REPORT

TO THE

DIRECTORS

OF THE

MANCHESTER, SHEFFIELD, AND LINCOLNSHIRE RAILWAY COMPANY:

BY

S. C. HOMERSHAM,

Civil Engineer:

COMPARING

THE QUANTITY, QUALITY, AND PRICE OF THE WATER THAT CAN BE SUPPLIED TO THE INHABITANTS OF MANCHESTER AND SALFORD, BY MEANS OF THE SURPLUS WATER ACT OBTAINED LAST SESSION BY THE MANCHESTER, SHEFFIELD, AND LINCOLNSHIRE RAILWAY COMPANY,

WITH

THAT OF THE WATER WORKS SCHEME PROMOTED BY THE CORPORATION OF MANCHESTER:

AS WELL AS

SOME REMARKS UPON THE CONSTRUCTION OF RAIN GAUGES AND THE ANNUAL DEPTH OF RAIN FALLING IN DIFFERENT LOCALITIES AROUND MANCHESTER.

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59. HIGH HOLBORN.
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PREFACE.

THE following pages explain fully the inducements that led the author, when professionally consulted in the autumn of 1846, to advise the Directors of the Manchester, Sheffield, and Lincolnshire Railway Company to apply for parliamentary powers to legalize the sale of a large quantity of excellent water, which came into their possession from becoming the purchasers of the Peak Forest and Macclesfield Canals, and to empower them to construct such additional works as would enable them to store and supply this water in the purest state, at a cheap rate, for distribution to the inhabitants of Manchester, Salford, and Stockport.

Since the year 1844, the Manchester and Salford Water Works Company have been the purchasers of a portion of this water to supply their tenants, as the quantity they derive from the River Medlock, and the drainage ground of the Gorton Reservoirs, has not in some years been found equal to *one half of* their requirements: the quality of the water procured from the last-mentioned sources, polluted as it is (especially in warm weather), from many causes, has been rendered much less objectionable by its admixture with the pure water obtained from the reservoirs of the Peak Forest Canal. With these claims upon the public of Manchester and Salford for support, combined with the conviction *that no other source presented itself from which a sufficient supply of pure water*, for their domestic use, could upon such advantageous terms be procured, the Manchester, Sheffield, and Lincolnshire Railway Company last year sought and obtained parliamentary powers to enable them to collect and filter this water, for the purpose of supplying it *in bulk* to any party who might become the distributors of it.

A comparison of this project as it obtained the Royal assent, with the scheme at present promoted by the Corporation of Manchester for the purpose of supplying water to the Borough of Manchester, is contained in the following Report, and may be interesting not only to the shareholders of the Manchester, Sheffield, and Lincolnshire Railway Company, but also to the public of Manchester, Salford, and Stockport. To render it more generally useful, a few introductory pages have been added.

19. Buckingham Street, Adelphi, March, 1848.

INTRODUCTION.

The inhabitants of the towns of Manchester and Salford are at present supplied with water, for domestic and other uses, by the Manchester and Salford Water Works Company, who derive the water supplied to their customers from different sources; namely, in part from two reservoirs, situated at Gorton, about three miles to the East of Manchester (which reservoirs collect the drainage from about 1600 acres of land, shown on the accompanying map, and coloured green), and in part from a reservoir at Beswick, to the East of the town of Manchester, which serves to collect flood-waters from the river Medlock; this water is afterwards pumped for distribution by steam-power to a service reservoir at a greater altitude. A well has lately been sunk (but is not yet completed) in the red sandstone, near the Gorton Reservoirs, from which water is pumped, also by steam-power, into the Gorton Reservoirs; and for the last three or four years water has been supplied to the Water Works Company, from reservoirs belonging to the Peak Forest Canal, (which canal is now the property of the Manchester, Sheffield, and Lincolnshire Railway Company). These reservoirs, called the Todd's Brook Reservoir, and Comb's Reservoir, will be found on the map near Whaley, about fourteen miles South-East of Manchester; the water from them is conducted to the Gorton or Beswick Reservoirs of the Manchester and Salford Water Works Company, by using the Peak Forest and Ashton Canals as a conduit. It will be seen, by referring to the map, that the Ashton Canal passes over some of the feeders of the Gorton Reservoirs, and that the Peak Forest Canal unites with the Ashton Canal: water is supplied at the extreme southerly end of the Peak Forest Canal from the Todd's Brook and Comb's Reservoirs, and drawn off into the feeders of the Gorton Reservoirs from the Ashton Canal. These are the sources from which the towns of Manchester and Salford are at present supplied by the Water Works Company. In a report made to this Company by their engineer, dated May 21. 1842, it is stated that, in the year 1841, 418,433,000 gallons were supplied from the drainage ground of the Gorton Reservoirs, and 30,096,000 gallons from the river Medlock, making about 1,443,000 gallons per day, as the total supply to the tenants of the Water Works Company in this year. This shows that rather less than one thirteenth of the total supply was in the year 1841 acquired from the river Medlock: at that time the well in the red sandstone was not sunk, nor any water taken from the reservoirs near Whaley. In July, 1844, the Water Works Company, not having sufficient water to supply their tenants, procured, in the emergency, a quantity from the Peak Forest Canal Company's reservoirs, which was delivered to them by the means before described. The Water Works Company soon after entered into an arrangement to take from this source 120,000,000 of gallons annually, for three years certain, at the rate of twopence per 1000 gallons; and in 1844 50,000,000 of gallons, in addition to this quantity, were supplied to them.

The Manchester and Salford Water Works Company in the Session of 1845 applied to Parliament for an act to enable them to procure a further supply of water, by constructing impounding reservoirs among the hills to the East of Manchester; but owing to the opposition given to this measure from various sources, they eventually abandoned their bill after having got through the Committee of the House of Commons. In the Session of 1847, three projects were prosecuted to procure a further supply of water for Manchester and Salford; one by the Manchester and Salford Water Works Company, who proposed to collect a supply of water in reservoirs, to be constructed in Lyme Park, about eight miles South-East of Manchester, and not far distant from Stockport; another by the Corporation of Manchester, who proposed to collect water in reservoirs to be constructed in the Valley of Longdendale; and the third, promoted by the Manchester, Sheffield, and Lincolnshire Railway Company, who having become the purchasers of the Macclesfield and Peak Forest Canals, proposed to make use of the powers granted to them by Parliament for the collection of water for the use of these canals, and to obtain such further additional powers as would enable them to collect it in the greatest purity, and marshal it at High Lane, near Marple, a suitable locality for afterwards supplying it to Manchester, Salford, and Stockport, at a great altitude above these towns.

The scheme promoted by the Manchester and Salford Water Works Company was in a short time abandoned. The project of the Corporation of Manchester was sanctioned by Parliament last Session; and, with some modifications, the Manchester, Sheffield, and Lincolnshire Railway Company also obtained the legislative powers sought by them.

The Manchester Corporation however, principally from the opposition raised by the millowners situated on the streams proposed to be affected by their works, bound themselves to apply to Parliament in 1848 for further powers to enable them to make larger reservoirs than were proposed last year, for the purpose of securing to the millowners, for the use of their mills, a regular stipulated quantity of water. According to my judgment the carrying out of the works proposed to be made by the Corporation will be attended with great unnecessary cost to the inhabitants of Manchester, and the water that can be procured will be bad in quality, and inadequate in quantity in dry seasons. The enormous fall of rain calculated on by the Corporation is founded in error*: the large mass of peat

* See Appendix Q. page 87.

and mossy land from which their water is proposed to be collected, cannot fail in warm weather to injure and discolour the water, and in such seasons, organic matter detrimental to health, must be held in solution in water procured from such a source.

I believe the public of Manchester to be strongly interested in closely examining the merits and demerits of this scheme, and I have therefore procured permission from the Directors of the Manchester, Sheffield, and Lincolnshire Railway Company to publish the following Report, made to them on this subject; and should it be found to contain any errors, no one will be better pleased to have them pointed out and rectified than myself. While writing upon the supply of water to Manchester and Salford, it is but right to mention that the notoriously bad quality of the water supplied to the inhabitants of Manchester and Salford, originates, in a great measure, from the number of houses situated on the drainage-ground of the Gorton Reservoirs; the nature of the drainage-ground itself (which is partly moss-land), and the kind of manure (a great portion of which is night-soil and ashes) that is spread in large quantities over the collecting-ground: indeed, the

Gorton Reservoirs may almost literally be looked upon, in warm dry weather, as little better than large cesspools, receiving the drainage and sewerage from a number of houses situated upon its gathering-ground*; and persons who know the river Medlock, will believe that water, procured from this source, is even worse than the water received in the Gorton Reservoirs from its own drainage-ground. For the preservation of the health of the people of Manchester and Salford, it is indispensably necessary that the worst of the water at present draining into the Gorton Reservoirs should be immediately diverted away from them, and a supply of wholesome water procured from other sources. This could be done by the Corporation or Water Works Company entering into arrangements with the Manchester, Sheffield, and Lincolnshire Railway Company to keep the present Gorton Reservoirs entirely supplied with water from the reservoirs of the Railway Company situated near Whaley.

The Railway Company, without the construction of any additional works, can *immediately* enter into arrangements to supply a quantity of water, equal at least to three and a half millions of gallons per

* See Appendix L, page 79.

day in the driest year known; and have the powers, under an Act of Parliament obtained by them last year, to construct additional works, which, when completed, will enable them to supply at least seven and a quarter millions of gallons per day from the same source. Five millions of gallons of this quantity could in a very short time be collected, and supplied to the Gorton Reservoirs. The whole of this water is of the very best quality, averaging only from two to four degrees of hardness in the Company's reservoirs; it is collected from the rain that falls upon very steep land of the well-known Millstone Grit geological formation, and if *regularly* supplied to the Gorton Reservoirs would be very little deteriorated in its passage thither. As soon as the necessary works could be completed, for which the Railway Company have legislative powers, seven and a quarter millions of gallons of water of *the very best quality*, could be delivered per day, filtered, from a proposed service reservoir situated at High Lane, near Marple, at an altitude of 320 feet above Brown-street, Manchester. Whenever any further quantity than seven and a quarter millions of gallons per day should be required, additional legislative powers could be obtained to procure almost any further quantity (say at least twenty millions of gallons of water per day) in connection with the present scheme, without detriment to any private interest. Under these circumstances it is a question for the inhabitants of Manchester to consider whether it would not be much better to make arrangements with the Manchester, Sheffield, and Lincolnshire Railway Company, for a supply of water in bulk*, than to procure it by the prosecution of the Corporation Scheme, which, if ever carried out, *can be of no immediate* benefit to Manchester, and is certain of entailing an enormous expenditure.

"'Tis distance lends enchantment to the view" of the promoters of the Corporation Scheme, and I fully believe distance only. At any rate discussion on a subject of so much importance must be attended with benefit, and can do no harm. This must serve as an apology, if any be needed, for the present publication.

* See Appendix R, page 87.

REPORT,

&c.

To the Chairman and Directors of the Manchester, Sheffield, and Lincolnshire Railway Company.

My Lord and Gentlemen,

I now propose to redeem the promise made in my Report, dated the 31st of July, 1847, and to prove how few are the sources from whence an abundant supply of good water can be supplied to Manchester for domestic purposes; and of these sources, how immeasurably superior is the district of country from which your Company derive their waters for the navigation of their Peak Forest and Macclesfield Canals, and the surplus of which waters (not required for navigation) were, by your Act of the last Session, rendered available, at your discretion, for domestic, trading, and other uses. To enable you the better to follow my remarks, I have prepared the accompanying map of the upland round Manchester, which shows at a glance the whole of the sources from which a supply of water can be collected for the use of Manchester. It also shows, in relative position, the gathering grounds and reservoirs that are now used to supply different towns, canals, and streams, in the immediate vicinity of Manchester, and will be found useful to refer to on this account.

The town of Manchester is situated at an average height of about 120 feet above the mean level of the sea at Liverpool, and is bordered on the North-West, the North, the East, and the South, by high hills and upland that, in a distance varying from twelve to eighteen miles from the town, rise 1100 to 1900 feet above the sea, when they begin to fall in a contrary direction. The highest points in this range of hills are Rivington Pike to the North-West of Manchester, 1545 feet above the mean level of the sea; Blackstone Edge to the North-East, about 1450 feet; Holme Moss to the East, about 1859 feet; Kinder Scout to the South-East, about 1981 feet; Axe Edge, South-East by South, 1751 feet; and Bosley Minns, nearly direct South, about 1260 feet. These hills rise very abruptly, and the numerous vallies and mountain gorges that intersect them in various directions contain channels, called rivers or streams, that drain off the rain which falls upon them. The names of the principal rivers deriving their waters from the sources now pointed out, are the Irwell, the Irk, the Medlock, the Tame, the Etherow, the Goyt, the Dane, and the Bollin. The waters of the whole of these rivers unite in the river Mersey, and by this channel are discharged into the sea at Liverpool.*

The rivers upon which the towns of Manchester and Salford are situated, are the Irwell, the Irk, and the Medlock; the two latter streams joining the Irwell within the town. The area of land upon which the rain falls that feeds these streams before entering Manchester is about 163,000 statute acres; of which about 11,300 drain into the river Medlock; 17,000 into the Irk; and 134,700 into the Irwell; these rivers, like all others having a similar origin, are very irregular as regards the quantity of water which passes down them at different seasons. After a continuance of wet weather, the rains flow off the ground immediately after reaching it; the streams are of course soon swollen, and the quantity of water passing down them in a few hours, is often as much as in dry seasons will pass off in as many weeks or months. These floods, though chiefly of short duration, frequently do considerable mischief (as was the case last year, when the Medlock overflowed in Manchester and inundated Little Ireland), and they are now more sudden and violent than formerly, owing to the great improvement recently made in the drainage of land for agricultural purposes. The courses of the tributaries of the rivers that pass through Manchester, are shown on the ac-

* See Appendix O, page 85.

companying map; and these streams are very remarkable for the many useful purposes to which they are applied. They are made to turn innumerable water-wheels, that give motion to machinery of various kinds; they are used to supply both the means of forming and condensing steam, that, properly directed, performs such a prodigy of labour with unceasing and untiring effect; they are used to scour, bleach, and dye the goods they have helped to spin and weave; and their flood-waters, collected in reservoirs, feed with water the canals and rivers that transport both the raw and manufactured material. They supply our houses with water for domestic purposes, and they perform the office of scavenger; removing from our dwellings the excretion and filth, that, remaining near us, would undermine our health, engender fevers, and cause premature death. If we examine the sources of the river Medlock, and notice the number of offices the water of this stream now performs, besides receiving a great portion of the drainage of the town of Oldham, we shall be satisfied that henceforth no wholesome water can be procured from it for the supply of Manchester; and we shall also be convinced, that what is now collected from it in flood seasons for the town's supply, must be eventually abandoned.

Examining in the same manner the sources of the river Irk, which receives also part of the drainage and sewerage of the town of Oldham, and the drainage and sewerage of Middleton, and Royton, remembering its limited drainage ground and pre-occupation, it will be obvious that no adequate amount of good water can ever be procured from this source for the domestic supply of Manchester. Turning to the map and examining in detail the many sources of the river Irwell, with its tributary the river Roch, and noticing the large towns of Bolton, Bury, Heywood, and Rochdale, with a number of other places situated upon it; and the way in which the ground is pre-occupied with reservoirs formed to collect water for mill-owners, canals, printworks, and the domestic supply of towns; and considering, above all, the difficulty and consequent expense of marshalling and bringing such water, when collected, into Manchester, I believe we may rest satisfied that, although a supply of water might be procured in this direction, yet that it could not be brought into the town without a very heavy expense.

Turning, then, from the upland that drains direct through Manchester, to the sources of the river Tame, the Etherow, the Goyt, the Dane, and the Bollin, that unite in the river Mersey below Manchester, we find that the river Tame, to its crossing of the canal in Ashton-under-Lyne, receives the drainage from 25,280 statute acres, of which the flood-water (or that passing down the streams after heavy rains) belongs to the Huddersfield, and the Ashton Canal Companies, and that the whole course of this stream and its tributaries are studded with mills. Notwithstanding this, a large quantity of water, I have no doubt, might be procured in this locality for the supply of Manchester without detriment to private interests, if the high land that forms a large portion of the top boundary of the drainage ground were not covered with peat and moss, which would so discolour and deteriorate the quality of the water in certain seasons of the year, as to render it, when collected, unsuitable for the domestic supply of a town. The only remaining sources, then, from which water could be collected to supply Manchester, are from the rain that falls upon the high land directly East of Manchester, and which at present drains into the river Etherow in the valley of Longdendale, and from the rain which falls on the high land South-East and South of Manchester, and which at present drains into the rivers Goyt, Dane, and Bollin.

You are aware that it is from the top portion of the drainage ground of the river Etherow (which consists, to its junction with the Goyt, of 36,170 statute acres) that the Corporation of Manchester propose to collect water for the use of the town of Manchester; and that it is from a portion of the drainage ground of the river Goyt (which consists to its junction with the Etherow of 42,070 statute acres), and from a portion of the drainage ground of the rivers Dane and Bollin, South of Manchester, and above the level of the Macclesfield

Canal (which consists of 22,800 statute acres), that you last year obtained legislative powers to collect and sell the surplus water not required for the use of the Peak Forest and Macclesfield Canals.

I think, for the reasons before given, that it may be fairly admitted that the two sources last-mentioned are the only ones truly available for a supply of water for the use of the inhabitants of Manchester; and I now propose to compare these two sources together, and to examine the relative value of each of them for the purpose of affording a pure and permanent supply of water to Manchester and Salford, as well as to Stockport.

In laying out a scheme to supply a town-population with water, it is of the very first importance that the *quality* of the water to be procured for this purpose, should be at *all seasons* of the year of the best description it is practicable to obtain; that the sources from which the water is to be obtained shall be capable of yielding a supply equal to the present, and any future demand likely to arise for at least twenty years to come; and that the cost of such water distributed to the inhabitants should be as low as is compatible with the first two propositions. If any two schemes should be equal in the first two respects, the cheapest is of course to be preferred; but if the same quantity of water, but of a bad or doubtful quality only, could be obtained at the lower price, then it would be preferable to choose the water of better quality, even at a somewhat greater first cost. The scheme of the Corporation of Manchester for supplying the town with water, as shown on the parliamentary plans deposited for 1848, is marked on the accompanying map (viz. at the top of the river Etherow, and East of Manchester); it proposes to impound the rain that will flow off about 18,000 statute acres of land in the valley of Longdendale, in five large impounding reservoirs, capable of containing collectively about 584,866,716 of cubic feet*: and, according to the report to the Corporation from their engineer, published in the *Guardian* newspaper of August 7. 1847, after the millowners shall have been supplied from these reservoirs, with seventy-five cubic feet of water per second for twelve hours of every working day, the remaining portion is to be taken to Manchester and distributed for the use of the town. To accomplish these last objects, the Corporation propose to construct a tunnel of a mile and a half long, through a hill near Mottram, and certain conduits or water courses, which are shown on the accompanying map, together with various service reservoirs, and a line of cast iron pipes. To make the water supplied to the millowners as useful as possible to them, the Corporation also propose to construct certain additional reservoirs for the mill-owners' use; the situations of which are likewise marked on the accompanying map.

