the following facts are clearly established;—that the rapidity of exhaustion from "artesioid" wells, in and about London, greatly exceeds the rapidity of the supply;—that the amount of this defalcation is marked by the extension of a progressive permanent depression of the "chalk water level;"—that this depression may, at certain points, be measured;—and that, every year, the supply of water from the chalk stratum becomes more precarious, and less to be depended upon, even should there be no addition to the number of "artesioid" wells in the metropolis.

The Paper is illustrated by numerous diagrams, from which Plate 6 has been compiled.

The Rev. Mr. CLUTTERBUCK said, he feared the paper was now produced under some disadvantage, owing to the long period which had elapsed, since his former papers were read at the Institution.* His statements were then looked upon with considerable incredulity, being considered more theoretical than practical; but after this lapse of time, and the most careful investigation, he was not inclined to retract any one of his former statements or deductions. If he had not felt that they contained a great philosophical truth, he should not have persevered in following up such a difficult question, as that of subterranean drainage, which could only be traced, by ascertaining personally, the levels of the water at different places; all information on the subject, obtained from well-diggers, being very indefinite.

It had been supposed, that the outcrop of the strata under the sea, was the only great regulating outfall of the chalk waters, and by viewing it too exclusively, as such, erroneous conclusions had been drawn; now he submitted, that this assumption was not always correct; for instance, the water level assumed an anticlinal direction, from the point where the water, running from the surface of the London and plastic clays, raised the level under the outcrop of those strata, showing that from that point the drainage was from, and not toward, the sea.

That a great and gradual depression of the water level under London had occurred, could not be denied; and he believed, that it was produced by the amount of pumping from the chalk stratum, the supply from which was not equal to the demand. There was really a progressive permanent depression; progressive as could be

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* *Vide* Minutes of Proceedings Inst. C.E., vol. ii. 1842, page 155, and 1843, page 156.

proved, and permanent so long as the present demand continued. The period had now arrived, when the water question must be regarded, not merely as a theory, but as a matter of stern practice, in which the health of tens of thousands was concerned. If what had been advanced did not show from whence water might be taken, it at least showed from whence it ought not to be taken, and it would be a mere delusion to suppose, that a sufficient quantity of water could be drawn from under London, for the supply of so great a population. The line marked **A A**, Plate 6, Fig. 1, was that produced by the London pumping, and the limit of depression was extending towards the natural source of the supply.

Mr. Clutterbuck then explained a diagram, showing the rise and fall of the water, in a well in London, for a period of eight years, in which a remarkable coincidence with the indications of the rain-gauge was exhibited. The alternations caused by the replenishment of the chalk stratum, by rain falling on its exposed surface, and its natural drainage, were distinctly traced; the average of the alternations from rise to fall was 4 feet 6 inches, of which, as he had stated in his paper, 3 feet were regained, and 1 foot 6 inches permanently lost, making an aggregate depression of 12 feet in eight years.

Mr. DICKINSON coincided in the greater portion of Mr. Clutterbuck's statements. With respect, however, to the green sand, which had been described as the water-bearing stratum under Paris, he begged to remark, that what was called by geologists the green sand formation, was, in point of fact, composed of very different substances; in some places, it was sand through which water passed with facility, while in others it consisted of iron-stone, or clayey sands, through which water would not pass. He thought it material, before coming to a conclusion, as to what it was possible to accomplish, by sinking down to the green sand, that they should take into consideration the great uncertainty of that stratum. It would be absurd to make borings in London for this purpose, because there was an immense thickness of argillaceous beds and chalk overlying the green sand, which would only be reached by a boring of about 1,400 feet in depth.

There was no reason for doubting the statement made by Mr. Clutterbuck, as to the progressive exhaustion of the wells under London, which were unquestionably fed, in a great measure, by water from the chalk. As, however, it was desirable, that the members of this Institution should not discuss mere matters of conjecture, but rather bring forward all the plain facts which could be of assistance in elucidating theories, or guide in drawing inferences, he would

restrict his remarks to the results noted and recorded, during a series of years, relative to the supply of water filtering into the chalk formation, on the northern side of the Thames.

It would, he presumed, be admitted by all parties, that water found at an elevation of 400 feet above the Thames, must be furnished, by hydrostatic pressure, from a higher source, and not be thrown up by any magical means; and hence, that the water in the chalk was supplied by the rain, or snow, filtering through the outcrop, wherever that might be. He had endeavoured to ascertain the quantity of water which could be delivered into the River Colne, using for the purpose a gauge which had been invented by Dr. Dalton, and which was described in the article "Evaporation" in Rees' Cyclopædia. It consisted of a cylindrical vessel of tinned iron, 10 inches in diameter, and 3 feet deep, to which were soldered two pipes, one at the top, and the other at the bottom; this he had filled with the soil of the country, and as the bottom was pierced with holes, the water passing through the soil contained in the vessel, was conveyed into a receptacle beneath, for the purpose of being measured with minute accuracy; if more rain fell on the surface than could be absorbed, or pass through the cylinder of soil, the pipe at the top conveyed the surplus down to the vessel in which the measurement was made. Dr. Dalton, by taking the soil of Lancashire indiscriminately, had calculated, that on an average of three years, the quantity of water which penetrated into the lower receptacle, and which went to the supply of the rivers, amounted to one-fourth. Mr. Dickinson had taken the soil of his own district, and had accurately recorded the result of his observations, from the year 1834 to the present time (*see* p. 158). Taking the average for this period, the quantity of rain that fell was nearly 26 inches per annum, of which rather more than three-eighths passed through to the springs; it appeared, that summer rains did not contribute, materially, to the permanent supply of rivers. Thus, by knowing beforehand, the amount of the rain which fell during the previous winter, it was easy to predict what the supply of water would be, during the succeeding summer. Mr. Dickinson differed from the assertions which had been made, that the quantity of rain falling on the surface of the earth, exceeded, by five, or six times, the quantity that was found to drain off by the rivers, which were its natural outlet; he had ascertained, that the quantity of water flowing down the river Gade, agreed, as nearly as possible, with the rain that filtered down to the springs, from the surface of the country, whence the water was derived; and he had no doubt, that the quantity of water delivered from the chalk, by all the out-

TABLE showing a comparison between the Quantity of Rain falling on the surface of the earth, and that which penetrated through it.*

MONTHS.	1843		1844		1845		1846		1847		1848		1849	
	Common Rain-gauge.	Dalton's Gauge.	Common Rain-gauge.	Dalton's Gauge.	Common Rain-gauge.	Dalton's Gauge.	Common Rain-gauge.	Dalton's Gauge.	Common Rain-gauge.	Dalton's Gauge.	Common Rain-gauge.	Dalton's Gauge.	Common Rain-gauge.	Dalton's Gauge.
January . . .	1·46	1·25	1·90	·80	3·35	2·40	3·97	5·05	1·80	..	1·33	·81	1·80	..
February . . .	2·42	1·95	3·62	1·50	·70	..	1·28	·84	1·42	1·76	3·25	3·00	2·18	·40
March . . .	·88	..	2·22	2·65	1·30	..	1·07	·02	·98	..	3·57	2·75	·97	·09
April	2·10	..	·33	..	1·45	..	2·52	·28	1·68	..	2·68	·70	..	..
May	5·00	·74	·47	..	2·25	..	1·59	..	2·15	..	·21	..	..	..
June	1·56	·25	1·18	..	1·60	..	·51	..	2·30	..	3·19	..	..	..
July	2·09	..	1·95	..	2·30	..	1·90	..	1·91	..	2·42	..	..	..
August . . .	2·66	..	2·72	..	1·97	..	3·28	..	1·21	..	2·38	..	..	..
September . .	·63	..	1·42	..	2·00	..	1·70	..	2·06	..	2·12	..	..	..
October . . .	4·82	·91	4·38	1·13	1·65	..	6·36	3·98	2·59	..	4·50	2·58	..	..
November . .	2·45	2·70	3·07	3·57	2·94	·30	1·47	·10	1·70	..	1·12	·47	..	..
December . .	·40	·30	·31	..	3·02	2·80	·90	..	3·40	2·38	2·92	2·68	..	..
	26·47	8·10	23·57	9·65	24·53	5·50	26·55	10·27	23·20	4·14	29·69	12·99	..	..

