashire.

4774 et seq. Some particulars as to the supply of Sheffield are given by Mr. Holmes, borough
4964. surveyor, and Mr. Jackson, chief constable.

5653–5735. Mr. McClean describes the works he has constructed for the supply of various towns grouped together in Staffordshire, and which are illustrated by the map, Appendix BD.

254. We have alluded, in Part I. of this report, to the proposal made by Mr. Bateman, that if his plan for supplying London from the hills of North Wales were carried out, his aqueduct might be used for the supply of a large and very populous manufacturing district in the midland counties through which it would pass. Messrs. Hemans and Hassard also contemplate affording a large supply to towns in the centre of England, by their conduit from the Lake district.

255. There are two remarks of a general nature that suggest themselves in regard to provincial supplies.

In the first place, it appears to us that the Legislature should always jealously watch any proposal for a town taking water from a gathering ground at a distance from it, lest by so doing it may deprive other places nearer to such gathering ground of their more natural source of supply. Mr. Bateman has put this argument so forcibly in the case of Liverpool that we may quote his words:—

277–9. "I think that it was altogether wrong that Liverpool should have been allowed to go to this district, because Darwen, Accrington, Blackburn, Wigan, and many other places are large and flourishing towns closely contiguous to the Liverpool gathering grounds, the whole district having a dense population where the inhabitants can only look to this little cluster of hills for a supply of water. Liverpool has put its paw upon that supply, and has very considerably limited the power of the surrounding districts getting an additional supply of water; and I would venture to suggest, as it is a national question, that if Liverpool should be permitted to go to Bala Lake for water, where it may take water without injury to any manufacturing interest, those hills being as it were the great manufacturers of water, the Rivington district should be held liable to have water abstracted from it for the supply of any neighbouring town which could not otherwise get a supply of water."

This argument ought not to be lost sight of in regard to the proposals for supplying London from Wales or Cumberland; for before either of these plans could be approved, it ought, we think, to be conclusively shown that the abstraction of water from these sources could not stand in the way of the supply of other places nearer to them. In regard to the Lake scheme, this would be, we conceive, a very powerful objection, as that district has already been several times pointed to as the best source of supply for large and growing masses of population in the north and centre of England.

At any rate, when circumstances render it necessary that water should be brought from a distance, care should be taken to include in the scheme the supply of all places along the route by which the water is conveyed. In the case of Liverpool, for example, if water should be procured from the upper Dee, as is proposed, the project should embrace the supply of Chester and all other places on the way.

256. Then, secondly, we would strongly call attention to the remarkable tendency that towns in the manufacturing districts have to arrange themselves in groups. Take for example the enormous group around Manchester, the group of the Potteries, the group of towns immediately to the north of Birmingham, the groups on the Tyne and near the mouth of the Wear, and many other instances.

This tendency ought always to be considered as an essential element of any arrangements for water supply. Such a group of towns uniting together may go for a much better and more perfect scheme than any one of them separately, and the Legislature ought not only to encourage but as far as possible to compel such a combination.

Instances of the favourable effects of such combinations are afforded by Manchester, which sends, or contemplates sending, supplies in all directions radially around the city, and in Staffordshire, where several towns have been successfully supplied in this way by Mr. McClean.

On the other hand, instances of the unfavourable results of a neglect of this precaution have been experienced in some parts of the country.

Referring again to the Cumberland Lake district, it is obvious that it might be made, by a united effort, available for providing an almost unlimited supply for great groups of manufacturing towns in the north of England; but it is only by a large union of districts that the expense of such a scheme could be justified.

We therefore consider that when any town belonging to a large group, particularly if forming the nucleus of it, comes to Parliament for a water bill, the scheme should be so designed as to include the whole group.

SUMMARY OF CONCLUSIONS AND RECOMMENDATIONS.

(*The figures in the margin refer to the paragraphs, in the body of the Report, from which these conclusions and recommendations are taken.*)

257. We may now give a summary of the conclusions we have arrived at on the whole inquiry, and of the recommendations founded thereon.

As to the Plans for obtaining Water from the Mountainous Districts of England and Wales.

§§ 31, 58–64. 258. We are of opinion:—

That Mr. Bateman's scheme is, in an engineering point of view, feasible and practicable, and that by it a large supply of water might be obtained for the metropolis; but that experience warrants great caution in judging of the sufficiency of a gravitation scheme
§ 36. of such magnitude.

That the quality of the water would be satisfactory as regards its purity; but that
§§ 25, 32. there are points dependent on its softness and colour, which might render it less suitable for the supply of the metropolis than the harder water at present used.

That the outlay for the scheme would be very large, amounting, according to the evidence laid before us, to about 11,000,000*l.*; but in the absence of detailed surveys, and in a project involving works of such great magnitude and novelty, and subject to
§§ 33, 34, 35. such large contingencies and elements of uncertainty, we do not consider that it is possible to arrive at any trustworthy estimate of the cost.

That, even assuming the work could be carried out for the estimated amount, the cost to the metropolis of obtaining water by this scheme would be much greater than is
§ 38. incurred by the present plan, and would continue to be so up to any quantity likely to be required within a reasonable lapse of time.

§ 39. That the scheme, if ever brought before Parliament, would probably be strongly opposed by interests connected with the River Severn.

That grave doubts may be entertained whether it is desirable that the metropolis should be dependent on one source of supply so far removed, and which might be liable to accidental interruption.

That great anxiety would be felt as to the formation of immense artificial reservoirs at the head of the Severn Valley.