To ascertain the *quality* of the water that can be

* See Appendix A, page 63.

collected by this scheme, the nature of the ground on which the rain falls, and *off* which it flows, into the impounding reservoirs must be ascertained; for rain flowing off the sides of hills into reservoirs, like rain flowing off the roof of a house into a rain butt, will be contaminated if it come in contact with any impurities that are capable of mixing with it, or being taken up in solution. Every one used to a manufacturing town must have noticed the sooty colour of rain water running from the roof of a house down its gutters, especially when a continued drought has been followed by a smart shower. Now, of the 18,000 acres off which the Corporation of Manchester propose to catch the rain, upwards of 12,000 acres, or *two thirds* of the whole quantity*, are covered with a decaying and decayed vegetable matter called peat, varying from twelve inches to twelve feet in thickness, the water passing off which, after rains in hot or warm weather, is something of the colour of dark sherry. By referring to the accompanying map, it will be seen that the moss or peat land is coloured brown, and the clear land tinted green; and that it is so intermingled as to render impossible any attempt to separate the water flowing off the peat land, from the water flowing off the comparatively clear land. It is true, that in a drought, and especially in cold weather, the water runs down the streams colourless, and but little contaminated with impurities; but the great bulk of the water (probably as

* See Appendix A, page 62.

much as three fourths of the whole quantity) flows off the ground immediately after rains, and comes down in a discoloured state, either holding in solution or mechanical admixture, according to the temperature of the atmosphere and the season of the year, a large portion of peaty and objectionable matter.* It is *argued* that this matter may be got rid of by standing in reservoirs; but the proofs are to the contrary. The town of Sheffield is supplied with water from a large reservoir at Redmires (situated high up in the hills to the West of the town), and capable of containing above 30,000,000 cubic feet of water. This reservoir receives the drainage from 912 statute acres of land, of which 670 acres are good pasture land, and 242 acres only, are moor or peat land; while the superstratum of peat is only from six inches to four feet in depth, and is firm, and clothed with grass, intermingled with a small portion of heath. After the water leaves this reservoir, it passes along an open conduit four miles in length, and is then mixed in other reservoirs with water, draining from 820 acres of clear pasture land; and yet this comparative small quantity of shallow peat land (being about one fourth of the total quantity draining into the Redmires' reservoir, and one eighth only of the entire gathering ground) so discolours the water, that Mr. James Smith of Deanston, in the Second Report of the Commissioners for Inquiring into the State of Populous Towns and

* See Appendix B, page 63.

Large Districts, page 316, remarks on the dark colour of the water, and strongly recommends filtration. It is notorious, too, in Sheffield, that the Water Works Company's water is discoloured, especially after heavy rain following a drought.

In a Report lately published on the sanatory condition of the borough of Sheffield, by James Haywood, Esq., professional chemist; and William Lee, Esq., C.E., the former, in mentioning the supply of water to Sheffield, remarks, page 54: "The water supplied from the Company is obtained from the hills of Millstone Grit in the high moors about six miles West of the town. It is there gathered into an extensive reservoir at the Redmires', from which it descends in a rapid stream to dams in the neighbourhood of Crookes. The water in the Redmires' reservoir is somewhat coloured by the peaty matter from which it flows; but this is *nearly all* converted into carbonic acid and water by oxidation in its rapid descent along the open feeder above-named: so that by the time it reaches the dam from which the town is supplied, it *is nearly* colourless." A chemical analysis is also given in the same page of the Report, which shows that each imperial gallon of the water contains *one and six-tenths of a grain of organic matter from peat.* No information is given in the Report as to the time of year, or temperature of the air, when this water was collected for analysis; but, considering the water analysed to be a fair average specimen, the evidence shows that the water flowing off a drainage ground of which only *one-eighth* part is covered with comparatively *shallow peat*, after being collected in a large reservoir and running through an open conduit four miles in length, is discoloured and impregnated with organic matter; what, then, is to be expected from the quality and colour of water flowing off ground *two-thirds* of which is covered with moss and peat, varying from twelve inches to *twelve feet* in thickness? The town of Bolton affords another instance. It is supplied with water from a reservoir about four miles North-West of the town, as shown on the accompanying map; this reservoir is supplied to a great extent from springs, but partly by surface drainage from land, a portion of which is covered with coarse grass growing over peat. Many thousand pounds have been expended to prevent the water being injured by the peat; and an attempt to separate the peat from the water by filtration has proved a complete failure.

Notwithstanding these facts, it is that very rain water falling upon, and collected from, such ground as before described, that the Corporation of Manchester are persevering in a project to collect for the use of the borough of Manchester. I can only account for this upon the supposition that sufficient care has not been taken to examine the quality of this water after heavy rains, especially in the summer and autumn seasons; for it is notorious to all persons living in the neighbourhood of these streams, that at such times the water is totally unfit for domestic purposes.*

The *quantity* of water that can be collected in reservoirs from a given area of ground, will depend upon the depth of rain, per annum, falling *on* the gathering ground; upon the amount of this rain flowing off the ground, and not lost by evaporation, soakage into the ground, or other cause; and upon the *size* or *capacity* of the reservoirs constructed to impound or catch the water after heavy rains. The plan of collecting, in reservoirs, the rain water that falls on hill sides, for the supply of a town, may be compared, as already stated, to the system, commonly used, of catching in a butt or cistern the rain falling upon the roof of a house; if a small butt be placed to catch the rain flowing off the roof of a large house, it will frequently happen, in seasons of dry weather, that the butt will be empty, and the inhabitants in want of water; while, in seasons of heavy rain, the butt will overflow, and a large body of water run to waste: in this case, by enlarging the butt, more water would be caught in wet weather, and, of course, a larger supply stored for use in dry weather. When, however, the butt shall have been enlarged to such a capacity as to catch all the water falling in the rainy season, any further enlarging the butt would be useless; as it can only catch from the roof of the house *all* the rain flowing off it. The

* See Appendix P, page 85.

same reasoning applies to entire years, as to seasons of a year. The depth of rain falling on and flowing off the roof of a house varies considerably in *different* years; in *one* year *double* the quantity of rain occasionally falls in a given place compared with another year; but it sometimes happens that two or three dry years, or two or three wet years follow one another. Now, if a butt, collecting water from the roof of a house, be only large enough to collect the water flowing off it in dry years; it is evident a large body of water will run to waste in wet years; and if the butt be made large enough to collect all the water that flows off in wet years, and, so enlarged, be only adequate to supply the wants of the inhabitants, then the butt will never be *filled* in dry years, and the inhabitants dependent on it in such years will not have a sufficiency of water. If, however, the whole quantity of water collected in wet years be not used (supposing no loss from evaporation), then the quantity of water that could be *regularly* yielded by the butt would depend upon the depth of rain falling on the roof of the house and flowing off it, in the AVERAGE of years, since the water falling in wet years would be stored from wet to dry years: the size of the butt, however, required for such a purpose, must of course be very large, as it must be sufficient to contain the superabundance of a succession of wet years, in order to compensate for the deficiency of a succession of dry ones. The *total* quantity of rain falling on the roof of a house will not always flow off into the butt; as, in very light showers, in windy and warm weather, especially on roofs not very steep and covered with tiles or thatch, a large portion will be lost by evaporation and carried off by the wind; while in heavy showers, after continued rain, such showers will nearly *all* flow off, and may be collected.

The only essential difference, between collecting in reservoirs, water that flows off the sides of hills in rainy weather, and collecting in butts water from the roofs of houses, consists in the circumstance that a much larger quantity of rain in the former case, is lost from evaporation, soakage into the ground, and supporting vegetation; this is especially the case where the tops of the hills are flattish, and covered with an absorbent material like peat, which holds water like a sponge, and exposes it for a length of time to the influence of the wind and sun; and where the soil is open and porous, and will admit of water percolating through it. To ascertain, then, the *quantity* of water that can be collected by the Corporation scheme, it is first requisite to know the depth of rain falling in a given time on the ground, from which it is proposed to collect water, the area or extent of this ground, its form, its geological character, and the nature of the covering that composes its surface, as well as the capacity of the reservoirs proposed to collect the rain flowing off it. The depth of rain is capable of being determined by suitable rain-gauges, placed among the hills, and observed for a series of years; or, if this have not been done, a very approximate estimate may be formed by ascertaining the amount or depth of rain that has fallen for a series of years in the immediate vicinity. By referring to the accompanying map, the position may be found, marked thus ⊙, of rain-gauges that have been kept, for a series of years, at Belmont and Bolton (North-West of Manchester); at Bury and Rochdale (to the North); at Blackstone Edge (to the North-East); and at Marple, Comb's Reservoir, and Chapel-en-le-Frith (to the South-East). The following table shows the result of observations made with those gauges, and gives the height of the ground on which each rain-gauge is placed above the level of the sea. And another table gives the result for the last year, of observations made with gauges placed to the East and South-East of Manchester among the hills.

Note. — The form of the gauges used at Sharples, Bury, Fairfield, Marple, Comb's Reservoir, and Chapel-en-le-Frith, are all similar in construction to those employed by the Literary and Philosophical Society of Manchester, see Pla-e I. The staffs of these gauges are half an inch diameter, with the exception of the gauge fixed at Sharples, which has a staff three-fourths of an inch diameter; these gauges have been regularly emptied once a month of the water collected in them: the form of the gauges used at Bolton, Newton, Woodhead Tunnel, and Brinks, are funnel gauges fixed near the ground, similar to that shown on Plate III.; the gauge used at the Whiteholme Reservoir is a funnel gauge fixed on the roof of a house. The whole of the staff gauges show, in all probability, an excess of the quantity of rain actually fallen. (See Appendix C.)

TABLE,

Showing the Depth of Rain fallen per annum for a series of years in different places situated in the upland to the West, North-East, and South of Manchester, as shown on the accompanying map.

Years.	Belmont Spring water reservoir, Sharples, near Bolton, 850 feet above mean level of the Sea.		Bolton about 320 ft. above mean level of the sea.		Bury about 300 ft. above mean level of the sea.		Rochdale about 500 ft, above mean level of the sea.		Whiteholme Reservoir, Blackstone Edge, about 1500 ft. above mean level of the sea.		Fairfield about 220 ft. above mean level of the sea.		Marple about 531 ft. above mean level of the sea.		Comb's Reservoir about 720 ft. above mean level of the sea.		Chapel-en-le-Frith, Engine Station, about 1121 feet above mean level of the sea.	
	ins.	tenths.	ins.	tenths.	ins.	tenths.	ins.	tenths.	ins.	tenths.	ins.	tenths.	ins.	tenths.	ins.	tenths.	ins.	tenths.
1832			53	·77	37	·96	43	·32	31	·63								
1833			51	·70	50	·61	56	·73	47	·37								
1834			43	·98	42	·48	42	·41	39	·94								
1835			46	·44	43	·94	47	·97	36	·43								
1836			53	·78	49	·57	61	·11	41	·25								
1837			42	·25	44	·05	45	·30	38	·17								
1838			47	·85	43	·28	45	·42	35	·55								
1839			45	·26	40	·70	45	·76	35	·79								
1840			45	·03	38	·83	44	·00	36	·90							48	·48
1841			53	·87	47	·37	48	·55	33	·50							52	·30
1842			38	·63	34	·49	37	·08	30	·70							41	.60
1843	63	·4	49	·40	40	·47	50	·59	36	·10	38	·00					41	.20
1844	50	·0	34	·63	28	·65	34	·41	24	·80	26	·35	29	·40	42	·70	33	·00
1845	55	·0	48	·11			51	·64	39	·80	38	·90	38	·80	51	·10	43	.90
1846	49	·8	40	·82			42	·04	37	·10	30	·20	32	·35	38	·10	38	·80
1847	61	·4	52	·32			51	·72	35	·70	40	·75	43	·70	51	·30	44	·00
Means	53	·92	46	·74	41	·72	46	·75	36	·29	34	·84	36	·56	45	·80	42	·98
Lowest	49	·8	34	·63	28	·65	34	·41	24	·80	26	·35	29	·40	38	·10	33	·00

TABLE,

Showing the Depth of Rain fallen during the past year of 1847, at various places situated in the upland, East and South of Manchester, as marked on the accompanying map.

1847.	Newton Station, 350 ft. above mean level of the sea.		Woodhead Tunnel, about 1000 ft. above the mean level of the sea.		Comb's Reservoir, about 720 ft. above the mean level of the sea.		Comb's Ridge, about 1670 ft. above the mean level of the sea.		Todd Brook Reservoir, about 620 ft. above the mean level of the sea.		Brinks, about 1500 ft. above the mean level of the sea.	
	ins.	tenths.	ins.	tenths.	ins.	tenths.	ins.	tenths.	ins.	tenths.	ins.	tenths.
	34	·69	33	·12	51	·30	35	·85	38	·39	29	·50

Note.—The observations for Belmont were procured from J. Magnall, Esq.; and for Bolton from H. H. Watson, Esq.; from Bury, from J. Norris, Esq., F.R.A.S., who, since September, 1845, has removed to Howick House, near Preston; from Rochdale, from J. Ecroyd, Esq.; from Blackstone Edge, from Mr. R. Mathews, the Engineer of the Rochdale Canal; and the rest from observations supplied by J. Meadows, Esq. The whole of the observations, with the single exception of Blackstone Edge, were made with rain gauges, fixed very near the ground.

From this table, it will be seen, that the depth of rain falling at the same place, is very unequal in different years; that the ratio which the fall of rain bears in one year, at one place, to the fall in another year, at the same place, follows no regular law; that the greatest amount of rain appears to fall West of Manchester * (which may be accounted for from its being the nearest to the sea); that the *average* depth, fallen in a series of years at Bury, does not exceed 41 ·72 inches in depth; at Blackstone Edge 36 ·29 inches in depth; at Marple 36 ·56 inches in depth; at Comb's reservoir 45 ·80 inches in depth, and at Chapel-en-le-Frith 42 ·98 inches in depth. And the *lowest* annual depth falling at the same places, does not exceed, at Bury 28 ·65 inches in depth; Blackstone Edge 24 ·80 inches in depth; Marple 29 ·4 inches in depth; Comb's reservoir 38 ·10 inches in depth; Chapel-en-le-Frith 33 ·0 inches in depth. A glance at the accompanying map will show, that the places named, varying in position as they do, both North and South of the Corporation gathering-ground, and not far distant from it, might very fairly be taken, as indicating the amount of rain falling in that locality in the absence of all other proof on the subject. The amount of rain, however, that has fallen during the last year on the Corporation gathering ground, has been ascertained by a funnel rain-gauge, nine inches diameter, placed near the ground at the Woodhead Railway tunnel, which shows that a depth of only 33 ·12 inches fell there during the last year †; another gauge was also fixed

* See Appendix Q, page 87. † See Appendix D, page 74.

near the same place, higher up the hill, but only a few months' observations have been taken with it, owing to its having been several times maliciously injured. These last observations, however, invariably show a LESS amount of rain fallen in the same time, than was registered in the gauge placed lower down the hill *; if, therefore, the *average* depth of rain falling per annum, in this locality, be taken at 44 ·0 inches in depth, and the lowest at 36 inches in depth, this quantity will be rather *over* than under the mark. † The proportion of the depth of rain falling *on* the ground, that will *flow off* the ground, and find its way into reservoirs, will be much less in this locality, than in many others; for although the sides of its valleys and gorges are very precipitous, yet the higher ground, which forms the great bulk of the collecting ground, is comparatively flat; and, as before stated, more than 12,000 acres, out of 18,000 acres, are covered with peat and moss, varying in depth from twelve inches, to at least twelve *feet*, which, after heavy rains, become covered with shallow pools of water; this peat and moss, at once operates to absorb the water itself, and to hold an enormous surface exposed to the action of the wind and sun; occasioning a large amount of the rain-fall to be evaporated, and carried away by the wind. Evaporation takes place much more rapidly, on elevated, than on low land; and in the hygrometrical tables, published by James Glaisher, Esq., of the Royal Observatory, Greenwich, 1847,

* See Appendix C, page 66. † See Appendix Q. page 87.

it is stated, p. 9.: "Water evaporates in the open air at very low temperatures, and the vapour rising in the air mixes with it in an invisible form until it is condensed, and assumes that of clouds, fogs, mists, or falls in the shape of rain.

"The amount of water thus changed into vapour is very large indeed. From experiments I have made during the years 1844, 1845, 1846, it appears to be nearly fifty inches annually. It is probable, that this quantity is much above the average; but all experiments that I have seen justify us in assuming that the average evaporation is thirty inches annually."

No very accurate information exists as to the proportion of the rain falling in different localities that is lost by evaporation, soakage into the ground, and supporting vegetation. This can only be arrived at, by ascertaining, for a considerable period (for dry years, wet years, and different seasons of the year, give a varying result), the depth of rain falling on a given area of ground, and the amount flowing off it: this is a very tedious operation, unless an expensive, self-registering apparatus, be fixed for the purpose. To ascertain the quantity flowing off the ground with any thing like accuracy, the stream receiving the drainage of a known area should be measured, at least every hour, both day and night *; and in certain seasons, every half-hour. Such experiments have been tried for short periods, and the inference drawn from them as well as from the yield of certain reservoirs that

* See Appendix E, page .

impound all the water flowing off a known area of ground, is, that on the average of the year, two-thirds of the quantity of rain falling on the ground, in steep valleys, will flow off, and may be impounded. I am of opinion, that in such situations, this amount is very near the truth; but, considering the great proportion of table-land constituting the Corporation gathering-ground, the large extent covered with peat and moss, and the unretentive nature of its sub-soil, I am fully of opinion that five-ninths of the quantity of rain falling on the ground, is all that can be calculated upon as flowing off it on the average of a commonly dry year. The exact area of land that slopes towards, or drains into, the reservoirs proposed to be constructed by the Corporation of Manchester, consists of 18,190 statute acres, and the number of cubic feet of water, the proposed reservoirs can contain, when full, is 584,866,716; which in equal to about 32,000 cubic feet of storage room per acre of drainage ground. This amount of storage room is by no means large, and will store but very little water, if any, from a wet, or average year, to a dry one.* This will be understood, from the fact that less than nine inches of water in depth, flowing off the collecting ground, will entirely fill the whole of the reservoirs, so that if these reservoirs were all *completely* full at the commencement of a couple of dry years following one another, a quantity of water equal

* See Appendix F, page 75.

to $4\frac{1}{2}$ inches in depth spread over the area of the collecting ground, would be *all* the assistance that could possibly be derived from this source; but as the fall of rain in any given year is very unequal in different months, it may, and indeed always does happen, that 6 or 7 inches in depth more will flow off the ground in two or three months consecutively, than will flow off at another period in the same time; and, unless the reservoirs be sufficiently low to admit this quantity as it falls, it will flow over the tops of the reservoirs and run to waste. Merely to equalize, and regulate for constant use, the amount of rain falling in heavy gluts in a dry year, so that the same quantity of water may be drawn from the reservoir every day in the year, it is found that a storage-room of *at least*, 24,000 cubic feet per acre of drainage ground, should be provided: this is equal to something more than a depth of $6\frac{1}{2}$ inches of rain flowing off the ground, so that, deducting $6\frac{1}{2}$ inches from 9 inches, $2\frac{1}{2}$ inches remain; and half this quantity, or $1\frac{1}{4}$ inches in depth over the whole area of collecting ground, is all the assistance that the storage-room can yield to the current flow of water from off the ground, in the event of two dry years succeeding one another.* Taking therefore 36 inches to be the depth of rain falling on the land in a dry year,

* This calculation is made on the supposition that the same amount of storage-room, when the whole of the water flowing down the stream is impounded, will suffice to regulate the quantity of water yielded to the mill-owners, as when the flood waters only are collected, this is a *very favourable* supposition for the Corporation scheme.

and assuming, as before stated, $\frac{5}{9}$ths of this quantity or 20 inches, as the depth that will be impounded; add to this, the $1\frac{1}{4}$ inches in depth yielded from the surplus storage of the reservoir, and $21\frac{1}{4}$ inches in depth calculated over the gathering ground, is all that can be depended upon; and this quantity, especially in the drought of summer, will be subject to a deduction, *when* collected in the reservoirs, from evaporation from the surface of the water, and other causes; so that it would not be prudent to calculate on an anuual amount of available water greater than 20 inches in depth, over the Corporation collecting ground. Now this quantity of 20 inches, after the millowners are supplied with the 75 cubic feet per second promised them for twelve hours of every working day, would yield only $5\frac{1}{2}$ millions of gallons of water per day for the use of the inhabitants of Manchester. It is true, that the promoters of the Corporation scheme, may contend that in the driest season, a certain quantity of water more than falls on the collecting ground flows out of the Woodhead Tunnel, which will assist in seasons of drought*; but against this, it must be remembered, that in warm or hot weather, and in seasons of drought, from 20 to 30 per cent. more water will be required for the use of a town population, than in wet or cold weather; and the amount of water that in such seasons flows out of the tunnel will hardly make up for this extra-requirement. Without at present entering into the question of the cost of this

* See Appendix G, page 75.

quantity of water, when collected for the use of Manchester, and only remarking that no provision whatever is made to filter it *, I will proceed to examine by the same rules as have been applied to the Corporation scheme, the quantity and quality of the surplus water that can be yielded, and collected from the gathering-grounds set apart for the Peak Forest and Macclesfield canal reservoirs, and which is placed at the disposal of your Company by the Act of last year.