* A similar table for eight preceding years, that is to say, from 1835 to 1843, is given in the Minutes of Proceedings Inst. C.E., vol. ii. 1843, page 160.

lets, would be found to agree with the quantity accounted for by the gauge, as passing into the bowels of the earth, for the supply of the springs.

If a well of exhaustion was sunk into that stratum of chalk, which cropped out on the other side of the clay ridge, where the river Colne was running from north to south, it would rob that river of its water, and, at the same time, diminish the supply to the wells in London, which was considered to arise from the chalk stratum beneath the clay. He deprecated all undertakings, in which the water for the supply of London was proposed to be obtained by boring, because, he thought it would be attended with disastrous results, and might, by the exhaustion of the strata, ultimately have the effect of drying up wells and rivers, so as to ruin whole districts of country.

When Mr. Telford was commissioned by the Government, to ascertain the best and cheapest mode of supplying London with water, he had imagined that by making his observations and experiments on the streams, in the middle of summer, there would then be that supply which could be best depended on. Now the fact really was, that a river, having its source in the chalk, would, at that time, be in its greatest fullness, and if examined in November, it would possibly not contain more than three-eighths of the water found in it in July. In the statement of Mr. Telford, that the Gade and other rivers were contaminated by deleterious matters from the paper-mills, he also differed, because, it was well known, that the paper-makers carefully prevented the waste of any portion of the alkalis and acids, used by them in preparing the materials for their manufactories.

Dr. Lyon Playfair said, he had recently had occasion to examine, both the water from Watford, and that from the deep wells in the chalk basin under London, and their analysis gave a few points which seemed to support Mr. Clutterbuck's views. First, on carefully examining the quality of the water of the streams at Watford, which, by percolation, supplied a large portion of the water in the London basin, it was found there was less common salt, than there was in the water of the wells in London. The amount of salt in the London wells was 25 grains per gallon, being a much larger quantity than was found at Watford; but there was another, and a great chemical change, which took place, in the percolation through the chalk, so much so, that it could scarcely be believed, that the well water found in the chalk, came from that formation. The water found on the top of the chalk at Watford,

contained from 10 grains to 25 grains of earthy salts per gallon, whilst that found in the chalk, in London, contained only from 6 grains to 7 grains, so that although it percolated through such a large extent of chalk, before reaching the London basin, it had, by some means, been deprived, to a great extent, of the earthy salts, which it possessed when at the top of the basin. New ingredients were now found in the water, and they must have been derived from the percolation through the chalk; these were salts of soda, especially the carbonate and sulphate. On examining the chalk, a certain quantity of silicate of soda was found. When the water which contained carbonate of lime in solution, filtered through the chalk, and met with this silicate, its carbonic acid seized the alkali, and formed carbonate of soda. Chalk, or carbonate of lime, was not soluble in water, unless in the presence of free carbonic acid; if that was taken away, the chalk, by being deprived of its solvent, would be precipitated. Now this actually took place, on account of the silicate, and thus the chalk was removed, and by a subsequent decomposition, the sulphate of lime also, so that water was finally obtained in the London basin, containing a very small quantity of earthy salts, but a large quantity of soda salts. Hence peculiar chemical reactions, ensuing during the percolation, entirely altered the character of the water. Dr. Playfair brought these points forward, to show the necessity of studying the chemical composition of water, and the change produced by filtration through rocks, because no person, from a mere superficial examination of the water in the deep wells, could presume that it came from the chalk. It was therefore difficult, from chemical considerations alone, to decide as to the truth of Mr. Clutterbuck's idea, that part of the supply in the London basin might be from percolation from the Thames, because the water received foreign ingredients from the chalk; still there were some grounds for believing in this filtration.

At a discussion which recently took place at the Chemical Society, on the subject of the composition of the water of the wells in London, a chemist mentioned a well in the London clay, the water of which was sometimes so salt as to be unfit for use, and it appeared that this was particularly the case, at the period of high-water of spring tides, when there was a great pressure of salt water. If that opinion was established by further observation, it would go far to establish the view, that the chalk waters received an infiltration from the Thames, and that, therefore, some of the supply of salt water might come from that source.

Dr. FARADAY said he was aware of the general facts stated by

Dr. Lyon Playfair, and imagined that the chemical character of the water filtering through such an extent of chalk, would necessarily be changed, as he had described.

It was natural, and easily demonstrable, that an infiltration of water from the Thames, or from any point where the outcrop of the chalk was under water, should take place. As the chalk formed a conduit for the issue of water before any artesian wells were made, when a hole was sunk into the reservoir, the natural outpouring would be checked, and when the exhaustion by pumping occurred, the waters from the rivers filtered back by the same crevices, through which they had formerly flowed. He agreed with Dr. Playfair, that to demonstrate this by chemical analysis, would be a delicate operation; still the chemist could greatly assist the general observer, and, between them, the truth would be arrived at by induction.

Mr. HOMERSHAM thought it was so much more desirable to obtain facts, than to discuss mere theories, that he had taken some pains to ascertain, accurately, the number of gallons of water now pumped up, per day, from the chalk under London. In 1838, a Bill was laid before Parliament, for a project for supplying the metropolis with water from the chalk under London, and from statistical researches, it was ascertained, that the quantity then pumped up by private wells, was about six millions of gallons per day, during six days of the week, and he did not think the quantity now pumped up could be correctly stated at more than twelve millions of gallons per day.

The area of the outcrop of the chalk, composing the hills above, and sloping towards Watford, was about twelve hundred square miles. Assuming twelve millions of gallons per day to be the quantity pumped up, it followed that a depth of one quarter of an inch of rain per annum, falling upon an area of twelve hundred square miles, would suffice, if it percolated, to furnish that quantity. He considered, however, that there was little water communication between the chalk under London and the hills around, but that a great portion of the water found was derived from the bed of the Thames, and of the English Channel, the bottom of which consisted of chalk, as was shown in the section from the Chiltern Hills to the sea, through Watford, London, and Gray's Thurrock. This view was confirmed by all analyses that had been made of the water procured from under London, which was found to contain a large quantity of soda and salt.

Mr. Homersham then exhibited a section of the strata in the experimental well sunk in 1840, at Bushey Meadows, by order of

the House of Lords, which had been overflowing ever since, and now produced eighteen hundred thousand gallons per day; the pumping which had taken place from under London since that time, had not affected it. Although a large quantity of water existed in the chalk of that locality, very little might be found in the chalk under London. It was well known that there were large fissures in the chalk under the valley of the Colne, along which currents of water passed, and were doubtless carried to the sea.

