GENERAL BOARD OF HEALTH.

MINUTES

OF

INFORMATION

COLLECTED IN RESPECT TO THE

DRAINAGE OF THE LAND FORMING THE SITES OF TOWNS,

TO

ROAD DRAINAGE,

AND THE

FACILITATION OF THE DRAINAGE OF SUBURBAN LANDS.

Ordered to be printed for the use of Local Boards of Health and their Surveyors, engaged in the Administration of the Public Health Act.

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GENERAL BOARD OF HEALTH.

MINUTES of INFORMATION collected in respect to the Drainage of Land forming the Sites of Towns, to Road Drainage, and the Facilitation of the Drainage of Suburban Land.

Town drainage is two-fold—foul-water drainage and simple-water drainage. The first comprehends sewerage as the term is now commonly used; that is, the removal from within dwellings or from their immediate neighbourhood of all solid refuse which can be carried off by water. The second—simple-water drainage—is the removal from the sites and suburbs of towns of superfluous water, causing dampness, whether such water be derived from land springs or rain-fall.

So generally is the latter or simple-water drainage neglected, that it appears from the late sanitary investigations that in town districts which are called drained, the foundations of the houses are very generally damp from the retentiveness, or the water-bearing power, of the soil in which they are built. Water rising from a damp foundation by absorption renders the floors and the walls damp, in proportion to the absorbent nature of the materials of which they are constructed. When experienced medical officers see rows of houses springing up on a foundation of deep retentive clay, inefficiently drained, they foretel the certain appearance among the inhabitants of catarrh, rheumatism, scrofula, and other diseases, the consequence of an excess of damp, which break out more extensively and in severer forms in the cottages of the poor who have scanty means of purchasing the larger quantities of fuel, and of obtaining the other appliances by which the rich partly counteract the effects of dampness. Excess of moisture is often rendered visible in the shape of mist or fog, particularly towards evening. An intelligent medical officer took a member of the Sanitary Commission to an elevated spot from which his district could be seen. It being in the evening level white mists could be distinguished over a large portion of the district. "These mists," said the officer, "exactly mark out and cover the seats of disease for which my attendance is required. Beyond these mists I have rarely any cases to attend but midwifery cases and accidents." Efficient drainage causes the removal, or at least a great diminution of such mists and a proportionate abatement of the diseases generated or aggravated by dampness.

After houses built in the manner described have been inhabited for some time, and especially if crowded, fevers of a typhoid type are added to the preceding list of diseases, in consequence of emanations from privies and cesspools. The poisonous gases, the product of decomposing animal and vegetable matter, are mixed with the watery vapours arising from the excessive damp, (such vapours being now recognized as the common vehicle for the diffusion of the more subtle noxious gases,) and both are inhaled night and day by the residents of these unwholesome houses. A further consequence of the constant inhalation of these noxious gases, which have an extremely depressing effect, is inducing the habitual use of fermented liquors, ardent spirits, or other stimulants by which a temporary relief from the feeling of oppression is obtained.

The system of drainage for houses, streets, yards, and covered spaces in towns which is now found to be the most economical as well as the most efficient for its main purposes, —the removal of matters injurious to the public health,— consists principally of tubular and impermeable drain pipes. The arrangements hitherto in general use for the purpose consisted of spongy brick drains, or drains of other material, which let in the land springs or the surplus moisture of the site, and when these brick drains were of proper inclinations they slowly carried it away, notwithstanding the obstacles created by their defective form, material, and construction; but too frequently on account of their permeability they let out and saturated the site with the foul water, which it is most important they should keep in and remove from it. Whilst these common brick drains thus let out much of the soluble portions of the cesspool matter, which saturates the foundations of houses, and ascends the absorbent brick walls, they detain, as sponges or as filters, much of the solid portions of the refuse matter. This accumulates in the drains and sewers, the gaseous products from its putrefaction escape through the permeable brick itself, and still more copiously through openings into houses, and through gully shoots into the streets, and pollute the atmosphere. *Vide Minutes of Information on House Drainage.*

As the apparatus for an improved system of house drainage must be impermeable, that all foul matter may be certainly removed—which it is most important should be removed quickly and completely and without any escapes whatsoever, either liquid or aerial,—the plain surplus land water, whether from upland springs or from the rain-fall in garden ground or in the space uncovered by houses or by the paving of yards or streets, will remain to be specially provided for, and it is deemed will be most economically carried off by arrangements of permeable pipes, on the same principle as those used for the drainage of land under cultivation.