Referring to the accompanying map, about eight miles South-East of Manchester, the summit level of the Macclesfield canal, will be found, stretching to the South, along the side of a ridge of high hills, and extending from Marple, to Bosley, a little beyond Macclesfield. The top level of this canal is more than sixteen miles in length, without the interruption of a lock, and at Marple it joins the summit level of the Peak Forest canal, which stretches for about eight miles, in a south-easterly direction, along another side of the same ridge of hills to Whaley. The top level of both these canals are of the same height, being situated at an elevation of about 520 feet above the mean level of the sea at Liverpool, or 380 feet above Brown Street, Manchester: both canals are thirty feet wide at the top, and five feet deep, and are constructed in the most substantial manner. The Peak Forest canal proceeds down a series of sixteen locks from Marple, in a northerly

* See Appendix H, page 78.

direction, to join the Ashton canal which connects Ashton with Manchester; and the Macclesfield canal proceeds, down a series of locks, from Bosley a little beyond Macclesfield, in a southerly direction, to join the Trent and Mersey canal that communicates with Liverpool and the Midland Counties. To supply with water the locks of the Peak Forest, and the Macclesfield canals, the Company are empowered, by Act of Parliament, to collect and impound the flood water flowing down certain streams which are fed from the rain that falls on an area of ground that will be found on the accompanying map, coloured green; reservoirs have been constructed to impound this water, and two will be found, coloured blue, near Bosley, which have been made and used for a series of years to supply the locks of the Macclesfield canal. Near Whaley, at the South end of the Peak Forest canal, two other reservoirs, also coloured blue, will be found, which have been made and used for a series of years to supply the locks of the Peak Forest canal; the Company have also powers to construct another reservoir on the Hockham brook, to the East of Whaley, for the use of this canal, and they collect certain water from the Reddicar brook that is not at present impounded in a reservoir, but runs into the Macclesfield canal about four miles South of Marple; in addition to this, all the water flowing off a large area of land from the hill sides, along which these canals wind their course, finds its way into the canals.

An important difference exists, between the method proposed to collect water in the Manchester Corporation reservoirs at Longdendale, and the method by which the Company owning the Peak Forest and Macclesfield canals derive their supply. In the former case, the WHOLE of the water flowing down the streams, at all times and seasons, is proposed to be impounded; and the millowners on the streams, below the reservoirs, are to be compensated for the abstraction of such streams by having measured out to them from the reservoirs a *regular*, and *unvarying* quantity, for twelve hours of every working day, for their use.

The Company are not empowered to collect the *whole* of the water which flows off the hill-sides, and finds its way down the streams, near which their reservoirs are situated; on the contrary, in dry seasons, and at such times as the quantity of water flowing down the streams at a given point, will flow through a given-sized orifice, called a gauge, the whole of the water passes down the stream to the millowners; but when continued or heavy rains, cause the streams to be swollen, then the whole of the water that will not pass through such gauge is impounded above the gauge in a reservoir constructed for the purpose, and such water, so impounded, belongs to the Company. This system of collecting water is very favourable to its *purity*, as when it flows off the hill-sides during heavy rains (except in a peaty or boggy district) it is much less contaminated than water (percolating slowly from the soil, and reduced in quantity by evaporation) which forms the streams in dry weather; besides, over most large tracts of land, consisting of thousands of acres, there will be found farm-houses and a considerable resident population, and all the excretion and filth created from these sources, with the soluble parts of manures placed on the land, must, of necessity, drain into the streams, and tend to foul them in comparatively dry weather, although, in heavy rains and floods, the water is not perceptibly soiled from these impurities. The system of only catching and impounding the flood water, is also attended with this advantage, that the mill-owners below the reservoirs are not only uninjured thereby, but frequently benefited to a considerable extent, as the water passing by them, after heavy rains, is far too large in quantity, and too sudden in its appearance and disappearance, to be of any use to them, and frequently does considerable damage by back flooding water wheels, inundating low land, and carrying away buildings and minor erections. The system of catching flood-waters only for the use of canals, has been found in practice eminently successful; the Peak Forest canal, from the time it was completed, forty-eight years since, has been entirely dependent upon the collection of flood-waters in reservoirs for the supply of its locks, and this system has always been found adequate for the purpose. Upon examination, the plan of collecting the flood-waters only of a stream for the use of a canal or town, will be found much more advantageous and practicable, than endeavouring to impound the *whole* of the water flowing down such stream, and supplying, first a REGULAR quantity to millowners, and afterwards taking the irregular and *uncertain residue for the use of a town or canal.* As already stated, the amount or depth of rain falling in one year, varies so much from the depth of rain falling in another year in the same locality, that *double* the depth of rain will sometimes fall in one year, compared with another year; and to attempt to impound this water, and yield any considerable quantity of it REGULARLY to millowners, is practically so expensive, that only two instances occur, on the large area of country shown on the accompanying map, of impounding reservoirs having been resorted to by the millowners themselves, on a scale of any magnitude, at *their own* expense.

The Turton and Entwistle reservoir, a few miles to the North of Bolton, was made by millowners in the years 1835 and 1836; although the site for its construction was very favourable, and the reservoir itself be large enough to contain about 50,000 cubic feet of water for every acre of ground draining into it, (or 50 per cent. larger in proportion to the ground draining into it, than the reservoirs proposed to be constructed by the Corporation of Manchester,) yet its success has not induced millowners to lay out more money in this manner; the other instance consists in the formation of a small millowner's reservoir near Glossop, about twelve miles East of Manchester, and which will be found on the accompanying map. When it is remembered that the interest of capital laid out in constructing, and the expenses attending the wear and tear of a reservoir, will always remain a permanent expense against the millowners constructing them, whether the mills be at work or idle; and also the cheap rate at which steam power can be employed, since the principle of expanding steam in the cylinder of a steam engine has been adopted, and that the quantity of coals consumed by a steam engine is very nearly in proportion to the work done, the reasons become fully apparent why money expended in constructing such reservoirs for millowners' purposes cannot be profitably invested. Before the introduction of steam power, a dry season compelled a millowner, driving his machinery by water power, frequently to stop the greater portion of his operations for many weeks and months together: now few water wheels, of any size, are at work without a steam engine set up in connection with them; so that steam power supplies the want of water power, in a dry season, or a very dry year, and will in most cases be found more profitable for millowners' purposes, than the expensive process of erecting impounding reservoirs to collect water in time of floods, and give it out in seasons of drought; no better confirmation of this view can be found, than in the almost universal adoption of subsidiary steam engines among millowners using water power.

The very uncertain and irregular amount of water running down streams, deriving their supplies of water from the drainage of hill-sides is notorious. In Rees' Cyclopædia, article Canal, it is stated: "In the great contest about the Rochdale canal, Mr. Rennie had all the streams which could be affected by the proposed reservoirs, gauged for about a year. He first ascertained the state of those streams at a time when the mills were amply supplied with water, and had proper gauges fixed upon them. The daily difference was measured, and the *surplus*, thus ascertained, amounted in the year 1793 to *sixteen times the ordinary produce* of the rivers." An examination of the books kept by the officers of the Peak Forest Canal Company, which contain, for a series of years, the amount of water running down the brooks, the surplus water of which feeds the reservoirs of this canal, combined with my own experiments on the subject, convince me, that, even in a commonly dry year, at least three-fourths of the water flowing down mountain streams, is not only not used by the millowners, but that, supposing the millowners were to combine to make impounding reservoirs, the amount of power procured in this way, would be much dearer to each millowner than steam power.

The millowners, then, when the plan is adopted of only impounding *flood-water*, are quite uninjured, and even benefited, by being relieved of a portion of the floods that frequently injure them in times of heavy rain: and a Canal or Water Company adopting this plan, know, from the capacity of their reservoirs, the amount of water they can depend upon for their own use. While, by adopting the contrary plan of impounding, or endeavouring to impound, the *whole* of the water passing down a stream, and giving out *first*, a *regular* and *constant* supply to millowners, and, *secondly*, depending upon the residue for their own use, it will be found, that additional costly reservoirs must be made of at least double or treble the capacity (in proportion to the ground draining into them) than would otherwise be required; and, even with such additional reservoirs, if a liberal supply be constantly guaranteed to the millowners in *dry* seasons of dry years, when most water is wanted, a scarcity is certain to be felt by those who are dependent on such residue.

A great portion of the depth of rain that falls in any given locality in a twelvemonth, occupies but a very short space of time in falling; and although in the vicinity of high lands and mountain districts, a larger depth of rain descends per annum than usually falls in flat level districts of country at a distance from upland, yet the number of days on which the rain actually falls, is usually *less* among the hills, than on flat land: this general fact was recognised by Sir Walter Scott in his allusion to the—

"Land of the mountain and the flood,"

and the following Table proves it:—

Names of Places.	Mean Level above the Sea.	Total Depth of Rain per Annum.	Total Number of rainy Days in the Year.	Number of Days in the Year on which Rain fell equal to, and exceeding, four-tenths of an Inch per Day.	Total Depth of Rain fallen per Annum exceeding four-tenths of an Inch in 24 Hours.	Greatest Depth of Rain fallen in 24 Hours.	Least fall of Rain in 24 Hours, when any Rain fell.
1844.	Feet.	ins. tenths.			ins. tenths.	ins. tenths.	ins. tenths.
Manchester - -	120	26·53	180	14	9·37	1·36	·01
Marple - - -	531	29·40	101	32	18·30	2·90	·10
Combs - - -	720	43·40	146	37	24·70	1·50	·05
Chapel-en-le-Frith	1121	33·00	124	30	18·00	1·10	·10
1845.							
Manchester - -	120	42·41	230	31	19·73	1·48	·02
Marple - - -	531	38·80	128	29	22·30	2·10	·05
Combs - - -	720	57·00	176	55	36·50	2·00	·05
Chapel-en-le-Frith	1121	43·80	142	50	28·9	1·70	·10
1846.							
Manchester - -	120	33·67	201	19	11·66	·77	·01
Marple - - -	531	32·35	152	17	9·7	·80	·10
Combs - - -	720	38·10	162	37	20·5	1·00	·075
Chapel-en-le-Frith	1121	38·80	136	32	19·20	1·20	·10
1847.							
Manchester - -	120	43·35	212	39	24·23	1·20	·005
Marple - - -	531	45·70	110	46	30·70	2·30	·100
Combs - - -	720	51·30	158	43	28·80	2·00	·050
Chapel-en-le-Frith	1121	44·10	142	38	21·10	1·30	·100

Note.—The observations from which this Table is formed were procured for Manchester, from Messrs. Ronchetti, of 43. Market Street; and for the remaining places, from Mr. John Wood, the Company's engineer, from gauges fixed near the ground.

The observations from which this Table has been made, were taken once in twenty four hours; and, doubtless, if the observations had been taken every hour, they would have shown the amount of rain, registered as falling within the twenty-four hours, to have actually fallen in very much less time; for instance, it was shown by a rain-gauge, fixed at Waterhouse lock, that, from seven o'clock in the evening on the 8th of May, 1847, to seven the next morning — or in twelve hours — a depth of 2 inches of rain fell; and on May the 9th, 1847, a rain-gauge fixed at the Comb's reservoir, not far from Chapel-en-le-Frith, caught 1·8 inches in twelve hours. And in the "Meteorological Observations," by Dr. Dalton, p. 37., second edition, he remarks, that on the 22d of April, 1792, at Kendal, 4·592 inches of rain fell in twenty-four hours. It is no very uncommon circumstance for $\frac{3}{10}$ths of an inch of rain to fall in hilly districts in one hour: and, to give one instance out of many, this quantity fell near the Comb's reservoir, and was registered by the gauge-keeper on the 5th of April, 1847. By examining the Table given above, it will be found that more than half the rain that fell at Chapel-en-le-Frith, in 1844, was registered to have fallen in the short space of thirty days; and if the fall of rain had been registered every hour, instead of every twenty-four hours, it would have been found to have fallen in a much less space of time. At the same place, in 1845, 28·9 inches in depth fell in fifty days, out of 43·8 inches, the total fall during the whole year.

It must be remembered, when the heavy rains here described fall, a very much larger proportion of these rains flow off the ground, and can be collected in reservoirs, than of the lighter description of rains, for a very small portion of heavy rain is lost by evaporation and soakage into the ground, compared with the lighter rain, and the water runs off the ground less contaminated with impurities, unless, indeed, the ground on which the rain falls, and off which it flows, be covered with peat and moss (as is the case over a large portion of the proposed Manchester Corporation collecting ground), when heavy floods cut deep channels through the peat, and the water flows off mixed and contaminated with its loose particles.* Taking the low fall of rain that fell in 1844 at Chapel-en-le-Frith, as being only 33 ins. in depth for the whole year, and seeing that 18 ins. in depth of this quantity fell on the ground in considerably less than thirty days; and remembering that of the quantity so fallen, by far the greatest portion flowed off the ground within a few hours of reaching it, the large amount of surplus water that can be collected, with considerable advantage to all parties, may be estimated, and will fully bear out the conclusions of Mr. Rennie in the contest about the Rochdale Canal before-mentioned.

* See Appendix B, page 63.

The area of ground from which the Company are empowered to collect flood-water in the Peak Forest Canal district is tinted green, and may be found on the accompanying map, a little to the South, South-East, and East of Whaley; the rain falling on the land to the East of Whaley, draining in the Hockham Brook, has never yet been impounded; a portion of the surplus water falling on the land to the South, and South-East of the same place, has been, for many years, collected in the reservoirs (shown on the map and coloured blue) for the use of the canal, and more recently for the supply also of the Gorton Reservoirs. Comb's Reservoir, to the South-East of Whaley, was constructed before the year 1800, when the canal was opened, and the Todd's Brook Reservoir, to the South of Whaley, by the year 1840. By the act of Parliament you obtained last year, the following supplies of water —viz., the water that can now be collected in the two reservoirs of the Peak Forest Canal, the water flowing off the land, draining direct into this Canal, the surplus water flowing off the land, coloured green, a little to the South of Macclesfield, the water flowing off the land draining direct into the Macclesfield Canal, and the surplus water flowing off the land that drains into the Reddicar Brook, about four miles South of Marple (coloured green)—can all be delivered by means of the Peak Forest and Macclesfield Canals as conduits*, into suitable reservoirs and filter-beds, situated at High Lane, alongside of the Macclesfield Canal, and from thence, after filtration, can easily be sent (by means of a line of cast-iron pipes) to the towns of Stockport, Manchester, and Salford. The bottom of the Service Reservoir at Marple, for receiving the water, after filtration, previous to its entering the pipes, would be 320 feet above Brown Street, Manchester, and 250 feet above the high part of Stockport.

The collecting ground from which the Peak Forest and Macclesfield Canal reservoirs are supplied with water is precipitous and steep; the tops of the hills vary from 1200 to 1700 feet above the mean level of the sea, as will be found marked on the accompanying map. Out of the whole quantity (14,633 acres), only about five or six hundred acres on the Comb's gathering-ground have any approach to table-land, or are covered with the smallest trace of peat or moss; and the comparatively small portion of moss or peat-land, that is found on the Comb's gathering ground, is entirely covered with long grass and heath. Its geological character is the lower series of the coal formation and millstone grit; most of the surface is fine grass pasture; and the greatest portion of the rain falling upon it, flows off, especially in heavy rains, a few hours after it reaches the ground in the utmost purity, and, when collected in re-

* See Appendix M, page 84.

servoirs, and allowed to settle for twenty-four hours, is as clear and bright as spring-water. The steep declivity of the sides of the hills, the retentive nature of the material with which they are covered, and the almost total absence of table-land, insure, especially in heavy rains, that a very small portion falling will be lost by evaporation or soakage into the ground; and the varied situations of the different reservoirs and gathering-grounds, compensating for partial droughts in any one locality, which are so common in hilly districts, justify the belief that in no one year, the fall of rain on the average of the gathering grounds, will be below 36 ins. I have adopted this depth in my calculations, from finding the average depth fallen in a dry year, at Marple, Combs and Chapel-en-le-Frith to coincide with it, as shown by the rain-gauges kept at those places. From the nature of the gathering ground (before described) two-thirds of this depth or quantity may be calculated upon as flowing off the land, leaving one-third to be lost by evaporation, soakage into the ground, and support of vegetation; upon a careful examination of the subject, I believe that 24 ins. of rain in depth, on the average of the gathering-grounds, flowing off in any one year, may be fully depended upon. Of this quantity by far the greatest portion (probably five-sixths) will flow off in floods, after heavy showers, and two-thirds be unable to make its escape through the millowners' gauges, leaving a depth of 16 ins.

flowing off the gathering-ground, to be impounded in the reservoirs. To allow for evaporation from the surface of the reservoirs themselves and other contingencies, I have only assumed that a depth of 15 ins. can be made available. That this quantity can be depended upon, with proper storage room, I feel no doubt whatever; and when it is remembered that considerably *more than half* the depth of rain falling per annum has been proved (from observations made over a series of years) to fall in gluts varying from four-tenths of an inch to two inches in depth in less than twenty-four hours; and that the size of the mill-owners' gauges will not admit, when running full, of more than a *five hundredth part of an inch in depth* over the surface of the collecting-ground to pass through them in the same time (or with a considerable head of water acting against the gauge, more than double this amount) the quantity assigned may be considered very moderate. I have checked this conclusion against the quantity of water *known* to have been yielded from the Comb's Reservoir (which has been in use forty-eight years), and found it to agree very accurately with it.