When Mr. Dickinson spoke of using Dr. Dalton's rain-gauge, he ought to have fully described its construction, and the situation in which it was placed; also, that acting upon a report made by Mr. Robert Stephenson, in 1840, he had, in 1843, contracted with Mr. Paten to sink a bore-hole at one of his mills, which had proved so successful, that he had adopted the same plan at three other mills, so that Mr. Dickinson was now lifting from four bore-holes, only five inches in diameter, eighteen hundred thousand gallons per day; while another paper manufacturer, in the same neighbourhood, was lifting from one similar bore-hole five hundred thousand gallons per day. Mr. Homersham would further caution the members of the Institution against placing confidence in the result of any one rain-gauge, for he had thirty, or forty gauges, fixed in various parts of the country, and many of them showed a great variation, even though within half a mile of each other.

He thought the true theory of the quantity of water which might be obtained from the neighbourhood of Watford, was, that a large portion of the rain falling upon the surface of the absorbent hills, from 800 feet to 1000 feet in height, around and sloping towards Watford, gravitated, and accumulated until it was conveyed by subterraneous cavities to the sea. At Lulworth Cove, near Weymouth, there was a large quantity of water running from the chalk into the sea, at low water; at Folkestone, Brighton, Dover, and at various other places along the coast where the chalk appeared, the same phenomenon might be observed; and at the Cornwall station of the coast guard at Dover, the whole of the fresh water used was obtained by collecting it, as it issued, at low tide, from a rock into the sea.

Mr. DICKINSON was at a loss to know where the twelve hundred square miles of chalk, just spoken of, were to be found; for it surely was not meant, that there was no outlet for all the chalk district, excepting the basin under London. If this was left indefinite, it might be extended to Brighton, or into Norfolk.

He was surprised that the bore-holes made at his mills should have been referred to; wells had existed, time out of mind, at every

mill, pure water being indispensable for the manufacture of paper, and he had merely added a bore-hole for the purpose of augmenting the supply, but the water did not rise higher than before; neither was it to be expected, that by piercing a larger number of fissures, the former water level would be elevated.

The Rev. Mr. CLUTTERBUCK would not advise any person to attempt to bore through the chalk into the lower green sand. What he wished to show was, that as the same principle governed the rise of the water, both in the Paris and the London basins, it signified little whether the source of the water was the chalk, or the green sand, as a mere matter of science. He agreed with Mr. Dickinson, that there was as much water in the rivers in the particular district of Hertfordshire referred to, in the month of July, as at any other time, but thought the question raised, with respect to the bore-holes at Mr. Dickinson's mills, so insignificant, that he could not understand why any stress was laid upon it.

The observations made by Dr. Lyon Playfair, on the chemical portion of the subject, went far to establish the fact of an identity in the chalk waters, which he had always considered to be the case; it appeared that there might be a great change going on in the water, not only whilst passing through different strata, but even in different parts of the same stratum; water filtering to a lower part of the chalk, would undergo this change, by a process of natural chemical manipulation, which completely altered its character. It was well known, that the Sanitary Commissioners attached much value to the comparative hardness or softness of the water. If, therefore, it could be shown, that at a certain depth in the chalk, water could be raised of a certain chemical character, and softer than that raised from a higher level, it made the whole subject, of the supply of water from the chalk, assume a different aspect.

He contended, that no reliance could be placed on calculations based on the assumption, that the river Colne was supplied from an area of twelve hundred square miles of surface; for even when one hundred and thirteen and a-half square miles had been spoken of, as being the area of that district of drainage, he had considered it to be over-stated.*

With respect to the experimental well sunk in Bushey Meadows, a section of which had been exhibited, he must be permitted to record his doubts as to the existence of those fissures at the bottom, through which borings were represented to have been made. When the sinking of that well was in progress, he had caused a small well of observation to be sunk in the chalk, at a distance of three hundred and sixty-

* *Vide* "The Parliamentary Gazetteer," Article 'Middlesex,' page 411.

three yards from the former, and he had found, that in the small well, the level was daily and gradually reduced, when the pumps in the large well were at work. On Monday. August 31, 1840, the pumps did not work, and the level in the small well on that day remained nearly stationary. He had also ascertained, on inquiry at the Watford Mill, which was some distance below the large well, that the water of the mill-stream fell off during the day, and began to increase about ten o'clock at night; that on the 31st of August, before alluded to, the only week-day, for a considerable period, on which the pumps did not work in the large well, an unusual supply of water was observed by the miller, who particularly noticed the circumstance, because Monday was always, as he said, "a short day." Mr. Clutterbuck therefore considered this a sufficient proof, that the water level was generally affected, and that the volume of water flowing down the river was reduced, by pumping from the experimental well in question.

He then directed attention to a section exhibited by Mr. F. Braithwaite, showing that the natural outfall of a certain portion of the water in the London basin was in the Thames, and he remarked, that the chalk rose, whilst the blue clay thinned out, towards Greenwich.

Mr. HOMERSHAM handed to the Secretary, the following letter from the person who was employed at the Watford Mill, during the whole time the experiments referred to were being made, to note whether any alteration took place; and it would be observed, that he stated positively, that no diminution in the quantity of water in the river occurred, during the time that any of the experiments in question were being carried out:—

Watford Station,
January 22, 1850.

SIR,

WHEN you were carrying out your experiments in Bushey Hall Meadows, in 1840 and 1841, I was engaged by Mr. Smith, the occupier of Watford Flour-mill, during the whole time these experiments were being made, to ascertain, by gauging the river every two hours, if any diminution of the water took place during the pumping of your engines, and I am happy to testify that no diminution did take place.

I remain, Sir,
Your obedient Servant,
(Signed) WILLIAM STAPLETON.

To Mr. R. Paten.

The Rev. Mr. CLUTTERBUCK explained, that the circumstance occurred in August, 1840, and his informant was a person named George Anstey, who had left the Watford Mill before the experiments alluded to by Mr. Homersham were made in March, 1841. During these latter experiments the river was swollen by heavy rains, and the effects of the pumping could not then be traced.

Mr. F. BRAITHWAITE thought the main question to be discussed was, whether there was an inexhaustible supply of water to be derived from the sand and chalk formations under London.

Mr. Clutterbuck's observations tended to support the fact, that, for a period of many years, there had been a progressive and serious depression of the water of the deep springs under London, and as facts were of much more importance than opinions, Mr. Braithwaite proposed to deal principally with the former. The diagram exhibited had reference to the well at Messrs. Combe's brewery in Castle-street, Long-acre, and was intended to show the monthly depression of the water of the sand spring, from July, 1837, to December 31, 1849, and with the accompanying table (*see* p. 166), had been constructed from daily observations during the above period.

It showed that in December, 1837,* the water had risen to within 113 feet of the surface, but that on August 31st, 1849, it only rose to about 163 feet 6 inches from the surface, indicating a total depression, within that period, of 50 feet 6 inches.

Being desirous of correcting that which, for a long time, had appeared to him a very important error, he had also prepared the two sections (Plate 7), one taken from Hampstead to Greenwich, and the other from Bow to Chelsea, or nearly at right angles to it. It was obvious, from these sections, that there was no such deep basin under the metropolis, as had for a long period been theoretically supposed to exist, and which had been laid down on several of the geological maps of London. In fact, he considered the ordinary charts rather illustrated the theory of artesian wells than gave correct representations of the London basin, as it really existed. The sections of the basin would no doubt be rendered more perfect, when the great survey, now being executed under the authority of the Government, was completed.