That as to Messrs. Hemans and Hassard's scheme for supplying the metropolis from the Lake district, the same general remarks apply; the distance is greater, the estimate higher, and the gathering ground more likely to be claimed for nearer supplies.

As to the Quantity of Water available from the Thames Basin.

§ 148. 259. We are of opinion:—

That the River Thames, supplemented, if necessary, by works for storing the flood waters, together with the River Lee, and the water obtainable from the Chalk to the
§§ 82–94. south and south-east of London, as well probably as from the Lower Greensand, will furnish a supply sufficient for any probable increase of the metropolitan population.

That the abundance, permanence, and regularity of supply, so important to a large metropolis, are secured much more efficiently by the great extent and varied geological character of a large hydrographical basin such as that of the Thames, than by the necessarily very much more limited collecting areas that can be made available on the gravitation system. In the former case also the supply streams are self-maintaining, while in the latter the channel must be subject to the accidents incident to its artificial construction.

As to the Quality of the Water from the Thames Basin.

§§ 213–215. 260. We are of opinion:—

That there is no evidence to lead us to believe that the water now supplied by the companies is not generally good and wholesome.

That for drinking purposes the hardness of the Thames water is quite unobjectionable, and in no way prejudicial to health. The weight of evidence seems in favour of hard water, as more free from certain dangers inherent in soft waters on account of their greater solvent power. §§ 165. 174. 213.

That for cooking no important objection to the Thames water has been clearly proved, except as regards the deposit in kitchen boilers, which deposit is easily removed. § 1[illegible]

That for washing, and for manufacturing purposes generally, soft water is preferable as more efficient and more economical, but there appears no means of expressing the amount of saving in a money estimate. Looking, however, to the fact that the hardness of the Thames water is moderate in degree, and is still further reduced by boiling, and considering also that the proportion of the whole metropolitan supply used for manufacturing purposes is exceedingly small, we cannot see that this advantage is of sufficient importance to render it necessary to go to a great distance for soft water. § 173.

That the artificial softening process does not appear to be applicable to the Thames waters on a large scale. § 176.

That perfect filtration is highly essential to the good quality of the water supplied; that this process is at present in many cases very imperfectly performed; and that more efficient means of enforcing the provisions of the law in this respect are required. §§ 209–212.

That when efficient measures are adopted for excluding the sewage and other pollutions from the Thames and the Lee, and their tributaries, and for ensuring perfect filtration, water taken from the present sources will be perfectly wholesome, and of suitable quality for the supply of the metropolis. §§ 216, 217.

As to the Quantity of Water likely to be hereafter required for the Supply of the Metropolis.

261. We are of opinion:—

That a probable increase of population to 4,500,000 or 5,000,000 may have to be provided for, though we believe that the time for such an extended provision will be very remote. § 223.

That 200,000,000 gallons per day is the highest demand that need be reasonably looked forward to for the metropolitan supply. § 229.

That the various companies are prepared, with only moderate additions to their present engineering means, to supply a quantity little short of this amount. § 232.

As to the System of Constant Service.

262. We are of opinion:—

That the constant service system ought to be promptly introduced, to the farthest extent possible, in the supply of the metropolis. § 241.

That it cannot be effectually introduced in London so long as the supply remains in the hands of private companies, to whom it would be inexpedient to confide the great powers necessary for the purpose. §§ 242, 243.

As to the general Control of the Water Supply.

263. We are of opinion:—

That it is a matter of vital importance that an abundant supply of water should be provided for all classes of the population, as well as for general public purposes, street watering and cleansing, public fountains, and extinguishing fires. §§ 245–250

That for these purposes, there should be a power of levying, as at Manchester, Glasgow, and elsewhere, two rates, one a special or domestic rate on all dwelling houses, the other a public or general rate upon all rateable property.

That no trading company could be permitted to levy or expend such compulsory rates, and that therefore the future control of the water supply should be entrusted to a responsible public body, with powers conferred on them for the purchase and extension of existing works, and for levying the rates referred to.

That this plan offers the only feasible means of introducing efficiently the system of constant supply, and for securing a compulsory supply to the poor; we believe that it would tend to economy, to the improvement of the quality of the water, and to ensure the proper provision for public objects and for extinguishing fires; and that it would increase the probability of beneficial results from the purification of the Thames. § 248.

As to the Supply of Provincial Towns.

264. We are of opinion:—

§ 255. That no town or district should be allowed to appropriate a source of supply which naturally and geographically belongs to a town or district nearer to such source, unless under special circumstances which justify the appropriation.

That when any town or district is supplied by a line or conduit from a distance,
§ 256. provision ought to be made for the supply of all places along such line.

That on the introduction of any provincial water bill into Parliament, attention should be drawn to the practicability of making the measure applicable to as extensive a district as possible, and not merely to the particular town.

All which we humbly submit to Your Majesty's gracious consideration.

RICHMOND.
J. THWAITES.
H. D. HARNESS.
B. S. PHILLIPS.
THOS. E. HARRISON.
JOSH. PRESTWICH.

William Pole,
Secretary

9th June 1869.

ROYAL COMMISSION ON WATER SUPPLY.

REPORT

OF

THE COMMISSIONERS.

Presented to both Houses of Parliament by Command of Her Majesty.

LONDON:
PRINTED BY GEORGE EDWARD EYRE AND WILLIAM SPOTTISWOODE,
PRINTERS TO THE QUEEN'S MOST EXCELLENT MAJESTY.
FOR HER MAJESTY'S STATIONERY OFFICE.

1869.