The area of land from which the Peak Forest canal reservoirs now collect flood water consists of 4030 statute acres, draining into the Todd's Brook reservoir, of 2984 acres into Comb's reservoir, and 826 acres into the Peak Forest canal, direct. The Macclesfield canal derives its supply of water from

1081 acres, draining direct into that canal, 782 acres the flood waters of which drain into the canal from the Reddicar brook; 1671 acres the flood waters of which drain into the Sutton reservoir; 2797 acres the flood waters of which drain into the Bosley reservoir, and 165 acres draining direct into the collecting reservoir at Marple, making a total drainage ground for the Peak Forest and Macclesfield canals united, of 14,336 statute acres, independent of the drainage ground at Hockham brook (consisting of 1734 statute acres,) the flood waters of which also belong to the Peak Forest Canal Company. The amount of water, supposing that fifteen inches in depth, passing off in floods from this area of land, be collected, would in a dry year amount to upwards of thirteen and a quarter millions of gallons per day. The daily amount required for the use of the Peak Forest and Macclesfield canals combined, is four and a half millions of gallons, and this would leave eight and three-quarter millions of gallons per day to dispose of, if sufficient storage room were made to prevent in times of flood, any portion of the water being lost. However, as you found it prudent, when before Parliament last year, to abandon for the present the *additional* reservoirs proposed to be made on the Todd's brook and the enlargement of Comb's reservoir, rather than submit to the exorbitant terms attempted to be enforced by the Committee of the House of Commons, the storage that can be made available to receive the flood water from this area of drainage ground now stands as follows:—

	Cube Feet.
Present Comb's Reservoir contains . .	54,289,000
Present Todd's Brook, do. . . .	47,412,270
Present Bosley, do. . . .	64,266,399
Present Sutton, do. . . .	12,807,000
Proposed addition to Bosley . . .	27,266,000
Proposed reservoir at Sutton . .	20,875,000
Proposed impounding reservoir at High Lane, near Marple	25,000,000
Additional storage room that can be made within Parliamentary limits of deviation, as alluded to in my last Report. . . .	40,000,000
Cube feet . .	291,915,669

$$\frac{\text{Cube feet } 291{,}915{,}669}{\text{Statute acres } 14{,}336} = 20{,}362 \text{ cube feet per acre of drainage ground.}$$

This amount of storage room could not be depended on, even in a dry year, to equalize for regular consumption over the year, the whole of the thirteen and a quarter millions of gallons per day; but, considering the varied positions and aspects of the drainage ground, I have no doubt that seven and a quarter millions of gallons per day, when the new works are carried out, may be considered as surplus over and above the wants of the canal; for taking the total storage room as 291,915,669 cube feet, or, 181,863,461,787 gallons, and dividing this by $11\frac{3}{4}$, being the sum of four and a half million gallons required daily for the canals, and of seven and a quarter millions per day surplus, there is a storage room for a supply, after this rate, for 154 days, or twenty-two weeks, independent of any rain-fall during that time. It may be as well to remark, although fifteen inches in depth only of available water have been calculated upon as being collected in floods annually from the 14,336 acres of gathering ground, that the *whole of the water* flowing off different patches of steep land composing the above quantity, which, added together, make *more than* 2000 *acres*, will flow into the reservoirs.

The natural form and character of the ground at High Lane, near Marple, upon which it is proposed to construct the subsiding reservoirs and filter beds, is admirably adapted for the purpose. Without any considerable expense, the service reservoir (to receive the filtered water from the filter beds) may be made so as to allow the filtration process to be carried on both night and day; and every facility that could be wished for exists for constructing suitable drains and culverts, for discharging and emptying the water from the filter beds and reservoirs when required. This is a matter of very considerable importance, and can scarcely be too highly estimated.

Comparing then, the quantity, and quality, of the water that can be procured by the new plans deposited by the Corporation of Manchester, and by the Surplus Water scheme for which you obtained an Act last year, it is obvious that your plan has, in both these respects, very material advantages; while a further very important advantage consists in its aptitude for *cheap and easy extension.* The flood waters from an additional 24,000 statute acres* can be impounded, and appropriated to this purpose, in situations that admit of such waters being conveyed by means of the Peak Forest and Macclesfield canals as conduits to the service reservoir at Marple; while a glance at the map will show any one but little accustomed to the consideration of these subjects, that to procure any further supply of water in connection with the proposed works at Longdendale, if not quite impracticable, could only be attained at very great expense.

I do not propose now to enter minutely into the question of the relative cost of the water that can be collected by the Corporation plans deposited this year, and by your Surplus Water scheme. To do so, it would be requisite, not only to examine the cost of the works shown on the Corporation deposited plans, but to consider the expense of filter beds in connection with their scheme (for it is impossible the inhabitants of Manchester *would long submit* to receive unfiltered water), and the annual expense of taxes, keeping in repair, and attending to, not merely the reservoirs and works for the supply of Manchester, but also the millowners' reservoirs. I will only remark that the porous and open nature of the bulk of the ground on which it is proposed to

* See Appendix I, page 78.

construct the reservoirs in Longdendale; the almost total absence of clay on the proposed sites of the principal reservoirs; the expensive preparations that must be made, to prevent damage from a sudden flood, while the banks of the Torside and Rhodeswood reservoirs are being constructed; the length of the conduit from the Woodhead reservoir to the mouth of the tunnel at Mottram (six and a half miles); the tunnel itself, together with the large quantity of *débris* and peat which every flood will wash down from the tops and sides of the hills into the reservoirs and conduits, demand both a *very large* first outlay in proportion to the size of the works, and *large permanent annual expenses* to maintain them.* On the other hand, your scheme has very considerable advantages, indeed, in the nature of the ground on which your reservoirs and works are to be constructed: no outlay whatever has to be made to compensate millowners, but only such, as necessary to store and deliver the water in a fit state for use: a great portion of the works required are already made (their value at least 80,000*l.*), upon which you can afford to take a very moderate return: your annual expenses must also be comparatively small, as the expense of repairs, and attending to most of the reservoirs and works, will not greatly exceed what is at present incurred for canal purposes. From these circumstances, even should the

* See Appendix K, page 79.

Corporation of Manchester be successful in borrowing money to carry out their proposed works, at a moderate rate of interest, yet it is certain that the inhabitants of Manchester (especially for the next dozen years) must be burdened with *a very much heavier impost for an inferior article*, than if water were purchased in bulk from you for distribution, by the Corporation of Manchester, in such quantities as may be from time to time required. *

By dealing with you for water in bulk, the Corporation would have this further advantage — that they would be enabled *immediately*, to divert from the Gorton Reservoirs the worst of the water flowing into them from off the drainage-ground that naturally feeds them (this water is notoriously bad, and greatly contaminated with the sewerage from the roads and houses of the population resident upon the drainage-ground, as well as the nature of the manure spread over it), and might take their supply for the Gorton reservoirs almost exclusively from the reservoirs of the Peak Forest and Macclesfield Canals, and have it conducted to them (as is at present, and has been for several years, partially done) by means of the Peak Forest and Ashton Canals combined. This plan would *at once* secure for the use of the inhabitants of Manchester water of an infinitely superior quality to that at present supplied to them,— a matter, one would imagine, of very considerable importance.

* See Appendices M, page 81, and R, page 87.

I have endeavoured, in this report, to show, faithfully and fairly, the comparative value of the Manchester Corporation Water Work scheme, as at present proposed, and your Surplus Water scheme, as sanctioned by the Act of Parliament obtained last year. I firmly believe it will justify you, both with your shareholders, and the rate-payers of Manchester, for your promotion of the latter scheme,

I am, my Lord and Gentlemen,

Your very obedient servant,

SAMUEL COLLETT HOMERSHAM,

Civil Engineer.

London, 19. Buckingham Street,
Adelphi, Jan. 22. 1848.

APPENDIX.

APPENDIX A.

Area of Land draining into the different proposed Reservoirs of the Manchester Corporation Water Works Scheme.

Drainages.

		Acres.	Acres.
Into Woodhead Reservoir -	Moss or Peat	5750	8035
	Clear -	2285	
Torside Reservoir -	Moss -	4100	5890
	Clear -	1790	
Rhodes Wood Reservoir	Moss -	690	1365
	Clear -	675	
Hollingworth Reservoir	Moss -	960	1490
	Clear -	530	
Armfield Reservoir -	Moss -	600	880
	Clear -	280	
Catchwater Drains -	Moss -	200	530
	Clear -	330	
		General Total	18,190

Total Moss or Peat Acres, 12,300
Clear Land, 5,800
——18,190 Acres.

Cubic Contents of proposed Reservoirs.

	Cube feet.
Woodhead - - - - -	195,432,700
Torside - - - - -	240,000,000
Rhodeswood - - - -	80,000,000
Armfield - - - - -	38,755,556
Hollingworth - - - -	12,348,100
Tetley Fold - - - -	8,849,310
Denton - - - -	9,481,050
Total	584,866,716

$$\frac{\text{Cube feet } 584{,}866{,}716}{18{,}190} = 32{,}153 \text{ cube feet of storage room per acre of drainage ground.}$$

APPENDIX B.

When the surveying officers, in 1847, appointed by the Commissioners of her Majesty's Woods and Forests to survey the district of the proposed Manchester Corporation Water Works scheme (Messrs. James Rendall and George Wingrave Cooke), took specimens of the water flowing down the streams proposed to be impounded by the Corporation on the 18th of February in that year, these specimens were submitted to Professor Graham of the University College, London, who reported that the water taken from the Hollingworth brook contained 20·2 grains of solid matter (chiefly vegetable fibre or peaty matter) in each imperial gallon, that the Holling's Brook water contained 158 grains of solid matter per imperial gallon, that the Armfield Brook water contained 27·6 grains of solid matter per imperial gallon, that the little Crowden Brook water contained 134·4 grains of solid matter — the great Crowden Brook 184·6 grains of solid matter (peaty matter and sand) per imperial gallon.

To filter ten millions of gallons of water containing only 100 grains of peaty matter per gallon, would be to separate 173,611 lbs. or sixty-three tons fifteen cwt. of solid matter from this quantity of water.

In cold weather peaty matter is not held in water to any extent in solution, but in warm seasons water will dissolve peat. To satisfy myself on this point, and to ascertain the quantity of organic matter and salts taken up from peat by water in contact with it at different temperatures, and varied lengths of time, the following experiments were tried, at my request, by an eminent surgeon and chemist, in 1847, upon the principal waters of the Manchester Corporation scheme.

Results of Qualitative Analysis, showing the Degree of Hardness communicated to different Specimens of the same Sample of mixed Crowden Waters, and the Quantities of Organic and Saline Matters taken up by the same, during Experiments at varied Temperatures and given Lengths of Time.

Name of Water.	Temperature of the Air and Water.		Date of Experiment.	Specific Gravity.	Degree of Hardness.		Quantity of Matter in solution, per Gallon.			
	Air. Degrees, Fahr.	Water. Degrees, Fahr.			Distilled Water, = 1·4 Measure.	Degrees.	Total in Grains.	Organic Matter.	Saline Matter.	
Crowden waters, with heath peat, 25 minutes.	64	62	May 11		5·3	1·66	·	·	·	Heather peat, cut from the ascent to Bare-am moss, April 10. 1847, temperature of atmosphere, about 36° F. specimen used in experiment taken at depth of four inches from the surface.
Ditto, with heath peat, 24 hours.	58 to 70	57 to 65	May 12 to 13		5·5	1·7	9·900	4·600	5·300	
Ditto, with heath peat, 48 hours.	57·5 to 70	57 to 63	May 12 to 14		9·0	3·0	11·250	5·200	6·050	
Ditto, with Slidden moss peat, 24 hours.	58 to 74	58 to 67	May 17 to 18		10·8	4·33	15·180	6·550	8·750	This peat was taken at one foot below the surface of Slidden moss, May 13. 1847, about midday, when the temperature was at from 51 to 52 F.
Ditto, with Slidden moss peat, 48 hours.	58 to 74	58 to 67	May 17 to 19		9·3	3·2	17·300	8·900	8·400	
Ditto, with heath peat at 48 hours.	59 to 63	59 to 84	May 12		"	"	24·700	14·600	10·000	The heather peat, taken April 10, as above.

These experiments show the influence of temperature on the quality of water flowing off peaty or moss land, and the large quantity of organic matter taken up by it when in contact with peat at slightly increased temperatures, and will account for the general bad character given to the Corporation waters by those living near the brooks and streams proposed to be impounded. At certain warm seasons of the year the mass of peat on the tops of the hills is in a state of fermentation, and heavy rain occurring at such a time would render unfit for domestic purposes the water in the whole of the reservoirs.

The following is an extract from the letter of a gentleman who has lived close to these streams for many years: —"Suppose the Corporation scheme carried out, and at the end of a long summer drought their reservoirs are all but empty; suppose the weather to break, with a succession of thunder-storms, as is generally the case, and their reservoirs filled with water, about the consistency of coffee, what on earth are they to do with it? Why they would poison the whole population of Manchester!"

APPENDIX C.

RAIN GAUGES.

To ascertain the amount of the fall of rain in different localities by means of rain gauges, it is very important to pay attention to the form of the gauge made use of, as well as to the situation in which it is placed, otherwise errors of a very serious character may be the result; it has been known for many years, and is mentioned by Dr. Dalton, in the article Rain, written by him for Rees's Cyclopædia, published 1819, that more rain is collected in a rain gauge placed near the ground than in one fixed at a greater elevation from it. Dr. Heberden alluded to this fact in the Philosophical Transactions for 1769, and it has long since been recognized. The Literary and Philosophical Society of Manchester, with a laudable desire to ascertain the amount of discrepancy in the result that would be shown between certain funnel rain gauges fixed on the ridging of the roofs of the residences of parties connected with the Rochdale, Ashton-under-Lyne, and Peak Forest Canals, and other gauges placed near the ground in the same localities, fell into the error of employing for this purpose a rain gauge, which is thus described in a communication read before the Society on March 18. 1845, and published in the seventh volume of the Second Series of its Memoirs, p. 193.

"The gauge selected was the one now most approved of, and most commonly used, consisting of a hollow cylinder of copper or other metal, about seven or eight inches in diameter, and thirty-six or forty inches in length, with a receiving funnel of the same diameter as the cylinder, and closely fitted to the top. Within the cylinder, a float rises as it becomes filled with water. It is just so much smaller in diameter as to rise freely, *and in the centre is fixed an upright rod, marked in inches, and tenths of an inch, which, rising through a small hole at the bottom of the funnel, exactly indicates the depth of rain falling in any given time.* The surface of the water in the cylinder being completely covered with the float, except the mere annular space of about one-eighth of an inch, no evaporation takes place. The gauge must be occasionally emptied of the water it contains. It is sunk in the ground, within a strong box or case to prevent injury, and to allow of its being easily taken out; the top of the gauge being left about ten or twelve inches above the ground."

This kind of gauge is shown on PLATE I. and represents exactly the one fixed by the Manchester Literary and Philosophical Society in the year 1844, in a field near the Comb's reservoir belonging to the Peak Forest Company, and placed under the superintendance of Mr. John Wood, the company's resident engineer. Soon after this gauge was committed to Mr. Wood's charge it occurred to him that as the stick rose in the centre of the gauge with the float, the rain, in windy weather, would be driven against the stick, run down it, and add considerably to the amount of water caught by the guage. To avoid any material error from this source, Mr. Wood emptied the water caught by the gauges entrusted to his charge every month, and to satisfy himself constructed an experimental gauge, shown on PLATE I. FIG. 2: it consists of a staff half an inch diameter, standing up twelve inches in height above the cover of a cylinder seven inches diameter, having a hole an inch in diameter through it. Such a gauge placed near the ground at Marple collected in six months (from the beginning of July to the end of December) 9·5 inches in depth of water in the seven inch diameter cylinder. This result was obtained from the rain beating against and running down the stick, and falling through the hole in the top; from the beginning of January to the end of December, 1845, the same gauge collected 21·95 inches in depth, and in 1846, 15·4 inches in depth, and in 1847, 22·48 inches in depth. This experiment fully proves that if the stick communicating with the float rises above the top of the gauge, considerable error is introduced into the results shown by gauges of the construction used by the Manchester Literary and Philosophical Society.

In reading a communication made to that Society on February 6. 1844, and published in the Memoirs of this Society, vol. v. second series, I was surprised to find it stated (p. 171.) — " One very important fact shown by these observations is, that a much *greater* quantity of rain falls on the *summit* than at the *bottom* of the hills; and this appears to be uniformly the case, whether taken for a single month, or upon the general average." And again (p. 181.) — "Here, again, the important fact of the *greatest fall* of rain being upon the *high ground* is clearly proved." These observations are in direct contradiction to all other meteorological writers with whom I am acquainted. Dr. Dalton, in his Meteorological Observations and Essays, 2d edition, page 40., states — "That in very heavy and continued rains, the clouds are mostly *below the summit* of the mountain. Professor Daniel in his Elements of Meteorology, vol. i. p. 236., states: — "It has been ascertained *more rain* falls at the *bottom* of a mountain than the *top*." In a communication read before the Literary and Philosophical Society of Manchester, by John Fleming, Esq., and published in the 5th volume of the New Series of the Society's Memoirs, p. 252., it is stated — "On the *descent* of the hill, and probably about the *foot* of it, the *heaviest* rain will fall." And many well-recorded experiments prove the statements here quoted to be correct. To put this matter beyond a doubt, in the beginning of January, 1847, a 9-inch funnel gauge, similar to that shown on Plate III. was fixed near Todd's Brook reservoir, which is situated about 620 feet above the level of the sea. Its position is shown on the map; and another gauge, of exactly similar construction, was fixed on the gathering ground of this reservoir at Brinks, about 1500 feet above the level of the sea; a gauge was fixed near the Comb's reservoir, about 720 feet above the level of the sea; and another gauge on the gathering ground of this reservoir at Comb's Ridge, about 1670 feet above the level of the sea. The monthly return of the depth of rain registered by these gauges is given in the following table: —

Funnel Rain Gauge, nine inches diameter, for 1847.

Situations.	Jan.	Feb.	Mar.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Total.
	in. dec.	in. dec.	in. dec.	in. dec.	in. dec.	in. dec.	in. dec.	in. dec.	in. dec.	in. dec.	in. dec.	in. dec.	in. dec.
Todd's Brook, Brinks, top of hill, 1500 feet above level of sea -	1 ·14	1 ·68	0 ·77	1 ·93	3 ·95	1 ·05	0 ·95	2 ·40	4 ·40	2 ·77	3 ·35	5 ·05	29 ·50
Todd's Brook reservoir, bottom of hill, 620 feet above level of sea - - -	1 ·78	2 ·33	0 ·88	3 ·08	4 ·17	3 ·70	0 ·97	2 ·95	6 ·17	3 ·71	3 ·05	5 ·60	38 ·39
Comb's Ridge, top of hill, 1670 feet above level of sea - -	2 ·60	1 ·78	0 ·79	2 ·45	4 ·50	3 ·44	1 ·53	2 ·96	4 ·17	4 ·48	2 ·52	4 ·63	35 ·85
Comb's reservoir, bottom of hill, 720 feet above level of sea -	2 ·60	3 ·50	1 ·60	4 ·00	5 ·30	3 ·90	1 ·00	3 ·40	8 ·20	5 ·40	4 ·50	7 ·90	51 ·30

From these results it will be seen, that the gauges fixed at the *highest* altitude prove considerably *less* rain to have fallen than the gauges fixed at the *lower* altitude; and observations made with other funnel rain gauges, fixed close to the Bosley reservoir, near to the surface of the ground, 590 feet above the level of the sea, and at Bosley Minns, about 1265 feet above the level of the sea, and other funnel rain gauges, fixed at Woodhead, near the railway tunnel, and higher up the hill, record *precisely* the same results, namely, a much *less fall* of rain in the same locality at the *higher altitude* compared with the *lower altitude*, and entirely confirm the observations of Dr. Dalton, Professor Daniel, John Fleming, Esq., and other authorities. How, then, it may be asked, were the results in the communication read to the Philosophical Society of Manchester on the 6th of February 1844, arrived at?