He regarded the water question as one entirely of supply and demand; he was of opinion, that the sand stratum which overlaid the chalk, and which occupied the principal space between it and the plastic clay, was, about forty years ago, fully charged with water, the result of many years' filtration from the surface. At that period the wells sunk in high, as well as in low, situations, in London, were abundantly supplied, so much so, that in many instances, large quantities of sand were pumped up with the water, to the serious injury of the foundations of the adjoining buildings: since then, however, the limited supply to the sand springs had decreased to the

* In 1827, when this well was first sunk to the depth of 173 feet, the water rose to within 70 feet of the surface.

TABLE showing the decline of, and the effect of pumping on, the water in the sand-spring, underlying the blue and plastic clays in London, taken from the well, 173 feet in depth, at Messrs. Combe's Brewery, Castle-street, Long-acre.

	1837	1838	1839	1840	1841	1842	1843	1844	1845	1846	1847	1848	1849
	Ft. in.	Ft. in.	Ft. in.	Ft. in.	Ft. in.	Ft. in.	Ft. in.	Ft. in.	Ft. in.	Ft. in.	Ft. in.	Ft. in.	Ft. in.
January	..	113 6	118 0	119 0	119 0	126 0	130 0	131 0	137 0	140 0	133 8	139 0	148 6
February	..	114 0	118 0	119 0	121 0	125 9	130 9	133 0	136 0	140 9	134 8	144 0	150 9
March	..	116 0	116 9	116 0	121 6	126 6	130 0	135 6	132 6	140 0	133 11	145 3	152 6
April	..	113 6	116 6	118 0	122 0	124 0	129 0	133 0	135 9	139 0	135 2	142 0	150 9
May	..	114 6	115 9	121 0	123 0	128 0	129 0	133 0	138 0	146 6	135 11	141 0	153 0
June	..	113 0	116 0	119 6	124 0	130 6	129 0	137 0	139 0	142 9	139 10	147 0	158 0
July	116 0	113 3	117 6	120 0	125 6	131 0	130 9	138 3	139 6	146 3	146 6	153 0	160 9
August	116 0	113 0	119 0	120 0	124 6	128 0	133 0	135 6	138 0	144 3	147 0	150 9	163 6
September	116 0	118 0	117 0	121 6	124 3	131 0	134 0	134 6	139 0	140 3	146 0	151 0	160 6
October	115 0	118 0	117 0	121 0	124 0	130 6	132 6	..	139 6	139 6	143 6	147 6	158 0
November	114 0	117 6	117 0	120 0	121 0	131 0	130 6	135 0	138 3	135 3	142 6	145 3	159 0
December	113 0	117 0	115 0	119 0	124 6	130 0	132 0	135 6	137 0	133 0	140 0	147 6	155 9

extent he had shown, and the great number of wells subsequently sunk, had caused nearly all those in the high land to become nearly, if not quite dry, while those in the low land were rapidly losing their water. These facts certainly justified him in stating, that even the present comparatively limited demand, was far greater than the actual supply.

He attributed the erroneous notions, which had been so long promulgated, as to the inexhaustible supply of water from the chalk, to the partial, but temporary, success attending the sinking of the three artesian wells at Trafalgar-square, one of which was in the front of the National Gallery, and the other two in Orange-street.

Upon this important point, he wished to draw particular attention to the section (Plate 7, Fig. 2). It would be there seen, that the surface level at Trafalgar-square was 19 feet 2 inches lower than it was at Messrs. Combe's, and that the depth to the chalk, in the wells at the former place, was 30 feet more than it was at those of the latter; this gave an advantage of nearly 50 feet to the Trafalgar-square wells, thereby enabling a larger quantity of water to be drawn from a lower level; still, however, the depression was rapidly progressing, and he contended, that whenever the large pumps at the Orange-street waterworks should be fully at work, pumping from 600 gallons to 1000 gallons of water per minute, the effect on the springs would be more seriously felt.

It was a question for consideration, whether the water from the Trafalgar-square wells was derived chiefly from the sand springs, or entirely, as was insisted on, from "the great water-bearing stratum in the chalk." He believed it would be found, that a very large portion of the water in those wells, which communicated with one another by tunnels, in order to form one common well, was from the sand. When one of the wells was originally sunk, a boring was made to a depth of 100 feet in the chalk, yielding, at that period, as was stated, from 60 gallons to 100 gallons of water per minute. Shortly after the well was completed, a rapid and large increase of from 500 gallons to 1000 gallons of water per minute, occurred, which, instead of being correctly attributed to the intrusion of the sand springs around the bore pipe, was ascribed, by the advocates of the artesian well system, to some "rapid enlargement of the far-extending fissures in the chalk," caused by detrition, consequent on an immense and continual rush of water through them. Supposing for a moment, that these fissures extended many miles, in various directions, he would inquire what quantity of chalk must have been displaced by this tenfold enlargement, and what had become of it? But seriously speaking, he would ask, how the great depression of the neighbouring sand-

spring wells occurred, if the supply at Trafalgar-square came only from the chalk?

In consequence of the reported success at that place, Messrs. Combe and Co. ordered borings to be made into the chalk in one of their wells, first to the depth of 100 feet, then to 200 feet, and at last to 300 feet: unfortunately, however, not 25 gallons of water per minute were obtained.

A similar result was obtained at Messrs. Meux and Co.'s well, where borings to a depth of 160 feet were made in the chalk, yielding only 10 gallons per minute in addition to the former supply, so that eventually tunnelling had to be resorted to, which had since been twice extended.

At Messrs. Reid and Co.'s brewery, where a superficial area of chalk of 1600 square feet had been laid open, only 200 gallons of water per minute had been procured, and even that quantity had so considerably fallen off, that it was necessary to apply to the New River Water Company for a supply.

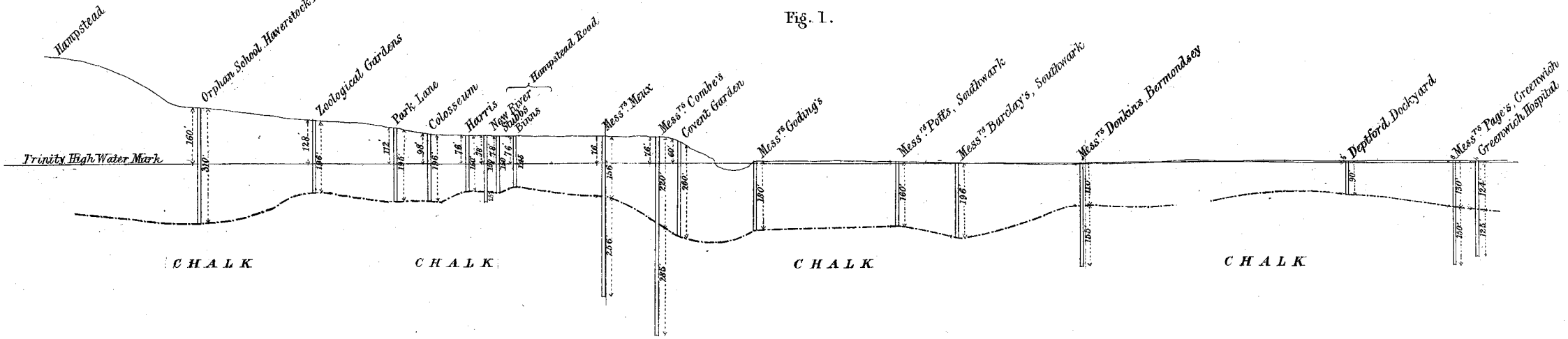
At Booth's distillery, at Brentford, where the chalk was found at 315 feet from the surface, and a boring was carried down about 100 feet, not more than 80 gallons per minute were obtained, and the principal part of that quantity came from the sand spring.