To explain this I must detail some further experiments made with a different kind of experimental gauge, called a staff gauge; near to the funnel gauge at Todd's Brook Reservoir, a staff gauge similar to that shown on PLATE II. was fixed*, and a similar gauge was also fixed near to the funnel gauge at Brink's. A staff gauge of the same construction was also fixed near to the Comb's reservoir as well as at Comb's Ridge. The monthly return of the rain collected by these gauges for the year 1847, is given in the following table, the depth of water registered being compared with the funnel gauge of nine inches diameter, and it may be remarked that the area of surface of the staff exposed to the wind, combined with the area of the hole exposed to the rain, is equal to the area of a circle of 9 inches in diameter: area of 9 inches = 63·61 square inches, 18·75 inches (length of staff) × 3·142 (half the circumference of the staff) + 49 inches (area of circle $2\frac{1}{2}$ inches diameter) = 63·61 square inches.

* It consists of a staff of wood $18\frac{3}{4}$ inches long and two inches diameter, fixed in such a manner that all the rain driven against it by the wind and flowing down it, shall be caught in a bottle.

Staff Rain Gauge, $18\frac{3}{4}$ *inches long*, 2 *inches diameter*, *for* 1847.

Situations.	Jan.	Feb.	Mar.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Total.
	in. dec.	in. dec.	in. dec.	in. dec.	in. dec.	in. dec.	in. dec.	in. dec.	in. dec.	in. dec.	in. dec.	in. dec.	in. dec.
Todd's Brook, Brinks, top of hill, 1500 feet above level of sea -	1 ·23	3 ·68	0 ·88	2 ·91	4 ·72	3 ·56	0 ·76	3 ·27	8 ·75	3 ·76	5 ·35	8 ·00	46 ·87
Todd's Brook reservoir, bottom of hill, 620 feet above level of sea - - -	1 ·28	1 ·69	0 ·38	1 ·27	1 ·89	1 ·50	0 ·25	1 ·05	3 ·35	2 ·28	2 ·33	3 ·40	20 ·67
Comb's Ridge, top of hill, 1670 feet above level of sea - -	3 ·87	6 ·16	1 ·34	3 ·71	4 ·47	4 ·36	0 ·98	1 ·26	10 ·89	6 ·66	6 ·56	8 ·73	58 ·99
Comb's reservoir, bottom of hill, 720 feet above level of sea -	1 ·29	2 ·36	0 ·58	1 ·71	3 ·06	1 ·24	0 ·37	1 ·63	5 ·60	2 ·87	3 ·47	3 ·71	27 ·89

From the foregoing table it will be seen that the staff gauges act directly the reverse of the funnel gauges, and very much *more* water is collected by those fixed *high up in* the hills than by those fixed *lower down.* Now, the rain gauges fixed by the Literary and Philosophical Society of Manchester are a sort of combination of funnel gauge and staff gauge, for when the stick attached to the float rises, it commences to collect water and to act as a staff gauge, and in this manner gives *very* incorrect results, which is satisfactorily proved from the fact before alluded to, viz.: —that the observations made with the rain-gauges fixed by the Literary and Philosophical Society of Manchester, show *more* rain to have fallen on the *tops* of the hills on which they have been placed than on the *bottom;*—which result is in direct contradiction to the commonly received theory of the formation and distribution of rain, as well as to the observations of all meteorological writers of authority.* I know it has been said that the sticks attached to the floats of some of the gauges fixed on the Corporation gathering ground were ordered to be tied down; but I have myself upon more than one occasion when in company with other parties seen a stick as much as *three-fourths* of an inch diameter, standing up 16 or 17 inches above the top of a gauge 7 inches diameter which was fixed on the Corporation gathering ground, and I have ascertained satisfactorily that at least one other gauge on the same gathering ground fixed higher up in the hills was often in the same state. Now, if a stick *half an inch* diameter and 12 inches high will collect, as is shown by Mr. Wood's experiments to be the case, sometimes as much as 22 inches in depth per annum in a cylinder 7 inches diameter, I will leave others to estimate the error that will be produced in a gauge of the

* The rain gauges employed on the Corporation gathering ground are similar in construction to the Society's gauges.

same diameter from a stick *three-fourths* of an inch diameter and 16 *inches high* placed in an exposed and windy situation. I have no doubt that in exposed situations rain gauges similar to those employed by the Literary and Philosophical Society of Manchester, when the stick is allowed to rise with the float, even when the gauge is emptied of water every month, show *incorrect results.* I am informed by J. Magnall, Esq., of Sharples, near Bolton, that a rain gauge placed in his own garden during part of last year, nearly opposite the gauge fixed at the reservoir of the Water Works Company, and not many hundred yards distant from it, showed about seven tenths of an inch per month less rain falling than the Water Works Company's gauge. Now, the Water Works Company's gauge has a stick in it that is allowed to rise with the float, although it is emptied of its water every month, and the gauge in Mr. Magnall's garden has no such stick. A staff gauge fixed at Fairfield during the past year only collected 3·18 inch. in depth, and other staff gauges that I have had placed on the roof of a large building near London collected very little water, which proves that in different situations the effect of a staff standing above a gauge produces different results. It is obvious, that when the rain falls vertically, in the absence of wind, the staff struck *endwise* operates much less to collect water than when driving rain is arrested by it *for its entire length.*

APPENDIX D.

The Manchester, Sheffield, and Lincolnshire Railway Company, have placed funnel rain gauges 9 inch. diameter similar to those before described, and shown on PLATE III. in different suitable situations on their line of railway to Sheffield: the observations made with these gauges may be expected in a few years to become of great value.

APPENDIX E.

The quantity of water flowing down streams fed from rain falling on the sides of hills varies with every passing shower; *no one or two observations per day can possibly give any thing like an accurate result;* a flood will sometimes last but a few hours, and yet in this time it frequently happens more water will run down the streams than at other times will flow down in as many weeks. I have had occasion to make observations on streams every hour in fine weather, and every half hour in showery weather for weeks together, day and night, and in unsettled states of the weather almost every measurement varied.

APPENDIX F.

The following examples of the capacity of different reservoirs now in use, with the area of ground draining into them, may be useful.

Turton and Entwistle Reservoir.

	Cube feet.	Cube feet per acre of drainage ground.
Cubic contents - -	100,000,000	=49,110.
Area of drainage ground, 2,036 acres		

This reservoir is shown on the map about fourteen miles to the North-West of Manchester.

Belmont Reservoir.

	Cube feet.	Cube feet per acre of drainage ground.
Cubic Contents - - -	78,000,000	=43,430.
Area of drainage ground, 1796 acres		

This reservoir is shown on the map about fourteen miles to the North-West of Manchester.

Bolton Water Works.

		Cube feet.	Cube feet per acre of drainage ground.
Cubic contents of reservoir	- -	22,471,910	=37,767.
Area of drainage ground, 595 acres			

This reservoir is shown on the map about four miles to the West of Bolton.

Ashton Water Works.

		Cube feet.	Cube feet per acre of drainage ground.
Cubic contents of reservoirs	- -	14,436,397	=38,453.
Area of drainage ground, 378 acres			

This reservoir is shown on map, about a mile and a half North-East of Ashton.

In the evidence given at Manchester, February, 1847, before the surveying officers, the drainage-ground of this reservoir was calculated at 608 statute acres. This statement is contained in a report, written to the Directors of the Ashton Water Works Company, by the engineer who constructed the works. I had subsequently reasons to doubt its accuracy, and therefore had it measured: 378 acres turned out to be the true quantity. At my request, Mr. Hibbert, the Company's Superintendant, in May, 1847, tried a series of experiments to ascertain the exact quantity of water used per *tenant* for domestic purposes, and this proved to be 6·245 gallons per head per day. In the dry year of 1844 the number of tenants supplied by the Company were, on the average of the year, 24,000, calculating seven gallons per head: this is equal to 61,320,000 gallons per annum. The quantity supplied to the mill-owners in this year was 72,000,000 gallons: this is equal to a total yield of 133,320,000 gallons in a year, or 21,392,811 cubic feet, or 15·5 ins. in depth, flowing off the collecting ground. On the 1st of April, 1844, the reservoir was down six ins. and continued to lower till October; and on the 1st of April, 1845, the reservoir was seven feet three ins. down, or six feet nine ins. lower than it was the 1st of April, 1844; and the reservoir was never full or run to waste, from April, 1844 to April, 1845.

Sheffield Water Works.

	Cube feet.	Cube feet per acre of drainage ground.
Cubic contents of Redmires' reservoirs -	30,000,000	=32,894.
Drainage ground, 912 acres,		
A new reservoir, situated at Redmires, is just completed (or shortly will be), capable of containing 22,000,000 of cube feet: this will make a total storage room of 52,000,000 of cube feet, or		57,050.

APPENDIX G.

The amount of water flowing out of the tunnel at Woodhead in January this year, was 2·323 cube feet per second, equal to about one and a quarter million of gallons per day of twenty-four hours.

APPENDIX H.

Any scheme for supplying a town population with water from surface drainage, especially when the constant supply is to be introduced, ought to provide for filtering the water. All river water, especially in warm summer weather, contains more or less organic matter in combination, which may in great part be separated from it by filtration. There is much more difficulty in filtering river water that is quite clear in hot summer weather (owing to the vegetable matter contained in it), than in filtering turbid water in cold weather. In the Appendix to the Illustrations of the Croton Aqueduct, published by Wiley and Putnam, New York, 1843, and written by Charles A. Lee, M. D., it is stated, p. 136., "River water always contains a more or less quantity of organic matter in suspension, or solution. As a general rule, the quantity is too small to produce any decidedly injurious effect; but physicians and medical writers agree in the opinion that water impregnated with it to any great extent must be deleterious. Where the decomposing matter is too small to produce any immediately obvious effects, it is difficult to procure any decisive evidence of its influence on the system. When the amount is considerable, it causes *dysentery* and *fevers*, often of a highly fatal character."

APPENDIX I.

The *flood water at present running uselessly to waste* from every 1100 acres of land, collected in suitable reservoirs from the district here alluded to, is capable of yielding about one million of gallons of water per day.

APPENDIX K.

The almost perpendicular sides of the hills in the valley of Longdendale are composed in great measure of shattered or broken sandstone, portions of which, in addition to the peat from the table land, are washed down in large quantities almost every flood. It is more than probable, whenever the projected reservoirs in the main valley are commenced upon, that a very large outlay will be required to make a secure and water-tight bank; and when this is accomplished it remains to be seen whether the interior of the reservoirs will hold water, which there is every reason to doubt, as the bed of the valley is most likely composed of a broken mass of sandstone and soil washed down from the sides of the hills by the action of repeated floods.

APPENDIX L.

I have ascertained that the number of buildings situated on the collecting ground that supplies with water the Gorton reservoirs, consist of 399 dwelling houses, forty farm houses, five mills, one weaving shop, one small dye works, and one large Moravian boarding-school for boys and girls: this collecting ground is also intersected in almost every direction by roads; and yet the *whole* of the water flowing off this land, contaminated as it must be with all kinds of objectionable matter, is collected and supplied to the inhabitants of Manchester. Even the benefit that would have accrued to the quality of the water in dry weather from keeping open the landowners' gauges is not taken advantage of*; and yet the inhabitants of Manchester are to be obliged to drink at this source, till the Corporation shall have spent some hundreds of thousands of pounds, and wasted three or four years in tunnelling through a hill at Mottram, and impounding, or *endeavouring to impound*, certain streams of water fed from an enormous tract of almost bare peat land; and this while an ample supply of water of the very best quality at a cheaper rate than it can possibly be procured by themselves, might be obtained from you and made available to supply the inhabitants with *immediately*. Surely "truth *is* stranger than fiction."

Below is an analysis of two specimens of water taken from the Fairfield Station feeder, and the Audenshaw feeder of the Upper Gorton reservoir in May last year, containing, as will be seen, in one specimen, upwards of three, and the other more than six, grains of organic matter per gallon *in solution*.

Names of Places.	Degree of Hardness, by Clark's Test.		Quantity of solid Matter in each Imperial Gallon, in Grains.			
	Distilled Water, 1·4.	Degree.	Matter in suspension.	Matter in solution.		
				Total.	Organic.	Saline.
Fairfield Station Feeder.	21·7 to 20	10·4	3·2	17·740	3·280	13·460
Audenshaw Feeder.	19·4 to 20	9·2	.	17·000	6·150	10·850

* See Appendix to the report of the Manchester and Salford Water Works Company's Engineer, dated May 31. 1842. (Page 53.)

Charles A. Lee, M. D., in the Appendix to the illustrations of the Croton Aqueduct before referred to, p. 149, remarks, "There can be no doubt, that the chief cause of the excess of mortality in cities, over that of the country, is to be found in the impure water, with which the former are so generally supplied."

Again, quoting Dr. Jackson, he adds, "It is evident that the health of a whole community may be so affected by impurities in water drank by them, as to give a peculiar morbid expression to their countenances which causes the observant eye of a traveller to remark it, while he in vain endeavours to account for the phenomenon. Who has not remarked the expression common in some of our cities, as in New York and Boston, which is called a 'care-worn and anxious expression?' This expression, I will venture to assert, is not so much the result of 'too much care,' *as it is of abdominal disease, produced by the habitual and continued use of impure and unwholesome water,* which has fixed upon us this morbid stamp."

APPENDIX M.

The price at which you offered, last year, to sell filtered water of the best quality delivered at Marple, situated 320 feet above Brown Street, Manchester,—viz. for three halfpence per 1000 gallons—would cost the Corporation, if they fetched seven millions of gallons per day of this water into Manchester, by means of a large main of cast-iron pipes (calculating five per cent. per annum to be paid on the outlay), about three-eighths of a penny per thousand gallons, including taxes and all contingencies; call it a halfpenny, then two-pence per 1000 gallons would be the cost price of pure water delivered into the town. Now a house, taking forty gallons per day (a larger quantity than is used on the average of the year by the Water Works Company's tenants at Ashton, on the constant supply system), would cost the Corporation two shillings and sixpence per annum, independent of the cost of distributing pipes, or a house, taking 60 gallons per day (exclusive of the cost of distributing pipes), could be supplied at three shillings and eight-pence per annum; and a large house, requiring 100 gallons per day, at six shillings and two-pence per annum. Wholesale consumers of water could be supplied, at a considerable profit to the corporation, for three-pence per 1000 gallons. To compare the cost of the water proposed to be procured by the Manchester Corporation scheme, with the Railway scheme, it is only requisite to ascertain the cost per 1000 gallons of the corporation water, delivered in their proposed service reservoir at Tetley Fold, with the cost of your water delivered at Marple, as it will cost about the same amount to bring water from either source into Manchester, taking five and a half millions of gallons per day as the produce of the Corporation scheme, and adding to it one and a quarter million of gallons as the produce of water derived from the Railway tunnel at Woodhead: this would make six and three quarters millions of gallons per day — call it seven millions of gallons per day — then seven millions of gallons per day, of filtered water, purchased of you, delivered at Marple, would cost the corporation 15,968*l.* 15*s.* per annum, or *any smaller amount* of water a *proportionally less sum.* Now the cost of the proposed corporation works to Tetley Fold, in round numbers, if estimated as follows, will be certainly rather *under* than *over* the mark.

	£	s.	d.
Combined capacity of the Woodhead, Torside, Rhodeswood, Hollingworth, and Armfield reservoirs, 566,000,000 cube feet at 450*l.* per one million cube feet, including land, and alteration of roads.*	254,700	0	0
Tetley Fold reservoir and connections -	8,000	0	0
Compensation to millowners for loss of water privileges, &c. - -	13,000	0	0
Millowners' reservoirs (to store night water) down the river Etherow - -	6,000	0	0
Tunnel, near Mottram, 2272 yards, at 12*l.* per yard - - - -	33,264	0	0
Millowners' gauge weir across the river Etherow - - -	1,000	0	0
Watercourse from mouth of Tunnel to Tetley Fold reservoir - -	2,300	0	0
Watercourses covered, and open from Hollingworth reservoir, to mouth of Tunnel - - - -	7,000	0	0
Watercourse, from Woodhead reservoir to Armfield reservoir, including occupation bridges - - - -	11,440	0	0
Omissions and contingencies - -	20,000	0	0
	356,704	0	0
Interest at 5*l.* per cent. on 356,704*l.* per annum - - - -	17,835	4	0
Management, taxes, maintenance -	1,000	0	0
	18,835	4	0
Add to this for filtration (to compare it with Railway Company's scheme) 2000*l.* per annum for interest of money, and for constructing, cleansing, and attending to filter beds - - - -	2,000	0	0
	£20,835	4	0

* It is usual to estimate the total cost of large canal reservoirs, at from

So that if this estimate of the probable cost of the Corporation works be correct (and the ratepayers of Manchester may be considered fortunate if the proposed works are carried out *without costing a very large additional amount*), seven millions of gallons of water per day by the Corporation scheme will cost 20,835*l.* per annum, and the same quantity by the Railway scheme 15,968*l.* 15*s.* per annum.

APPENDIX N.

There is something objectionable at the first sound of conveying water by means of a canal from one point to another; but when it is remembered that a canal is an artificial conduit into which no sewers or filthy drainage of any kind is allowed to enter; that a constant quantity of water (in the case of the Peak Forest canal, upwards of three millions of gallons per day of the best quality) is regularly passing in at one end and out of the other for the supply of its locks; it may be considered as scarcely possible to form any conduit that would answer the purpose better. When the sides of a canal are not lined with masonry, a current of water passing through it may become slightly turbid with earthy particles; but such water can very easily be decantered or filtered, and is not then materially injured in quality: it is the presence of organic matter (which is likely to become putrid in warm weather) and objectionable salts that render water unwholesome and unfit it for domestic use. When the sides and bottom of a canal are lined with stone, water may be conveyed by it to any distance in the utmost purity.

2½*d.* to 3½*d.* per cube yard,—450*l.* per million cube feet is something less than 3*d.* per cube yard. The Corporation engineer, in an estimate made about three years since to some of the directors of the Manchester and Salford Water Works Company, stated 500*l.* per million cube feet to be the mean result on five different sites.

APPENDIX O.

A beautiful model, showing the undulations of the ground, the rivers, canals, railroads, towns, and principal features of the country from Burnley to Congleton in the West of England, as far as the river Humber and the city of Lincoln on the East, has been lately made by F. A. Carrington, Esq.

This model shows very accurately the relative positions and altitudes of the towns of Manchester and Salford, with the upland and ridge of hills surrounding them from North to South, and may be seen by any one interested in the supply of water to Manchester, upon application to Mr. Carrington, at his residence, 10. Henrietta Street, Covent Garden, London.

APPENDIX P.

From inquiries specially instituted in the valley of Longdendale, among persons living near the streams proposed to be impounded by the Corporation for the use of the inhabitants of Manchester, I am credibly informed, that upon heavy rains following a drought in the summer time, the water flowing down the streams is about the colour of London porter, and so strongly impregnated with moss and peat, "that it can at such times be smelled a field off;" considering the quantity of peat mixed with the specimens of water collected last year by the surveying officers appointed by Government, in the valley of Longdendale, during cold frosty weather, and considering also the effect of a slight increase of temperature in rendering peat soluble in water, this may readily be believed. To impound in reservoirs the water flowing down the streams at such times, *the peat mixed with it must be also impounded;* this might subside in time, but the water would still be in contact with it, and the result, in warm weather, would be to keep the water discoloured and charged with organic matter in solution. I have specimens of water collected below the junction of the Crowden brooks, after heavy rain, at 5 P.M. on May 16., last year, when the temperature of the air was 53° Fahr., and the temperature of the water in the brook 44°; it was a *very* dark colour when collected; I have kept it ever since, and it is still similar in appearance to dark-coloured Sherry. Any one who would take the trouble, in the summer time, to procure specimens of water from the reservoirs belonging to the Rochdale Canal Company, situated at Blackstone Edge, the collecting-ground of which reservoirs is covered with peat of a less objectionable character than that covering the top of the proposed Corporation collecting-ground in Longdendale, may be easily satisfied on this point. I examined the water contained in two of these reservoirs in February of this year, and it was then of a sensibly brown tint.

The millowners' compensation reservoir belonging to the Bolton Water Works Company, situated at Belmont, about five miles North-West of Bolton (see Map), has 1796 acres of land draining into it, 878 acres of which is from pasture land, and 918 acres boggy peaty land, varying from six inches to six feet in depth; the whole surface is covered with coarse grass and heath, and the heaviest rains will not wash down the peat *mechanically* mixed with the water; although the reservoir collecting this water be about 33 per cent. larger in proportion to the area of the ground draining into it, than the reservoirs proposed to be constructed by the Corporation in Longdendale; yet this water in summer-time is of a sensibly brown tint, and quite unfit to supply the wants of a town population.

APPENDIX Q.

The annual fall of rain calculated on by the Corporation of Manchester, and upon which the quantity of water that can be collected by their scheme is founded, amounts to from 54 to 63 inches in depth; it is almost needless to remark, that in supplying a population with water for sanitary and domestic purposes, it is necessary to secure an abundance for use *in the driest season of the driest year,* as in warm summer weather from 20 to 30 per cent. more water is used than in wet and cold weather. The table at page 33. proves that at such times no such quantity as that calculated on by the Corporation, falls on the *East* side of Manchester; and that the quantity of rain falling among the hills to the *West* of the town, is the *greatest,* and among the hills to the *East* (where the Corporation works are proposed to be constructed) the *least,* which last result may be accounted for from their greater distance from the sea. The kind of rain-gauges employed to ascertain the depth of rain falling in Longendale, which are similar to those employed by the Literary and Philosophical Society of Manchester, appear to have misled the Corporation. (See Appendix C. page 66.)

APPENDIX R.

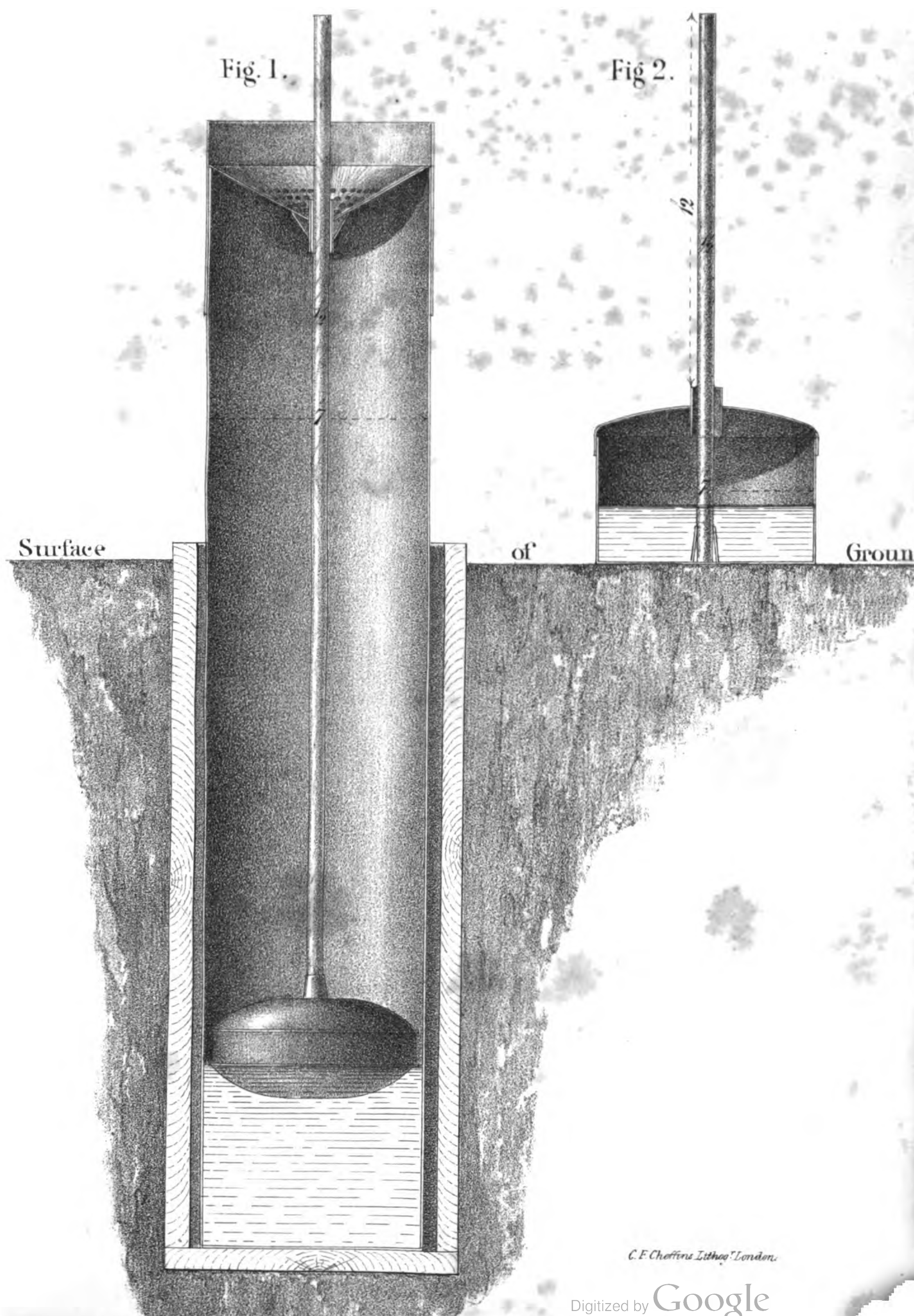
As you are aware, in the Spring of last year the Corporation could have made arrangements to secure for the use of the inhabitants of Manchester, eight millions of gallons of filtered water per day (as much as will be required for the domestic use of the Borough for some years to come), delivered at Marple, 320 feet above the high part of the town, for 1½*d.* per 1000 gallons: in August last year (after having spent a large sum of money in opposing your scheme), the Corporation, in conjunction with the Water Works Company, purchased of you, for three years certain, two hundred millions of gallons per annum of the same water *unfiltered*, to be delivered in the Gorton reservoirs, at 3*d.* per thousand gallons; or at *double* the price they might, by adopting a wiser course, a short time previously have secured the same water *filtered.*

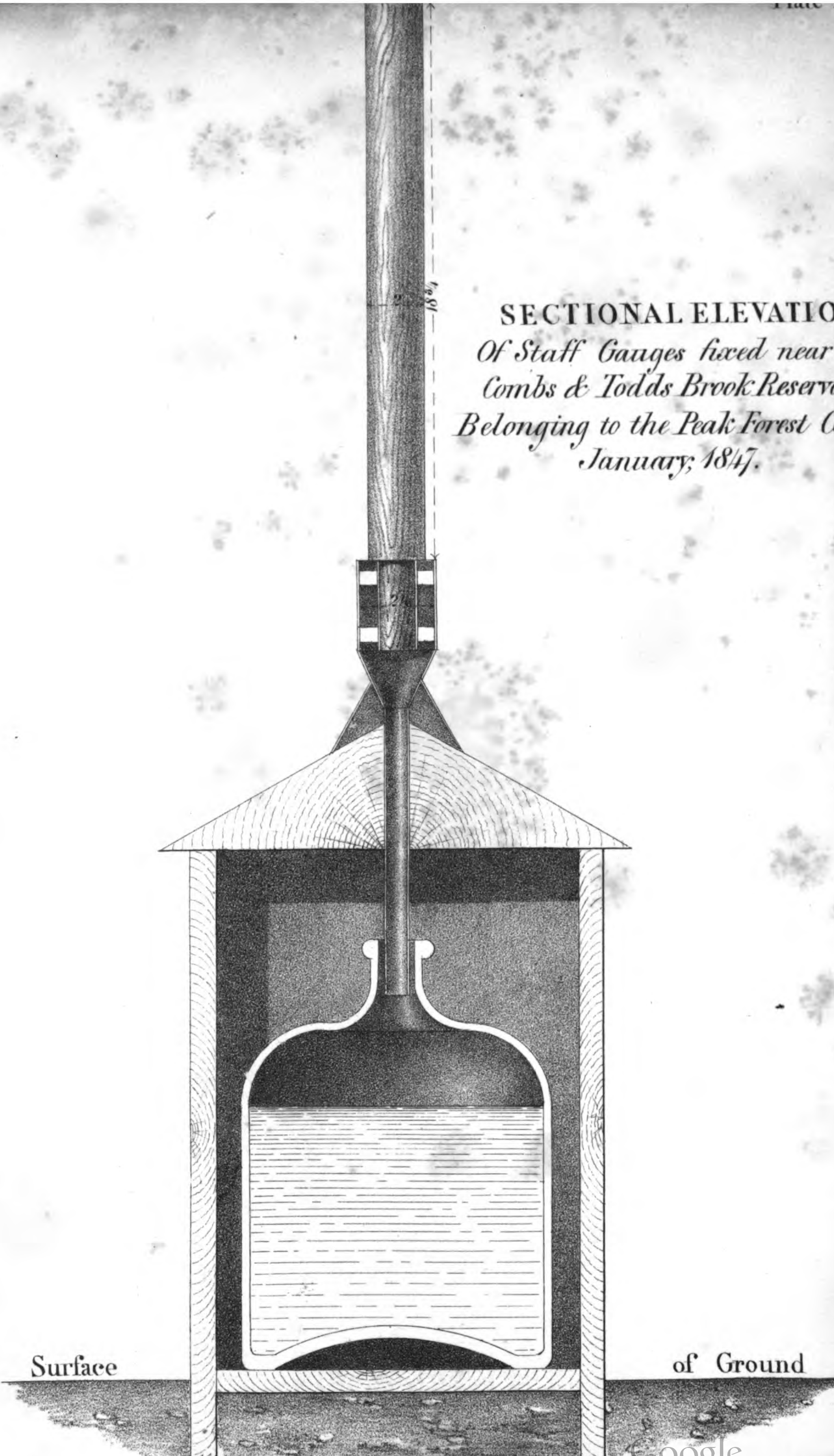
THE END.

LONDON:
SPOTTISWOODE and SHAW,
New-Street-Square.

SECTIONAL ELEVATION
Of Rain Gauge used by the Literary & Philosophical Society of Manchester, fixed at Marple Janaary, 1844.

SECTIONAL ELEVATION
Of Mr. John Woods Experimental Staff Gauge, fixed at Marple July, 1844.



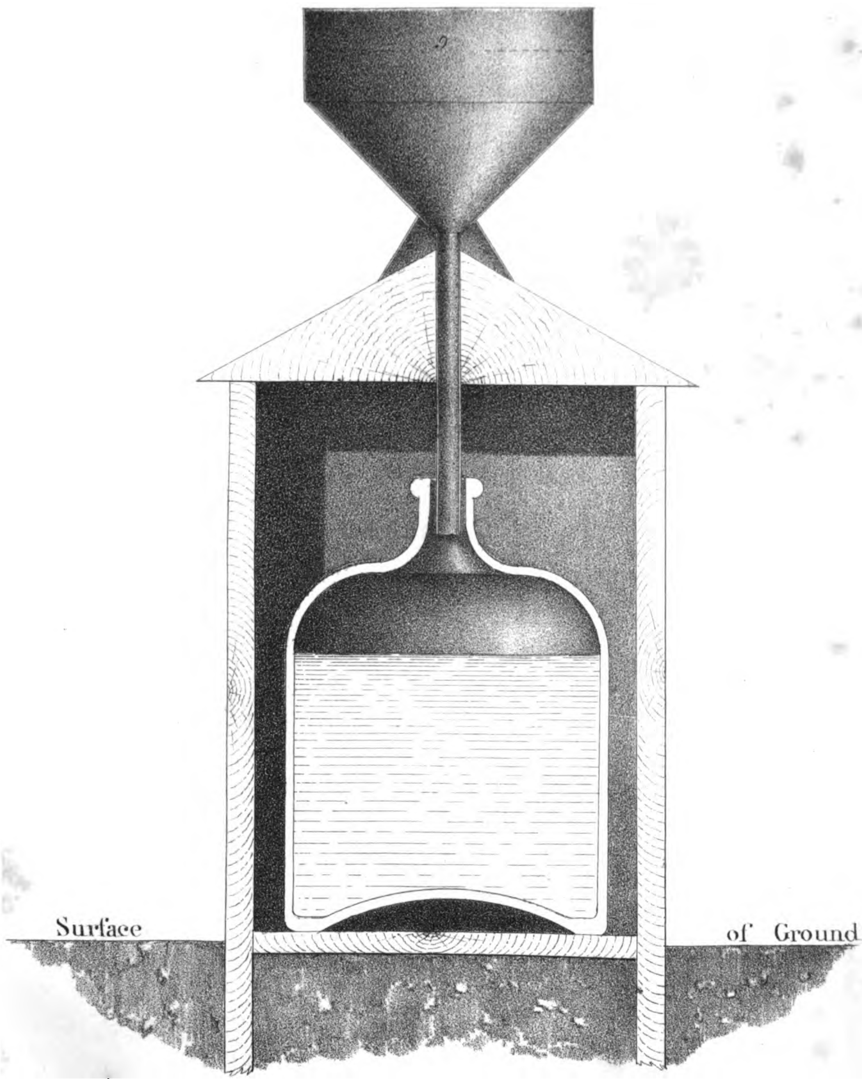


SECTIONAL ELEVATION

Of Staff Gauges fixed near the Combs & Todds Brook Reservoirs Belonging to the Peak Forest Canal January, 1847.

SECTIONAL ELEVATION

Of Funnel Rain Gauge used by the Manchester Sheffield and Lincolnshire Railway Company.



C.F. Cheffins Lithog.r

John Weale 59, High Holborn 1848.

SUPPLEMENT

TO

THE REPORT

ON THE

SUPPLY OF SURPLUS WATER

TO

MANCHESTER, SALFORD, AND STOCKPORT.

BY S. C. HOMERSHAM,

CIVIL ENGINEER.

LONDON:
JOHN WEALE,
ARCHITECTURAL LIBRARY, 59, HIGH HOLBORN.

M.DCCC.XLVIII.

LONDON:
GEORGE WOODFALL AND SON,
ANGEL COURT, SKINNER STREET.

SUPPLEMENT.

Since the publication of the "Report on the Supply of Surplus Water to Manchester, Salford, and Stockport," an article has appeared in the *Manchester Times*, imputing to that Report, "misrepresentation of fact or suppression of truth," in the arguments advanced against the Manchester Corporation Water Works scheme, and several *assertions* are made by the author of the article in question, to countenance these charges.

Before taking leave of this subject, I think it due to myself, and to those who support the Surplus Water scheme, to show that the allegations contained in the *Manchester Times* are, to say the least of them, mere reckless statements, made at hap-hazard, and unsupported by facts.

The author of the article in the *Manchester Times*, commences by claiming for the Manchester Corporation Water Works scheme, that it has in its favour the decision of the Surveying Officers appointed by government in two preliminary inquiries. Even were this allegation true, the argument would have but little weight with those who have had occasion to watch such proceedings, and to examine the reports resulting from them; but the truth is, that the last preliminary inquiry into the Manchester Corporation Water Works scheme, which took place at the commencement of this year, was totally unopposed on the merits of the scheme, and therefore was only cursorily examined by the Surveying Officers, while the "Committees of both Houses of Parliament," so pompously alluded to by the *Manchester Times*, decided at least as much in favour of the Surplus Water scheme as of the Manchester Corporation scheme.

The Surveying Officers, in the contested inquiry which took place before them, in 1847, state in their Report on the Corporation Water Works, (see page 5,)—

"We are of opinion from the evidence adduced, that in very dry years *not more* than 30 inches of rain should be reckoned as flowing from this (the Corporation) district;" and further, at page 6 of same Report, alluding to the quality of water draining from peat-moss, the Surveying Officers say, "*We believe, except in cases of great necessity, such water should never be used for Water Works purposes;*" and again at page 7 the Surveying Officers remark, "We venture to suggest that if the legislature should be of opinion that it is inexpedient that the moss drainage should be taken into the pipes, a clause should be inserted, *forbidding under a penalty* the introduction into the reservoirs of any waters other than those which are proposed to be taken by the deposited plans *.

"We submit, also, *that there should be a provision compelling the efficient maintenance of the catch-water drains; a most important and most necessary provision if this water is not to be filtered.*"

Now, in opposition to these recorded opinions of the Surveying Officers, the Corporation profess to found the quantity of water which can be yielded by their scheme on an annual depth of from 36 to 42 inches of rain, *flowing off their gathering ground*, instead "of the *not more* than 30 inches" contained in the Government Surveying Officers' Report; and it may be remarked, that since the report of the Surveying Officers in 1847 was published, additional evidence has been produced, showing, beyond a doubt, that the Surveying Officers were quite right in stating that "*not more*"

* In 1847, the Corporation proposed to cut off, by catch-water drains, a large area of drainage ground deeply covered with peat and moss, but the construction of these drains has since been abandoned.

than a depth of 30 inches should be calculated as flowing off the ground, for it has been *clearly demonstrated* that the 30 inches was an *over* and not an *under estimate*. See page 34 of "Report on the Supply of Surplus Water;" and it must be remembered, that the depth of water—*only* 15½ *inches*—which is *proved* to have been procured in 1844 from off the gathering ground of the Ashton Water Works reservoirs, includes the produce of the stream as well as the flood water. (See page 76 of "Report on the Supply of Surplus Water.")

The Corporation have also altogether abandoned the construction of the catch-water drains proposed in the first instance to be made for the separation of the peat water, and so strongly insisted upon as necessary by the Government Surveying Officers. Any person who will attentively read the Surveying Officers' Reports made in 1847, will find nothing in them to countenance the extravagant expectations held out to the inhabitants of Manchester by the promoters of the present Corporation scheme *.

In the "Report on the Supply of Surplus Water," it is expressly stated, (page 25,) that the water flowing down the corporation streams "in a drought, and especially in cold weather, is colourless, and but little contaminated with impurities;" but it must be remembered *that the great bulk of the water* (see page 48 of Report) flows off the ground immediately after heavy rains, and at such times *all the water flowing down the whole of the streams* proposed to be impounded by the Corporation, especially in warm weather, is discoloured and contaminated with peat. (See Appendix B, page 63 of "Report on the Supply of Surplus Water.")