Mr. Braithwaite could adduce many other instances, and he would appeal to almost every brewer and distiller in London, whether their wells had not proved a continuous source of expense and trouble to them; so much so, that he verily believed, that, were it not for the greater refrigerating power of well-water, the temperature varying only from 52° to 54° Fahrenheit, many of those gentlemen would have long since had recourse to the Water Companies for their supply.

He would now only touch upon two other points relating to this interesting question; these were as to the wells in certain localities being tidal, and as to the water of the deep springs becoming more saline. For this purpose he would instance the well at Greenwich Hospital, where the land spring ebbed and flowed 2 feet 6 inches, the sand spring 3 feet, and the chalk spring 4 feet 6 inches every tide. He attributed the fact of the water becoming more saline, to the great depression of the springs under London; consequently the salt, or brackish, water of the river Thames (which, at present, had obtained a preponderating column), descended through the sand and fissures in the chalk, which, in his opinion, extended as much under the river Thames and the sea, as under the land, causing the presence of that quantity of various salts, which had been recently detected by the analyses of the water of the deep wells.

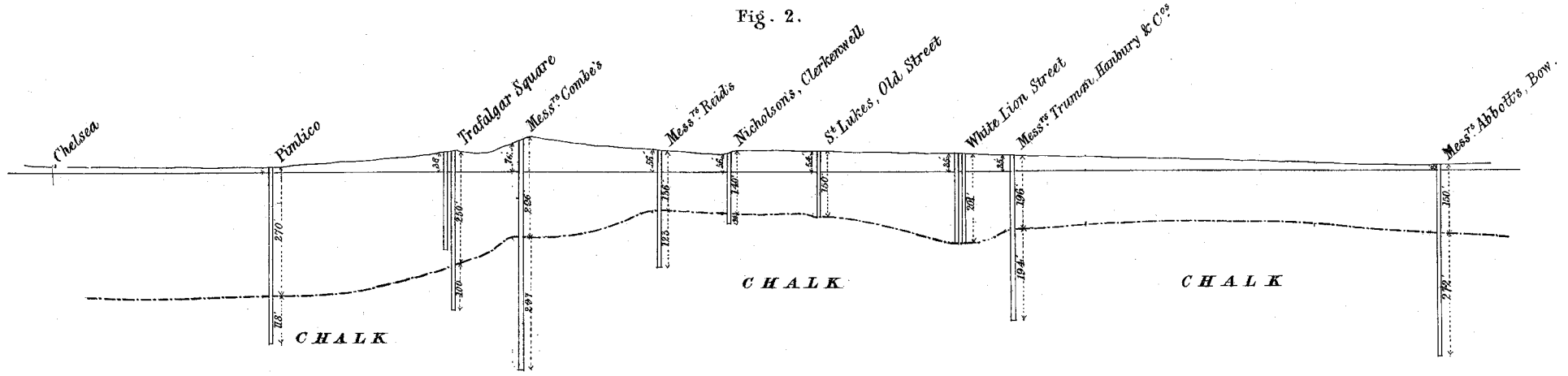
SECTION FROM HAMPSTEAD TO GREENWICH.

Fig. 1.



SECTION FROM CHELSEA TO BOW.

Fig. 2.



Longitudinal Scale.

0 1/4 1/2 3/4 1 2 Miles.

Vertical Scale.

400 300 200 100 0 50 400 Feet

Fred.k Braithwaite, del.

Day & Son, lith.rs to the Queen.

Mr. TABBERNER wished to make a few remarks, more particularly in reference to the observations of Mr. Braithwaite. He entirely agreed in the proposition, that the sections of the London basin, as they were usually shown, did not correctly represent the chalk formation, in fact, they grossly misrepresented it. He must dissent, however, from Mr. Braithwaite's views, as to the water contained in the sand, between the clay and the chalk strata, being the chief source of the supply of water obtained from the Trafalgar-square wells, or from Messrs. Combe's, or from any other of the deep wells.

The Trafalgar-square well was nearly 400 feet deep, extending about 100 feet into the chalk formation, from which four hundred gallons of water could then be raised per minute. When the bore-pipe into the chalk was plugged up, and the pumps were brought to work only on the water in the sand-bed, they could draw all the water available from that source; but when the bore-pipe into the chalk was opened, and all the engine power was brought to bear upon the body of water rising from it, no permanent effect could be produced on the water in the well.*

Much had been said about Messrs. Calvert's and Messrs. Barclay's wells affecting each other, and about these firms being compelled to work their wells on alternate days. Now the facts relative to these two wells were, that formerly both Messrs. Calvert's and Messrs. Barclay's were sunk only into the sand above the chalk; they then, undoubtedly, did affect one another, but there had been no recorded test of that fact since 1825. Subsequently Messrs. Barclay had bored about 150 yards into the chalk, and had obtained a plentiful supply of water. Since 1843, however, the quantity of water had gradually diminished; the cause of this would be evident, from a circumstance he had only ascertained about six weeks since. When the bore-pipe was first introduced into the chalk, it was intended, if possible, to continue to draw the water contained in the sand; to accomplish this, the pipe passing through the sand into the chalk, was perforated with a quantity of holes; the consequence was, that the sand had percolated with the water through those holes, and being precipitated into the bore-pipe in the chalk, had become consolidated in the pipe to a depth of 73 feet,

* Messrs. Easton and Amos were now increasing the works at Trafalgar-square by the addition of another well, making in all three borings into the chalk, connected with one another, by tunnels; it was estimated that, on the completion of these works, from 1000 gallons to 1200 gallons of water per minute would be raised.

thereby preventing the full flow of water from the fissures of the chalk. The sand had now been cleared out of the bore-pipe in the chalk, and the water had been gradually rising ever since. That was certainly an instance which argued against t ews of Mr. Braithwaite.

Mr. Tabberner contended, that any geological map would show, that the sand above the chalk formation did not crop out to the surface, and that, therefore, the water found in the sand above the chalk, was derived from the upper fissures of the latter; hence all wells sunk only into the sand bed, between the clay and the chalk strata, were subservient to each other, and those which abstracted the largest quantity of water, would, more or less, affect all the other wells sunk only into the sand.

The Rev. Mr. CLUTTERBUCK remarked, that as stress had been laid on the fact of some wells upon the sea-coast being tidal, he would endeavour to explain how this occurred. The vent, or outfall, in such a case was not fixed, but alternated with the tide; the level adjusted itself to these variations, and it was only between high and low water, that the water escaped from the chalk into the sea. During heavy gales, the mean level of the sea was raised, the tides flowed higher, the wells, at other times pure, then became brackish, by the infiltration of sea water, and the level inland was raised; but it was physically impossible, that water could be forced into the bed of the sea, below low-water mark. The same effect was sometimes produced by inland floods. In January, 1841, there was an unusually high flood in the valley of the Colne, from the sudden melting of the snow, and he had then ascertained, that wells in the neighbourhood of Watford, at a distance of half a mile from the river, rose from 2 feet 6 inches to 3 feet, under the influence of that flood, falling nearly to their original level on its subsidence. The same apparent effect might also be produced by natural, or by artificial causes. If the vent, or outfall, was lowered, the water level would decline in proportion. "If water be discharged from a shaft in the chalk, by a power not capable of exhausting it entirely, the rapidity of the reduction of the level will gradually decrease, until it is exactly balanced by that of the supply; when the exhaustion ceases, the level will rise in the inverted ratio of its reduction; if the level be measured in a line from the point of exhaustion, a similar reduction will be found, falling off at an angle decreasing with the distance from it."* To illustrate this, an experiment made at Gravesend, in 1837, might be mentioned. A well,

* *Vide* Minutes of Proceedings Inst. C.E., vol. ii. 1842, page 157.

from which eighty gallons per minute were discharged, was supposed to injure a well at 200 yards distance; after pumping for an hour and a half, the water in the former was reduced 4 feet, and in the latter ¾ qrs. of an inch, and so on in proportion; after fifty-six hours, the wells were reduced respectively 10 feet and 6 inches, but after seventy-two hours, no further reduction was made in the former, and only an additional inch in the latter.

As the possibility of obtaining a supply of water for London, from the chalk district of country round Watford, had been hinted at, and as it was well known that he entirely dissented, on purely scientific grounds, from the practicability of any such scheme, he would openly combat the opinions expressed in a report made for the proposed company. In the first place he found in that report the following passages:—"That a portion of the rain water which percolates the surface of the chalk, gradually gravitates, until upheld by the density, or impervious character of particular beds of chalk, it accumulates in the interstices which abound in various directions, and being conducted by the inclination of the beds, and in the direction of such interstices, is found oozing out from the sides of the hills, or bottoms of valleys, in the form of springs, which, uniting together with the surface drainage, produce streams or rivers." . . . . . "Another, and by far the greater portion, encountering no such impervious beds, continues to descend through the various subterranean fissures, until arrested by the bed of gault clay lying beneath the chalk, it fills the lower cavities, and accumulates to such a height, as to force its way through subterranean passages, communicating with the sea; in this manner an enormous amount of water is discharged through the shingle, or sand, which covers the coast, and even into the bed of the sea itself."*

Now Mr. Clutterbuck never heard of any such condition of the chalk stratum as was here described, and he considered it a mere delusion to suppose, that any such separate streams of water ever existed in any part of the chalk district. The chalk stratum appeared to be densely charged with water, to a level, or point, indicated by the line which he had called the water level. "In the upper districts, during the replenishment of this subterraneous reservoir, which usually occurs between December and March inclusive, the water accumulates in a proportion increasing with the distance from the river or vent, and falls off in a corresponding ratio during its periodical exhaustion, which usually takes place between April

* *Vide* Report to the Directors of the London (Watford) Spring-water Company. By S. C. Homersham, Esq., C.E., London, 1850.

and November. This alternation of level, which in the upper districts exceeds 50 feet in perpendicular height, would be represented by a line fixed at the river or vent, and rising at an angle proportionate with the increase furthest from it, the extent of its rise, or fall being determined by the quantity of rain percolating the chalk."* It was the overflowing of this level that formed the springs and streams of the chalk district. The quantity of water delivered by the springs, was regulated by the rising and falling of that line, of which the alternations were found to correspond with the quantity of rain percolating the surface.

It had, however, been boldly affirmed, that the springs issuing in the valley of the Colne, always delivered an equal quantity of water. It had been sworn before a Committee of the House of Lords, that "the most copious rains never augmented, nor the greatest drought diminished, the quantity from these springs."† The same witness affirmed, at another time, having particularly mentioned the well-known spring called Otterspool, "That it was a well-known fact, that during the severe drought of 1838, there was no visible effect in the diminution of water from these springs;"‡ whereas Mr. Clutterbuck had a letter from the gardener of the proprietor of that spring, stating that in 1838, the pool, or spring, ceased flowing for a time.

Mr. Clutterbuck brought forward these statements, because it was on the supposition of their truth, that the scheme for pumping water from the well in question was based. The statements in his paper bore only indirectly on that scheme, to which he should not have alluded, had not the section of the well been exhibited at the meeting.

Mr. HOMERSHAM said, when an inquiry into all the facts relating to the supply of water to the metropolis, must shortly take place before other tribunals, he thought the subject ought not to have been brought before the Institution. As it had been brought forward, he would endeavour to meet the charges which Mr. Clutterbuck was endeavouring to sustain against one particular scheme.

He did not deny that there had been a constant depression of the water level under the London clay, though he might state, on the authority of those who had sunk the wells at Trafalgar-square, that, in some instances, it had risen.

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* *Vide* Minutes of Proceedings Inst. C.E., vol. ii. 1842, page 156.

† *Vide* Evidence of Mr. Robert Paten, before the House of Lords, Question No. 10.

‡ Letter to the Editor of the "Morning Herald," Jan. 23, 1841.

The chalk not only cropped out to the south of the Chiltern Hills, but also under the Thames, from Woolwich to Gravesend; in fact, the whole bed of the Thames, from a little below Woolwich, ran on chalk, which was connected with the bed of the sea. The argument that the water level had been depressed under London, would tend to show, that as the rain absorbed by the Chiltern Hills, was not carried off by surface drainage, and did not come under London, it must be found elsewhere. He thought the fact of the wells at Trafalgar-square, and of deep wells generally, containing from 66 grains to 75 grains of saline matter in each imperial gallon, showed clearly, that the water under London, was partly derived from the Thames, and partly from the sea; it appeared to be quite clear, that it was not derived from the upland district. It would be as absurd to suppose, that the pumping from under London had exhausted the Thames, or the sea, as to say that it had exhausted the water in the chalk formation above Watford.

He contended, that it was proved beyond all doubt, that a large quantity of water did exist in the valley of the Colne, as many mill-owners were now, and had been for many years past, engaged in pumping up that water for their own use. The level of the ground at Bushey Meadows was about 160 feet above Trinity high-water mark, and when the chalk was pierced into, the borings intersected large fissures, from whence the supply of water was derived, and which might be termed subterranean rivers, fed from the absorption of the rain falling on the upland district, and connected with Brighton, Weymouth, and other places on the coast.

Mr. DICKINSON did not consider, that the work of the Watford mill could be any test of the effect of the experimental well, inasmuch as the quantity of water pumped up by a small steam-engine, from a well 50 feet deep, would be inappreciable by an ordinary miller, having no means of estimating it, but by the working power of a large mill.

He considered the general question of the supply of water to be one of great importance. The project of boring into the chalk was set on foot some years ago, by Mr. Paten, who had been employed, at various times, to bore in the chalk stratum at Mr. Dickinson's, and at other mills, and from having proceeded to a great depth, a considerable quantity of water was liberated, and rose to the surface, from the numerous fissures in the chalk, tapped by that process. Thus the quantity of water in the wells was augmented, and they afforded an additional supply for washing purposes.