It is certainly claimed, page 3 of Surveying Officers' Report for 1848, "That by a self-acting arrangement of the works, explained by Mr. Bateman in his answer to question 40, the *pure* water will be separated from that which may become occasionally discoloured, so as to supply the town *only with the pure produce of the streams;*" yet, as the

* See Appendix C, page 17.

description of this "*self-acting arrangement*" has never been made public, and knowing as I do, from measurement, that the dry weather yield of such streams as can be brought to Manchester *unmixed with flood water* does not exceed 2½ millions of gallons per day, and also that the peat and moss land is intermingled with the drainage ground of every stream, see page 62 of Report, I hold it is quite impossible that any arrangement can be effectual for regularly supplying an adequate quantity of pure water to Manchester, and more especially now that the drains at first proposed to be made for this purpose are abandoned.

It is charged that the quantity of water yielded by the streams has been neglected to be taken into account in the "Report on the Supply of Surplus Water," and further stated: "It is evident that if we have to depend upon the supply secured by a butt, that it must be large enough to supply us during the longest drought; but that when the supply is from a *natural source*, it is enough for the reservoirs to contain sufficient to make up the deficiency between the demand and supply afforded by the dry weather streams, which, in the present instance, afforded a very considerable quantity." Now, streams are entirely the produce of rain falling on the adjoining land which slopes towards them, *and have been fully taken into account* in estimating the total quantity of water yielded by the corporation gathering ground. I cannot comprehend what is meant in the above statement, "when the supply is from a *natural* source." No "*natural*" sources of streams, up to the present time, are known, except the drainage from the adjoining land of the rain which falls there. If some other "*natural source*" can be proved to exist, from which the water is produced that flows down the streams proposed to be impounded by the Manchester Corporation, it will be a very fortunate circumstance for the inhabitants of Manchester, and the author of such an opportune discovery will be entitled to their especial gratitude.

We now arrive at the most serious charge made by the author of the article in the *Manchester Times* against the conclusions of the "Report on the Supply of Surplus Water," *and it is principally to this one charge* that I feel interested in replying.

It is well known to all who have paid attention to these matters that, as a general rule, the total quantity of water flowing down a mountain stream in a given time is in proportion to the area of ground which drains into such stream, combined with the amount or depth of rain falling. The streams proposed to be impounded by the Corporation of Manchester form no exception to this rule; and the natural form and character of their drainage ground is such, that no difficulty exists in ascertaining their exact area; so that the only point open to dispute is the annual amount or depth of rain falling.

A certain amount of the rain falling on a given drainage ground does not flow off the ground, but is taken up by absorption, evaporation, and supporting vegetation; and this is especially the case in warm seasons. A large portion, however, of the produce of rain, especially on steep and retentive ground, and during or immediately after heavy and continued showers, drains off the ground almost as quickly as it falls from the clouds; another portion, percolating through the ground where it happens to be porous, frequently gravitates to a considerable depth, till arrested by an impervious stratum; and conducted by the inclination of such stratum, it is frequently found oozing out in hill sides, and forms what are usually denominated springs; another portion, not penetrating so deeply into the ground, slowly gravitates down the sides of the hills, below the surface of the soil, till it flows out at the bottom in the form of streams*. These streams, in hilly districts, especially near their sources, and after a long drought, contain an insignificant quantity of water, while, on the other hand, after heavy rains, the amount flowing down them is very considerable. *The whole produce of the streams*, however, both the quantity flowing down them in a drought and the quantity flowing down them in floods (which occur

* See Appendix A, page 15.

during or immediately after heavy showers) is equally the produce of the rain falling in the locality.

It is evident from the foregoing, that if any error existed in the construction of the rain gauges placed on the Corporation gathering ground, which would either cause them to show a greater or less amount of rain than that actually fallen, any calculations made on such data of the quantity of water which could be yielded by the Manchester Corporation gathering ground would be erroneous.

I have shown, Appendix C, page 66 of "Report on the Supply of Surplus Water," that the form of gauges made use of by the Manchester Corporation cannot be depended upon to give accurate results; but the author of the article in the *Manchester Times*, without endeavouring to defend the Corporation rain gauges, states, on his own authority, without however giving a single fact to support the assertion, that the rain gauges erected by the Manchester, Sheffield, and Lincolnshire Railway Company on the Corporation gathering ground, and shown in Plate 3 of the Report, are "so constructed that there must inevitably be free evaporation; and when we remember that evaporation is more rapid the higher the elevation, we have a ready explanation of the gauges retaining less water on high than on low ground. So great is the error of these gauges that the quantity of rain indicated by them as having fallen at Woodhead is very considerably less than the quantity which is proved to have run off the ground."

Upon reading this confident statement, I immediately requested Mr. John Wood, who has charge of the Railway Company's rain gauges, to place an open-mouthed phial, about three-fourths filled with water, in the stand of a rain gauge placed on high ground, as well as a similar phial in the stand of a rain gauge fixed on lower ground. Accordingly, on the 6th of last May, a small bottle, two and a half inches diameter, with an open neck, three quarters of an inch diameter, was placed in each of the rain gauge stands that are fixed at Chapel-en-le-Frith, Comb's Reservoir, and Comb's

Ridge; the exact level of the water in each of these bottles was marked on the outside; from the time of placing these bottles in the stands up to the present time (nearly three months), the level of the water in each of them is, as accurately as can be measured by the eye, the same as when first placed in them, ***thus showing that any loss which has taken place*** in the manner so boldly asserted by the writer in the *Manchester Times* IS INAPPRECIABLE. Considering that the description of rain gauge used by the Railway Company is recommended by the celebrated Luke Howard, and that the collecting bottle is protected from both the action of the sun and wind, it was pretty evident that no great error could exist from the cause asserted, and the experiments I have related ***prove such to be the fact:*** besides, the table given in page 33 of Report, and collected from so many independent sources, fully supports the accuracy of the Railway Company's rain gauges.

It is much to be regretted that positive assertions,—unsupported by proof of any kind,—should be made in relation to the important subject now under consideration; no ultimate good can possibly arise to any party by the perversion of facts. If the author of the article in the *Manchester Times* felt reason to doubt the accuracy of the results given by the rain gauges used by the Manchester, Sheffield, and Lincolnshire Railway Company, why not have satisfied himself if there were any truth in his suspicions by direct experiment, instead of committing himself by such unfounded statements?

I would beg to call the especial attention of the writer of the article in the *Manchester Times* to his own observation:—"So great is the error of these gauges, that the quantity of rain indicated by them as having fallen at Woodhead is very considerably less than the quantity which is proved to have run off the ground." When two opposite results are arrived at by a different method of making experiments, that *both* cannot be correct is evident; but when one result is fully proved to be right, by many corroborating experiments *made independently of each other*, as happens to be the case with the Railway

Company's rain gauges, it is quite certain that the other result *must be erroneous;* a conclusion which doubtless the writer in the *Manchester Times* never dreamt of applying to the measurement of the flow of water off the Corporation gathering ground. Admitting, as the *Manchester Times* does, that the quantity of water flowing down a mountain stream in a given time cannot be ascertained by only measuring the produce of such streams twice a day "if such measurements are continued only for a short time," it is not very clear how the adding together the 730 measurements obtained by this process in a year "will give a result approximating* to the true mean." (See Appendix E, page 75, of "Report on the Supply of Surplus Water.")

The objection that the placing of the Manchester, Sheffield and Lincolnshire Railway Company's rain gauges about thirty inches above the ground, or the height of an ordinary dining table, causes them to give inaccurate results, is equally unsupported by any fact or proof.

Meteorologists differ as to the elevation at which they fix their rain gauges above the ground, their practice varying from a few feet to a few inches: the height of the funnel of the Railway Company's rain gauges is less than a mean of these heights, therefore any objection on this ground can be of little value †.

The writer in the *Manchester Times* also objects to the cost of reservoirs being computed in proportion to their capacity. He states, "A reservoir is commonly made by throwing an embankment across the gorge of a valley or ravine. The cost depends, in a great measure, upon the size of the embankment, but the capacity upon the formation of the ground."

In calculating the cost of many large works an approximate estimate is usually made by some ready rule, the result of experience; thus, castings in iron are estimated by the ton; large buildings and warehouses by the cube yard; and

* See Manchester Times, April 22nd, 1848.

† See Appendix B, page 16.

large reservoirs for storing water by the cubic contents. In such cases practice proves that the actual cost does not usually materially differ from approximate estimates made in this manner.

Upon a detailed examination of the Corporation Works, it will be found, that although the Woodhead Reservoir will require a comparatively small amount of earthwork in its embankment in proportion to its capacity, yet, on the other hand, the Armfield and Hollingworth Reservoirs, in proportion to their size, require a very large amount of earthwork to form their embankments.

The expense of preparations to prevent accident from sudden floods, while the works are being constructed, (an important item when the area of drainage-ground is large, as at Woodhead,) and the cost of waste weirs, discharge pipes, besides other expensive works belonging to reservoirs, are very nearly in proportion to the area of ground draining into them. Now, taking collectively the five principal reservoirs proposed to be made by the Corporation, there is reason to believe that the calculations made by the rule used in the "Report on the Supply of Surplus Water," will prove an *under* rather than an over estimate of the cost.

In executing works to supply a town with water, it is absolutely essential to construct them of the most durable materials, and in the soundest manner, otherwise great inconvenience and costly repairs are sure to result after completion. However, it is now useless to say more on this head; whatever else may for a time be unascertained, it is *quite certain* that the cost of the works will be well known to the inhabitants of Manchester before many years are over.

I have now answered all the objections of any importance which have been made to the "Report on the Supply of Surplus Water;" it is not my intention to mix up any mere personal matters with this subject; when a writer makes positive assertions, it might be as well to back them with *some kind of proof*. I have at least shown that the statements of the writer of the article in the *Manchester*

Times require such guarantees before they can be credited.

In my "Report on the Supply of Surplus Water to Manchester, Salford, and Stockport," I have proved (See Appendix L, page 79) that, for the preservation of the health of the inhabitants of Manchester and Salford, it is requisite an ample quantity of wholesome water should *immediately* be supplied to them in lieu of the contaminated produce of the drainage ground of the Gorton Reservoirs, and the River Medlock. I have also proved that a much larger supply of water than is at present distributed in Manchester and Salford by the Water Works Company, could *at once* be procured by the Corporation for distribution in Manchester, from the Manchester, Sheffield, and Lincolnshire Railway Company, of an excellent quality, and at a cheaper rate than water is supplied to the inhabitants of any town in the kingdom. (See Appendix M, page 81 of Report.) I have shown that by the powers obtained from Parliament by the Manchester, Sheffield, and Lincolnshire Railway Company, during the session of 1847, a large supply of the purest water, at a *known* cheap rate for distribution, could be permanently secured for the inhabitants of Manchester; and that easy extension works could be carried out in conjunction with their present powers, to procure any further quantity of water whenever a demand for it should arise. The Corporation prefer the shadow to the substance; they insist that the three millions and a half of gallons of water per day, in the possession of the Railway Company, and at this moment available for the supply of Manchester, shall continue to run to waste, as the greatest portion of it has done heretofore; that the inhabitants of Manchester shall be debarred from its use, and shall be compelled for some years longer, to the evident detriment of their health, to drink from the unwholesome Medlock, and the polluted produce of the Gorton Reservoirs, eked out with such an additional supply from the Railway Company as urgent necessity compels them to take. In the mean time the Corporation propose to tunnel through a hill at

Mottram—try experiments on a magnificent scale to ascertain, for themselves, what has been settled to the satisfaction of other persons long since, if peat water stored in reservoirs be wholesome; whether the main valley of the Etherow be retentive; or the depth of water flowing off the ground in a dry year at Woodhead be twenty, thirty, forty, or more inches. Should the result of these experiments turn out as the most sanguine promoters of the Corporation scheme could desire, perhaps the writer in the *Manchester Times* will inform his readers what object the Corporation will have accomplished for the ratepayers and inhabitants of Manchester—beyond spending very foolishly some hundreds of thousands of pounds of their money, to procure, some four or five years hence, that which is within reach at the *present moment,* and saddling them with a heavier burden, for many years to come, than there is any necessity for?

It may, however, be pleaded that the Corporation is likely to accomplish *one thing*—they may prevent the Manchester, Sheffield, and Lincolnshire Railway Company from parting with, "*for a consideration,*" * to the inhabitants of Manchester, a large quantity of surplus water, at present running uselessly to waste, and which the inhabitants of Manchester are perishing for want of:—a worthy achievement, (the merits of which the writer in the *Manchester Times* will doubtless expatiate upon in due course,) and a grateful return when it is remembered that at the present moment, and for some time past, the Railway Company have furnished a supply of wholesome water, in the dryest seasons, to dilute the impurities contained in the water supplied to Manchester from the Gorton Reservoirs, and have done so much for the permanent prosperity of Manchester, by giving it not only the most improved communication with the coal-beds of Yorkshire and the rich districts of Lincolnshire, but in literally creating a new port (Great Grimsby) for the outlet of its manufactures.

When these experiments of the Corporation, some years

* See *Manchester Times.*

hence, shall force, even upon themselves, the conviction that the whole basis of their calculations as to the quality and quantity of the water that can be yielded by their scheme is visionary and delusive, it may be a fortunate circumstance for the inhabitants of Manchester if the resources of the Manchester, Sheffield, and Lincolnshire Railway Company can then, as at present, be made available for their use.

The following paper, being "An Account of some Observations made on the Depth of Rain which falls in the same localities at different altitudes in the hilly districts of Lancashire, Cheshire, and Derbyshire," relates to the subject discussed in Appendix C of the "Report on the Supply of Surplus Water." By permission of the Council of the Royal Society of London, I am enabled to publish it; it may be found interesting to all engaged in inquiries similar to those of which it treats.

London, 19, Buckingham Street,
Adelphi, Aug. 1848.

APPENDIX.

APPENDIX A.

In the "Report on the Supply of Surplus Water," it is stated (page 42) that water, "when it flows off the hill-sides during heavy rains (except in a peaty or boggy district), is much less contaminated than water (percolating slowly from the soil, and reduced in quantity by evaporation) which forms the streams in dry weather." This statement is made from the result of the author's experience in several different towns, where it is notorious that the water taken from the rivers is much softer and less contaminated immediately after heavy rains, and in wet seasons, than during droughts, as well as upon a chemical examination of the flood and stream water of the district more particularly alluded to.

The stream water of the Todds Brook was analyzed in April, 1847, by G. Newport, Esq., F.R.S., and Dr. Ronalds, and also the flood water collected in the Todd's Brook reservoir, the stream water was found to contain 5·994 grains per gallon of solid matter in solution, and the reservoir water only 4·440 grains per gallon.

The analysis of the same water, made by P. H. Holland, Esq., and Dr. R. Smith, in December, 1846, and published in the "Minutes of Evidence on the Manchester Waterworks Bill," page 64, shows that when the Todd's Brook stream water was 2·2 degrees of hardness, the reservoir water was only from 1·3 to 1·85 degrees of hardness.

In a Report "On the Well Waters of Glasgow," by R. D. Thomson, M.D., Professor of Practical Chemistry in the University, and published in the "Journal of Public Health, for August, 1848," page 270, it is stated in reference to the quality of well-water, that "the quantity of matter dissolved will depend in some measure upon the rapidity with which the water percolates, and upon the amount which passes through the strata, and hence we may expect that in rainy weather the solutions will be much more dilute, and that the constitution of the well-waters may vary considerably at different seasons, *just as we find that rivers contain much less solid matter in a given weight of these waters during rains than during the dry season of the year.*"

At the same time it must be remembered that flood water, derived from arable land, and some kinds of soils, is always charged in heavy floods with a large quantity of foreign matter in mechanical suspension; such water, however, usually becomes quite clear by subsidence and filtration, after which process it will be found purer, and the matter in solution less in quantity than is contained in the dry weather stream-water procured from the same source.

I have thought it right to give this explanation, owing to different reviewers having made some remarks in relation to this subject, which call for an answer.

APPENDIX B.

In a valuable paper lately published, entitled, "Remarks on the Weather during the Quarter ending March 31st, 1848," by J. Glaisher, Esq., of the Royal Observatory, Greenwich, and to whom I am indebted for a copy of the same, there is given a Monthly Meteorological Table, for the above period, of thirty-four different places, situated in different parts of England, mostly compiled from the observations of different Meteorological observers; referring to the fall of rain, it is stated (at the bottom of page 8), "The height of the receiving surfaces of the rain gauges above the soil, at Helston, is 6 feet; at Torquay, 5 feet; at Southampton, 9 feet 7 inches; at Greenwich, 5 inches; at Maidenstone Hill, 1 foot; at Walworth, 4 feet 6 inches; at St. John's Wood, 2 inches; at Latimer, 7 feet 6 inches; at Cardington, 3 inches; at Stone, 4 feet 6 inches; at Derby, 1 foot; at Highfield House, 3 inches; at Stonyhurst, 4 feet 10 inches; and at Leeds, 3 feet 6 inches."

In the same paper, page 7, it is shown that, during the month of last March, a rain gauge kept at Latimer Rectory, near Chesham, Bucks, by the Rev. Samuel King, and placed 7 feet 6 inches above the surface of the ground, registered the amount of rain falling as 3 inches 9-tenths, and that another rain gauge in the same locality, placed on the ground, registered 4·05 inches. In this case a difference of 7 feet 6 inches in the level of the gauges made 105 thousandths of an inch difference in a month, being equal, at the same rate, to a difference of 1¼ inch in depth per annum.

Now, the Railway Company's gauges are about 2 feet 6 inches above the ground, or only one-third of the height of the rain gauge at Latimer Rectory; so that it is quite clear that no error worth estimating can be produced from this source. It is well known that if the receiving surface of a rain gauge be placed many feet above the surface of the ground, the quantity indicated as falling is less than that shown by a rain gauge placed near the ground; but the height of the receiving surface of the Railway Company's gauges is not sufficient to produce any difference, material to the present investigation.

APPENDIX C.

The amount or depth of rain proved by the rain gauge fixed at Woodhead (see page 34 of "Report on Supply of Surplus Water") to have fallen there, during the past year of 1847, is 33 inches. Calculating that as much as two-thirds of this quantity flows off the ground, and that only the remaining third is lost by evaporation, absorption, and supporting vegetation, this leaves a quantity of water equal to 22 inches in depth over the whole surface of the drainage ground as capable of being collected, if reservoir room be made of sufficient capacity to store the floods for use in seasons of drought. From this water when so stored, the mill-owners, by Act of Parliament, are *first* to have supplied to them 75 cube feet per second for 12 hours of every working day (312 days in the year); this is equal to 17,259,734 gallons for each day in the year, or a quantity of water equal to about 15½ inches in depth per annum over the whole area of the collecting ground. Subtracting 15½ inches from 22 inches, 6½ inches remain; taking the produce of the water flowing from the Woodhead Tunnel (see Appendix G, page 77 of "Report on Supply of Surplus Water") as equal to the evaporation from the reservoirs, although in a dry summer season the produce of the tunnel would not equal it, the amount of water remaining for the use of the inhabitants of Manchester would be equal to 7½ millions of gallons per day.