With reference to the supply of water from a well sunk at Wat-

ford, at a spot where the surface of the ground was about 180 feet above the level of the sea, it was evident what district and what area of country the water, which was to be pumped up from the well, was to come from. The Colne branch of the rivers above Watford drained a very large area of clay country, carrying off the water from about seventy square miles, and though it was swollen to a torrent in very wet weather, it was, according to Mr. Telford's report, almost dry at other times. In short, that branch of the Colne, which gave a name to the river, and the district of country which was drained, were not adapted for supplying a well, which must derive its supplies from springs; therefore, if spring water was obtained at the Watford well, it would be by liberating and abstracting the water contained in the chalk stratum, and then the question arose, from what part of the chalk the water would be supplied. It had been stated, that by sinking a well at Watford, a district of country of one hundred and thirteen and a-half square miles would be drained; but from observations Mr. Dickinson had made, he doubted the correctness of the statement, nor did he consider that so large an area of country could be laid under contribution for that purpose. He therefore ventured to dispute the position, as it was not based on an adequate knowledge of the nature and mode of the supply of water in that district.

It should be borne in mind, that there was a great difference in the nature of rivers, though they were all drains for the countries through which they flowed. In some cases such drains carried away the superficial wash of a clay district, in other cases they were fed by springs rising out of an absorbent stratum, which slowly and gradually delivered out the water that fell on the stratum of the ground.

The discharge of water out of the district of chalk country around Watford, by means of the streams, called the Verulam, the Gade, the Chess, and the Misbourne, fully accounted for the quantity of rain, which was ascertained to be absorbed into the chalk, upon the area of one hundred and thirteen and a-half square miles; he argued, therefore, that the water now yielded, by other parts of the chalk stratum, to the Thames, the river Lea, the Wycombe stream, and the wells under London, could never contribute to the well at Watford; because the vent from the chalk, by these outlets, was lower than the bottom of the proposed well, and he treated the supposition, of the proposed well being supplied from twelve hundred square miles of the chalk stratum, as perfectly delusive, and alleged, that if, by engineering powers, the water could be withdrawn from that part of the chalk stratum, it would diminish the streams, dry up the springs,

and wells, and produce a most injurious change on the whole district of country.

Mr. TABBERNER observed, that one of the main points of the discussion appeared to be, the intention of establishing the fact, that the general level of the water in the sand and chalk formations, had been lowered, within the last forty, or fifty years. This could not be reasonably doubted, but the alternations of the level of the water, in the many deep wells sunk in and around London, depended upon the wetness, or dryness of the season. The average annual depth of rain, falling upon the exposed surface of the chalk, was 21 inches, and supposing only 10 inches of that quantity percolated into the depths of the chalk, an abundant supply would, he contended, be found in it. As to the level of the water varying, and in course of time, and in different seasons, lowering, it was a natural consequence. If an additional number of pumps were working upon a certain reservoir, and, from the dryness of the season, the infiltration to the reservoir was inadequate to supply their demand, the level would naturally be lowered. Such was the case with respect to the water in the chalk. In the first instance, one hundred wells might have been sunk, then if the number was increased to five hundred, necessarily a greater depression would ensue, as the number of wells was increased; but, he contended, that so long as the 10 inches of rain continued to percolate annually into the chalk, repletion was always to be depended upon, and consequently an inexhaustible supply would be found, even if ten times the number of wells were to be sunk into the depths of the chalk.

He differed from those gentlemen who had spoken of the saline properties of chalk water. The facts appertaining to that part of the subject were simple. According to the analysis of Professor Brande, the solid contents in the water of the well at the Royal Mint, were 38 grains, whilst in that at the Trafalgar-square wells the solid contents were about 68 grains. If the water contained in the deep chalk fissures was impregnated with salt water, the water at those two places would be identical, as would the water in all the deep wells; but the fact was, that the water in almost every well differed in the proportions of its saline contents. The water, as it fell upon the exposed surface of the chalk, was pure; as it percolated through the fissures, and passed downwards, it took up its constituents, being affected in a greater or less degree, according to the distance traversed, and to the variation in the alkaline properties of the chalk formation. Mr. Tabberner's own opinion was, that the salt found in the water of the chalk, was derived from the original deposit of the tertiary seas, and not, as was supposed, from

the percolation of the present sea water, into the deep wells under and around the metropolis.

Mr. HORN said, that at his works in St. Luke's, there was a deep well, sunk where the surface of the ground was 55 feet above Trinity high-water mark, which suffered considerably from the sinking of the water level. This well was sunk in 1834 to a depth of 95 feet, and gave a good supply; subsequently it failed, and in 1841 a further depth of 122 feet was added, from which a copious supply, for three pumps of 5 inches in diameter, and 18 inches stroke, working night and day, proceeded. At the present time, after a cessation of working of four days, the water was 21 feet below the level at which it stood in 1841. Several well-borers had told him, that they found the level of the water, in the wells in London and in its vicinity, had been lowered full 20 feet; and that they had never found anything approximating to a stream of water in the chalk; they had frequently sunk the auger through a chasm, but no augmentation in the height of the water had followed.

Mr. F. BRAITHWAITE said, he had prepared a table, (*see* p. 177,) of the analyses of seventeen samples of water, from wells in and around London. From this it would be seen, that in all the wells where the water of the sand or the chalk springs was considerably depressed below Trinity high-water mark, the quantity of solid saline matter, in an imperial gallon, was very large. He would particularly instance the well at the Watford Station,—that at the Camden Station of the London and North-Western Railway,—and that at Trafalgar-square. The water of the well at the Watford Station, which was above the influence of the tide, contained only 23·7 grains of solid matter, in an imperial gallon, of which 19·54 grains were carbonate of lime, and only 1·9 grain of saline matter. The water of the well at the Camden Station, which only rises to within 44 feet of the high-water mark in the Thames, contained 44 grains in each imperial gallon, of which 41·70 grains were saline matter, with little or no carbonate of lime. The water of the well in Trafalgar-square contained, according to the analysis of Professor Brande, in 1846, 66·1 grains of solid matter, in each imperial gallon, of which 59·9 grains were solid saline matter, with only 3·1 grains of carbonate of lime; from this well a large quantity of water was daily pumped.

As this statement of the large body of saline matter in the water of the well at Trafalgar-square had been questioned, Mr. Braithwaite had instituted further inquiry, and had ascertained, that instead of the statement being incorrect, an analysis of the same water, which had been made at the latter end of 1849, at the College of Chemistry, showed an increase in the amount of solid matter, there being then

ANALYSES of Seventeen Samples of Water.