The Corporation lead the inhabitants of Manchester to expect, instead of the 7½ millions of gallons per day, from 23 to 29 millions of gallons per day. This they do by persisting that from 36 to 42 inches of rain in depth per annum will *flow off the ground*, or that from 54 to 63 inches of rain in depth per annum *falls on* the ground; notwithstanding that, during the year 1847, only 33 inches* is *proved* to have fallen at Woodhead. The smallest estimate made by the Corporation is, that 3 inches more flows off the ground, than is proved at Woodhead in the year 1847 to have fallen on it!!

* See page 34 of "Report on the Supply of Surplus Water."

AN ACCOUNT OF SOME OBSERVATIONS

MADE

ON THE DEPTH OF RAIN

WHICH FALLS IN THE SAME LOCALITIES, AT DIFFERENT ALTITUDES,

IN THE HILLY DISTRICTS OF

LANCASHIRE, CHESHIRE, AND DERBYSHIRE.

BY S. C. HOMERSHAM,

CIVIL ENGINEER.

READ BEFORE THE ROYAL SOCIETY OF LONDON, MAY 25TH, 1848.

HAVING been present at a meeting of the Royal Society of London on the evening of the 18th of May last, when a valuable and interesting paper was read, "On the Meteorology of the Lake Districts of Westmoreland and Cumberland," by J. F. Miller, Esq., of Whitehaven, in which paper the following remark occurred,—"It would be premature, from the scanty data before me, to draw any conclusion as to the gradation in the quantity of rain, at these great elevations above the sea. *But it seems probable that, in mountainous districts, the amount of rain increases from the valley upwards, to an altitude of about* 2,000 *feet, where it reaches a maximum;* and that above this elevation the quantity rapidly decreases. The table for 1846 exhibits the rain fall of the summer months only; but the additional returns of 1847, obtained in every variety of season, confirm the above deductions in every essential particular, so that we may fairly assume the combined results to be indicative of a physical law, so far at least as relates to the particular locality in question."

I am desirous of laying before the Royal Society certain observations made under my own direction, which lead me to differ from the author of that paper in the conclusion he has deduced from his facts.

Mr. Miller kindly furnished me some time since with many, if not the whole, of the results of his experiments in these districts up to the beginning of March last. I have been careful to ascertain whether Mr. Miller's own experiments fully bear out the conclusions suggested in the quotation above made, because this conclusion is in direct opposition to the recorded observations of the Honourable Daines Barrington, F.R.S., Dr. Dalton, Professor Daniell, Samuel Marshall, Esq., of Kendall, and John Fleming, Esq., of Manchester; and also to observations made in 1841 by Captain Lefroy, then Director of the Observatory at St. Helena; the results of which observations were published in 1847, by order of Her Majesty's Government, under the superintendence of Lieut.-Col. Sabine, F.S.R.S., in a volume entitled "Observations made at the Magnetical and Meteorological Observatory of St. Helena."

The Honourable Daines Barrington, F.R.S., states in the "Philosophical Transactions" for 1771, page 294, that in 1770 he caused two rain gauges to be placed, one on Mount Rennig in Wales, 1350 feet above the level of the sea, and the other upon the plain below. From July 6th in this year to October 29th, the gauge on the top of the mountain caught 8·165 inches of rain; the one at the bottom 8·766 inches, showing half an inch *more rain to have fallen at the bottom* than on *the top* of the mountain.

Dr. Dalton, in the "Memoirs of the Literary and Philosophical Society of Manchester," vol v., New Series, page 236, says:—"From the observations made in Great Britain, it appears to be an established fact, that more rain falls in the hilly part of the country than in the plain; *but it also appears that the quantity of rain in a low situation is greater than in an elevated situation in the vicinity.*"

Professor Daniell, in his "Elements of Meteorology," vol. i., page 236, states, "It has been ascertained more rain falls at the bottom of a mountain than the top." Samuel Marshall, Esq., of Kendall, also states, in a communication published in 1839, in the "Transactions of the Meteorological Society," vol. i., page 115, that, "It is a fact sufficiently well established, that more rain falls in low situations than in more elevated ones, even when contiguous."

And more recently, John Fleming, Esq., states, in the "Memoirs of the Literary and Philosophical Society of Manchester," vol. v., Second Series, page 252, that, "On the descent of the hill, and probably about the foot of it, the heaviest rain will fall." In the "Observations made at the Magnetical and Meteorological Observatory of St. Helena," before alluded to, it is stated at page 102 of the index :—"In 1841, Captain Lefroy, then director of the observatory at St. Helena, established rain gauges at three other points of the island, for the purpose of ascertaining a comparative estimate of the quantity of rain. The stations were—

"1. Near the highest pinnacle of the island, on a very narrow ridge of rock.

"2. Lower down on the same ridge of hills.

"3. Longwood Observatory.

"4. James Valley.

"The three first stations might be comprehended in a circle of one mile radius, and the fourth is but little more distant. The quantities of rain received at these stations, during nine months of 1841, were as follows :—

"1. At 2644 feet	of elevation,	22·63 inches.
2. At 1991 feet	"	27·11 "
3. At 1782 feet	"	43·42 "
4. At 414 feet	"	7·63 "

This table shows that at 1782 feet elevation, much *more* rain fell in a given time than at *the higher* elevation of 1991 feet. The reason why so small a quantity as 7·63 inches only was recorded in the same time at 414 feet elevation, is not very apparent; but it would probably be found, upon examination, that this result is due to some local circumstance in the position of the gauge, and not to its elevation—

a conclusion to which I am led by an examination of the localities, compared with the quantities of rain collected in Mr. Miller's experiments.

In a Report which I have recently published, "On the Supply of Surplus Water to Manchester, Salford, and Stockport," page 70, I have shown that, during the past year of 1847, I had four rain gauges fixed, one at the bottom of Todd's Brook Valley, situated in Cheshire, near Whaley, 620 feet above the level of the sea; another at Brinks, the top of the hill bordering this valley, 1500 feet above the level of the sea, and that 38·39 inches in depth was received at the bottom of the hill, and only 29·5 inches at the top of the hill. A third gauge was fixed at the bottom of the Comb's Brook Valley, situated in Derbyshire, near Chapel-en-le-Frith, 720 feet above the level of the sea, and that 51·30 inches in depth was caught at the bottom of the hill, and only 35·85 inches at the top of the hill.

Since the Report just referred to was published, I have been favoured by Thomas Hawksley, Esq., C.E., with the results of some important unpublished experiments made by him for the Corporation of Liverpool, on the amount of the fall of rain at Rivington, and in the Valley of Roddlesworth, near Preston, in Lancashire. Six rain gauges, placed near the ground, were fixed in these localities at the beginning of January, 1847, three at Rivington, and three in the Valley of Roddlesworth. The situations of these gauges are shown on the accompanying ordnance map of the district, (see last page,) the three gauges fixed at Rivington being marked in red ink, Nos. 1, 2, and 3; they are respectively 410 feet, 710 feet, and 750 feet above the level of the sea.

The quantities falling per month are shown in the following table, and also the monthly fall for January, February, and March, 1848, all of which results prove the same general fact, that more rain falls at the bottom than at the top of the hills in the same localities.

TABLE

Showing the quantities of rain fallen per month in three rain gauges, fixed near the ground, in the district of Rivington, Lancashire, during the year* 1847 *and three months of* 1848, *with their respective heights above the level of the sea.

	January and February.		March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Total.
	ins.		ins.	ins.	ins.	ins.	ins.	ins.	ins.	ins.	ins.	ins.	ins.
1847.													
No. 1. 410 ft. above the level of the sea.	5·60		1·47	2·69	6·22	4·22	1·30	2·91	6·28	5·69	5·07	7·38	48·83
No. 2. 710 ft. above the level of the sea.	5·36		1·22	2·75	6·09	4·20	1·26	2·92	5·63	5·37	4·85	6·83	46·48
No. 3. 750 ft. above the level of the sea.	5·51		1·25	2·69	6·04	3·79	1·11	2·78	5·59	5·27	4·75	7·18	45·96
1848.													
No. 1. 410 ft. above the level of the sea.	3·13	7·93	3·81	...	...	...	...	...	...	...	...	...	14·87
No. 2. 710 ft. above the level of the sea.	2·89	7·86	3·91	...	...	...	...	...	...	...	...	...	14·66
No. 3. 750 ft. above the level of the sea.	2·88	8·00	3·77	...	...	...	...	...	...	...	...	...	14·65

The foregoing table shows that the gauge at the lowest elevation, 410 feet, received 48·83 inches in depth of rain, during the year 1847; the gauge at 710 feet elevation a smaller quantity, namely, 46·48 inches; and at the greatest elevation, 750 feet, a still smaller quantity than either of the other two gauges, or only 45·96 inches. The three gauges fixed in the Roddlesworth Valley are marked in red ink on the map Nos. 4, 5, and 6, they are respectively 550 feet, 700 feet, and 900 feet above the level of the sea.

The depth of rain falling for every month in 1847 is given in the following Table, and also the monthly fall for January, February, and March, for 1848.

TABLE

Showing the quantities of rain fallen per month in three rain gauges, fixed near the ground, in the Roddlesworth Valley, Lancashire, during the year 1847 *and the three first months of* 1848, *with their respective heights above the level of the sea.*

	January and February.		March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Total.
	ins.		ins.	ins.	ins.	ins.	ins.	ins.	ins.	ins.	ins.	ins.	ins.
1847. No. 4. 550 ft. above the level of the sea.	6·42		1·33	2·31	5·69	4·52	1·05	3·72	5·86	6·25	5·53	7·54	50·22
No. 5. 700 ft. above the level of the sea.	6·79		1·35	2·72	6·30	4·93	1·20	3·95	7·10	7·09	6·55	9·12	57·10
No. 6. 900 ft. above the level of the sea.	6·46		1·28	2·80	6·59	4·43	1·50	3·21	6·60	6·39	5·99	7·28	52·53
1848. No. 4. 550 ft. above the level of the sea.	2·70	8·61	3·64	...	...	...	...	...	...	...	...	...	14·95
No. 5. 700 ft. above the level of the sea.	3·19	10·25	4·26	...	...	...	...	...	...	...	...	...	17·70
No. 6. 900 ft. above the level of the sea.	2·90	8·36	3·21	...	...	...	...	...	...	...	...	...	14·47

The gauge at the lowest elevation in this locality (550 feet) received 50·22 inches of rain during the year 1847; the gauge at 700 feet elevation 57·10 inches during the same time; and the gauge at 900 feet, the highest elevation, 52·53 inches.

Here it will be observed, that the gauge at 900 feet elevation received, as before, a considerably *less* amount of rain than the gauge at the lower elevation of 700 feet, but that the gauge at the lowest elevation of 550 feet forms an exception, as this gauge received about 2¼ inches less in depth during the same time than the gauge at 900 feet elevation, and nearly 7 inches less than the gauge at 700 feet elevation.

A personal knowledge of this locality, or a glance at the accompanying map, may serve to explain this departure from the general rule observed, for this gauge is placed at the bottom of a steep valley, bordered to the west by very precipitous and high land, and it is in this manner sheltered, to a considerable extent, from the prevailing rainy winds.

Two rain gauges which I have caused to be fixed, one in the neighbourhood of the Bosley Reservoir, situated near Congleton, Cheshire, 590 feet above the level of the sea, and the other at Bosley Minns, 1265 feet above the level of the sea, in the same locality, show that, during the first four months, January, February, March, and April of the present year, 11·75 inches fell on the bottom of the hill, and only 11·65 inches on the top of the hill.

The amount of rain received in the rain gauge placed near the bottom of a hill at Todd's Brook, (before referred to,) during this period, was 13·03 inches in depth, and at Brinks, the top of the same hill, only 11·51 inches.

The amount received in this time at Comb's gauge at the bottom of the hill, was 19·70 inches, and in the gauge at the top of the hill only 10·45 inches, as shown in the monthly report of the observations made with all these gauges which are given in the following table :—

TABLE

Showing the quantities of rain fallen per month in certain funnel rain gauges, 9 inches' diameter, and placed 2 feet 6 inches above the surface of the ground, at Todd's Brook, near Whaley, Cheshire; at Comb's Brook, near Chapel-en-le-Frith, Derbyshire; and Bosley, near Congleton, Cheshire, with their respective heights above the level of the sea.

SITUATIONS.	January.	February.	March.	April.	TOTALS.
	Ins. tens.	Ins. tens.	Ins. tens.	Ins. tens.	Ins. tens.
Todd's Brook, Brinks, top of hill, 1500 feet above level of sea.	1·75	5·49	2·22	2·05	11·51
Todd's Brook Reservoir, bottom of hill, 620 feet above level of sea.	1·76	5·60	3·21	2·46	13·03
Comb's Ridge, top of hill, 1670 feet above level of sea *.	1·56	4·86	2·39	1·64	10·45
Comb's Reservoir, bottom of hill, 720 feet above level of sea.	2·60	9·20	4·60	3·30	19·70
Bosley Minns, top of hill, 1265 feet above level of sea.	1·90	4·75	2·75	2·25	11·65
Bosley Reservoir, bottom of hill, 590 feet above level of sea.	2·38	4·21	3·29	1·87	11·75

A knowledge of the facts before mentioned induced me to examine Mr. Miller's experiments soon after receiving them, with a view to ascertain how far they confirmed or were in opposition to the recorded observations and facts stated by the

* The gauge at Comb's Reservoir is a cylindrical gauge, 7 inches' diameter, and 18 inches above the level of the ground, and has a float and staff to indicate the amount of rain falling: this gauge probably shows an excess of the amount of rain. See Report, Appendix C, page 66, on "Supply of Surplus Water to Manchester, Salford, and Stockport."

many eminent meteorological authorities before quoted, for which purpose I procured the best map of the lake district I could obtain, and marked upon it the situation of Mr. Miller's rain gauges, and then compared together the results obtained by the rain gauges placed in the valleys or the bottom of the hills with the rain gauges placed upon the tops of ***the same hills*** or bordering ***the same valleys.*** By proceeding with reference to locality in this manner, it soon became apparent that the valuable and interesting facts collected and recorded by Mr. Miller, with very few exceptions, which it appears to me may be easily accounted for, agreed with the observations of other meteorological writers. Indeed this could not fail to be the case, unless the generally received and admitted theory of the formation and distribution of rain, as laid down by Dr. Dalton, ***was also disproved.***

Upon examining Mr. Miller's facts, it will be found, from April to December, 1846, both inclusive, that at Whitehaven, 90 feet above the level of the sea, 38·063 inches fell; while at Round Close, 480 feet above the sea, and not far distant, only 36·195 inches fell in the same time; and during 1847, that 42·92 inches are recorded to have fallen at Whitehaven, and only 42·023 at Round Close.

On examining with reference to locality in a similar manner the rain gauges placed in the Valley of Borrowdale, or Derwent Water, in which vale the quantity of water received by four rain gauges at different altitudes are recorded by Mr. Miller, namely, one at Seathwaite, 242 feet above the sea; one at Sty Head, 1290 feet high; one at Seatoller, 1334 feet high; and one at Sparkling Tarn, 1906 feet high; it will be found, as shown in the following table, which I have drawn up from a careful analysis of Mr. Miller's experiments as communicated to me by himself, taking the longest period during which he has registered experiments at each of the localities, that from June 1846, to November 1847 inclusive, 193·69 inches fell at a level of 242 feet above the sea; at the greater elevation of 1290 feet a less quantity, or 164·12 inches, fell;

TABLE.

Borrowdale, or Derwent Water.

Months.	Seathwaite, 242 feet above the sea.	Sty Head, 1290 feet above the sea.	Seatoller, 1334 feet above the sea.	Sparkling Tarn, 1906 feet above the sea.
1846.	Inches.	Inches.	Inches.	Inches.
June	6·42	6·26	5·70	6·55
July	20·80	17·76	18·35	22·72
August	10·58	11·03	8·15	12·03
Sept.	4·60	4·22	3·75	5·06
October	25·43	15·35	17·42	20·35
Nov.				
Dec.				
1847.				
January	41·06	32·52	27·51	31·82
February				
March				
April				
May	8·08	7·56	7·13	7·59
June	7·27	7·12	5·71	8·13
July	3·32	3·66	2·50	4·15
August	10·48	10·22	10·38	12·00
Sept.	13·28	10·92	12·06	12·43
October	20·52	17·50	19·02	18·0
Nov.	21·85	20·00	18·07	22.64
Dec.				
Totals	193·69	164·12	155·75	183·47

at the greater elevation still of 1334 feet, a yet smaller quantity, or 155·75 inches. The last example, however, at an elevation of 1906 feet, shows that 183.47 inches fell in the same time, being, in this instance, less by 10 inches than the quantity which fell at the elevation of 242 feet, but much more than the quantities which fell at the elevations of 1290 and 1334 feet. This last fact I think may be accounted for by reference to the peculiar position of Sparkling Tarn (the mountain on which this last gauge is fixed). This mountain is only 1906 feet high, but is in the *immediate* vicinity, that is, within a mile and a quarter to a mile and a half of the mountains Scawfell Pike and Bowfell to the South, and within a mile and a quarter of Great Gavel to the North. These mountains vary from 2900 to 3166 feet in height, the lowest of them being upwards of 1000 feet higher than Sparkling Tarn, while Sparkling Tarn is fully exposed to the westerly winds; and the clouds being carried inland by this wind, between the gorge formed by these high mountains, it may be easily conceived that a large portion of rain in the transit of the clouds would be deposited on the top of Sparkling Tarn; so that the large amount of rain falling at this altitude in this locality would appear to be the exception and not the rule.

In the valley of Wast Water, the amount of rain falling at Wastdale, 166 feet above the level of the sea, from March 1846, to November 1847, both inclusive, is shown to be 170·55 inches; and at Scawfell Pike, which borders this valley to the east, 3166 feet high, only 128·15 inches fell in the same time.

In the valley of Ennerdale, at Gillerthwaite, 286 feet above the sea, 133·86 inches fell; while at Great Gavel, 2925 feet high, during the same time, only 124·68 inches fell.

All the valuable facts here alluded to, supplied by Mr. Miller with one exception only, prove that the greatest amount of rain falls in the same localities at or near the base of a hill, and not at so great an altitude as 2000 feet above the sea; and the one exception, namely, that at Sparkling Tarn, 1906 feet high, shows that from June, 1846, to November, 1847 (both inclusive), 183·47 inches fell; while at Seathwaite, the bottom of the valley, bounded by Sparkling Tarn, during the same time, as much as 193·69 inches fell, or 10 inches more at the lower than at the higher locality, thus confirming the conclusion arrived at by my observations, which also fully accord with the meteorological authorities I have quoted.

As the amount or depth of rain falling in a given time in Great Britain, in different localities and under different circumstances, is a matter of very great practical importance to Civil Engineers generally, and especially to those engaged in designing works to supply large towns with water, to regulate the flow of rivers, or to drain large tracts of land, independent of their importance in a philosophical point of view, I have been unwilling to allow the valuable facts collected by Mr. Miller, with such perseverance and industry, to pass without a few comments, which, as it appears to me, may tend to make them more generally useful, by explaining their supposed discrepancy with the generally received views of such accurate observers as Dr. Dalton, Professor Daniell, Captain Lefroy, and the other authorities quoted in this paper, confirmed as the observations and recorded experiments of these last-named gentlemen are shown to be by the more recent experiments herein detailed.

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