Saline and other matters in One Imperial Gallon of 70,000 grains.	GRAHAM, 1844			BRANDE, 1846			PHILLIPS, 1849			BOSTOCK, 1834	BEALE, 1841		BRANDE, 1846				College of Chemistry, 1849
	Greenwich Hospital.	Page's Well, Greenwich.	Lambert's Well, Deptford.	Brewery, London	Trafalgar-square.	Royal Mint.	Camden Town Station.	Watford Station.	Tring Station.	Treasury Pump.	Robarts, Roehampton.	Robarts, Roehampton.	River Thames, at Chelsea.	River Colne.	New River.	River Lea.	Trafalgar-square.
	Grs.	Grs.	Grs.	Grs.	Grs.	Grs.	Grs.	Grs.	Grs.	Grs.	Grs.	Grs.	Grs.	Grs.	Grs.	Grs.	Grs.
Carbonate of Lime	19·08	21·23	16·74	6·2	3·1	1·5	..	19·54	14·72	34·3	48·0	24·0	16·5	18·1	14·7	10·2	3·27
,, Soda	..	..	..	11·7	14·6	12·0	17·60	..	..	..	..	..	..	..	..	..	18·28
Sulphate of Soda	3·62	0·60	2·67	24·2	19·6	18·1	13·00	..	..	..	8·0	8·0	..	..	..	..	8·74
,, Lime	..	..	..	..	..	..	..	0·94	1·09	16·1	32·0	24·0	1·5	1·2	1·6	6·2	..
Carbonate of Iron	0·52	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Muriate of Soda	0·37	3·12	1·91	12·7	25·7	8·3	11·10	1·90	1·38	12·6	16·0	8·0	1·7	2·0	1·7	6·6	20·05
Carbonate of Magnesia	..	..	0·84	1·1	2·4	..	..	..	..	..	..	..	..	..	..	..	2·25
Sulphate of Magnesia	2·04	2·88	2·75	..	..	..	..	..	..	..	..	..	..	..	..	..	..
,, Potash	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	13·67
Carbonaceous matter	..	..	..	..	..	..	2·30	1·32	1·61	..	..	..	t	t	1·2	2·4	0·68
Silica	..	..	..	0·4	0·7	..	..	..	..	..	..	..	..	..	..	..	0·97
Phosphates	..	..	..	0·4	t	t	..	..	..	..	..	..	..	..	..	..	2·03
Loss	1·67	..	1·33	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Total	27·30	27·83	26·24	56·7	66·1	39·9	44·0	23·7	18·8	63·0	104·0	64·0	19·7	21·3	19·2	25·4	69·94

69·94 grains, instead of 66·1 grains, per imperial gallon, of which quantity only 3·27 grains were carbonate of lime.

On looking at the table of the annual decline of the spring-water under London,* it would be seen, that from 1827, to December 1849, there had been a loss of 90 feet; and at the table of analyses, whereby it was established, that the spring-water above tidal influence was but slightly impregnated with saline matters, while on the other and water under such influence, was abundantly impregnated, it might fairly be inquired, to what other source could the saline matter, found in the spring-water of deep wells, in London, be attributed, if not to the salt, or brackish water of the Thames.

It was indeed a very important question, and one seriously affecting the interests of a number of brewers, distillers and others, who mainly depended on a supply of well water, and he hoped the effects of increased pumping on the deep wells, would be well considered, before any attempt should be made, to obtain a supply of water for the inhabitants of London generally, by means of artesian wells.

Mr. F. O. Ward observed, with respect to the Trafalgar-square wells, that as a large portion of the water from the fountains returned continually into the wells, it was probable some great change took place, in the chemical constitution of the water, from its exposure to the air in a state of agitation.

He suggested also, whether, in the analysis of the water from the chalk, any attempt had been made to ascertain the presence of Bromine, for as that substance existed in the sea-water of the British Channel, its detection would go far to confirm the opinion, of the infiltration of sea-water to the depths of the chalk.

Mr. Simpson, *V.P.*, said, it was well known to those who had sunk into the chalk, that fissures did exist; he had himself found them wide enough to admit of the insertion of his arm, and, in two, or three instances, he had been able to creep into them; but during an experience of thirty years, he had never found those fissures so large and so continuous, as they were in the limestone, which contained large caverns, forming perfect water-conduits, or almost streams.

The subject of the depression of the water level under London, was not new to him, as he had noticed it so far back as the year 1822, or about the same time as Mr. Beaufoy. He then made observations on several wells, and found the water level lowered about 1 foot annually, and as the number of wells had increased, of course

* *Vide* ante, page 166.

the water level had descended. He did not think this arose from the supply being affected or lessened, but from the ducts in the chalk not conveying the water so rapidly, as to fill up the depression caused by the pumping. In the discussion, the large supply of water to the chalk, arising from the melting of snow and hail, appeared to have been forgotten; he had found, from a series of experiments, that 4 inches of hail, or 7 inches or 8 inches of snow, were equal to 1 inch of water.

The variations in the quality of the water, frequently arose from imperfections in the construction of wells, the upper springs not being sufficiently shut out from the lower ones. The quality of the water, in the upper strata of the metropolitan basin, varied considerably, a great deal being very impure; and that in the sands between the London and the plastic clays was often so much so, as to be totally unfit for use in boilers; if a mixture of these waters percolated downwards, it would, undeniably, give a different character to the water in the chalk springs. At Streatham and Norwood, many of the springs were known to be so strongly saline, as to be used medicinally.

All these circumstances should be taken into account, when the subject of water supply was discussed, and more especially when the chalk formation under London was referred to, as it was quite clear, and appeared to be admitted by all parties, that a depression of the "chalk water level" had been going on, in an increasing ratio, for the last thirty years.

Mr. CLARK said, he had lately examined a well for Mr. Smith, at Hamper Mills, near Watford, which had been bored by him 18 years ago, and he had found 17 feet of water for the suction-pipe to draw from. It had been working without diminution of supply, up to the present time, although there were two pumps 5 inches in diameter, and two of 4 inches diameter, equalling together 140 strokes a minute, of a lift of 11 inches diameter. Mr. Smith had assured him, that he had never known the water fail. In Mr. Clark's opinion, no diminution had occurred in the chalk springs, but the observed depression was in the sand-springs. There was an abundant supply of water, from the chalk, at the Hanwell Asylum, and it was now flowing over the surface of the ground; and in the Woolwich Dockyard, he had bored a well into the chalk, 600 feet deep, whence a supply of 1000 gallons per minute was obtained, at a depth not exceeding 70 feet from the surface. He thought the chalk stratum had not been yet sufficiently proved, to know positively what it was capable of affording.

Mr. SIMPSON, *V.P.*, observed, that he had been consulted, as to

the well at Hanwell, just alluded to, and he could say, that it was one of the best specimens of workmanship in the country. The shaft was 6 feet in diameter, the bore-pipe 15 inches in diameter, the spring, when tapped, produced 127 gallons per minute, and the water rose 23 feet above the surface of the chalk, so that the whole of the lower part of that establishment, was supplied without pumping.

The Rev. Mr. CLUTTERBUCK thought the general question of the supply of water to London, was one of such vast importance, that it was in the highest degree essential to possess accurate and authentic geological information, before commencing such great works as those of the drainage and water supply, now in contemplation for the metropolis, in order that they might be executed on a sound and certain basis. He therefore suggested, that the geological survey now being carried on by Government, in a remote district of North Wales, where no urgent need existed for early geological information, and where no new works of paramount importance were in progress, or in contemplation, should be at once transferred to the metropolitan districts, with a view to throw light on the real structure, mechanical and chemical, of the deep water-bearing strata, relative to which such conflicting opinions had been advanced.

He then contended, that the original position, assumed in the paper, had not been weakened by the subsequent discussion; that the observations of the chemists had tended to confirm the statement, of the probability of an infiltration of water from the Thames; and that the practical conclusions to be drawn from the observations recorded in his several papers were:—That the natural drainage and replenishment of the chalk stratum might be accounted for, by observing the alternation of level in various localities, and at different seasons:—That any large quantity of water abstracted from the chalk stratum, at any given point, caused a depression of level around the point of such abstraction:—That in the upper districts, any such abstraction of water would interfere with, and diminish the supply of the streams, by which the drainage of the district was regulated:—And lastly, that the depression of the level under London, by pumping from "artesioid" wells, had proved, that the rapidity of the demand, already exceeded that of the supply, and that any attempt to draw a large additional quantity, for public use, would be attended with disastrous consequences.