It has been supposed by those who have not had sufficient practical acquaintance with the improved system of town drainage, that the rain water from the roofs of houses as well as from the roads should be separated from the refuse removed by the house drains, and carried away by other drains, but it is found that water from the roofs brings down soot and dirt, and that this water and the surface water from streets and roads of much traffic is often more foul even than common-sewer water, and is valuable as a manure; and unless there be a very large proportion of such water, its separation from the sewage would involve the expense of double sets of drains, and injuriously complicate the arrangements.

Besides the space occupied by houses,—the jurisdiction of a Local Board of Health will often be defined by a natural drainage area, comprehending the line of water shed, dividing a hill top or a ridge, and bounded by a brook or river beneath dividing a valley. Generally the covered portion of the land occupied by a town itself forms only a small portion of the area under the jurisdiction of a Local Board, the greater proportion being occupied by tillage or grazing land, the perfect drainage of which is, on the sanitary grounds hereunder stated, of importance proportionate to its proximity to the town, and on agricultural grounds the importance is proportionate to the greater value for culture of land near a market.

The complete drainage of the agricultural portion of the natural drainage area in which a town is situate is of special importance to fit it for the reception of the town manures, especially if they are to be applied in the liquid form by way of sewage irrigation, and also for the better drainage of the public roads and footpaths within the area, by which their usefulness and durability will be alike increased.

Suburban lands requiring drainage may be divided into two classes;—garden, villa, and house lands in and immediately adjoining the town; and market garden, tillage, grazing land, and commons in its vicinity.

As a question of economy or pecuniary policy it is important that provision should be made for the removal of all stagnant water and superfluous moisture from land otherwise suitable for building upon or in the neighbourhood of dwellings. It frequently happens that the richer portions of a community choose their places of residence at a distance from the town with which they are connected by business or otherwise, because of the difficulty of finding pleasant and healthful places of residence in the vicinity. There are two chief causes of this difficulty: one, the prevalence of smoke, which so far as it arises from steam furnaces is preventible; the other, dampness of the soil, which by draining can be avoided without adopting the ordinary expedient of choosing for a place of residence a soil naturally dry. It is evidently of great social importance that everything which tends to drive the more opulent, who are also generally the more educated and refined, classes to distant places of residence should be removed; and it is also evidently of economical importance that a locality should not lose the contributions of its more opulent members towards the local taxes and subscriptions. It is clear, also, that whatever renders a place better suited for the residence of the wealthy must enhance the value of the property, and that the expenditure for effecting such a change may prove a very profitable investment.

The sanitary interests also of the locality urgently demand attention to the drainage of its suburban land; for excess of moisture most powerfully influences the local climate both as to dryness and temperature, as shewn in the report of the Metropolitan Sanitary Commissioners under the following heads:—

1. Excess of moisture, even on lands not evidently wet, is a cause of fogs and damps.

2. Dampness serves as the medium of conveyance for any decomposing matter that may be evolved, and adds to the injurious effects of such matter in the air:—in other words, the excess of moisture may be said to increase or aggravate atmospheric impurity.

3. The evaporation of the surplus moisture lowers temperature, produces chills, and creates or aggravates the sudden and injurious changes or fluctuations of temperature,

by which health is injured.* *Vide Sanitary Report*, 1842, pp. 80, 92; *Second and Third Metropolitan Sanitary Reports; and postea*, pp. 66-69.

Where there is a large accumulation of surplus moisture, having animal or vegetable matter in suspension or solution, the injury to the public health is so direct and considerable as to amount to a nuisance requiring authoritative intervention. The evils thus arising, which are found in the greatest intensity in low-lying town districts, in valleys near rivers, or on sites below high-water mark, have been exemplified in the General Sanitary Report and also in the Second Report of the Metropolitan Sanitary Commissioners. The inhabitants of drier districts are often afflicted with marsh diseases from the ill-drained lowlands; thus, after the prevalence of easterly winds over the Essex and Kent marshes, cases of marsh fever and ague are found scattered throughout the whole extent of the metropolis.

* Every one must have remarked on passing from a district with a retentive soil to one of an open porous nature,—respectively characterised as cold and warm soils,—that often whilst the air on the retentive soil is cold and raw, that on the drier soil is comparatively warm and genial The same effect which is here caused naturally may be produced artificially by providing for the perfect escape of superfluous water by drainage, so as to leave less to cool down the air by evaporation. The reason of this difference is two-fold. In the first place, much heat is saved, as much heat being required for the vaporisation of water as would elevate the temperature of more than three million times its bulk of air one degree. It follows, therefore, that for every inch in depth of water carried off by drains which must otherwise evaporate, as much heat is saved per acre as would elevate eleven thousand million cubic feet of air one degree in temperature. But that is not all. Not only is the temperature of the air reduced, but its dew point is raised, by water being evaporated which might be drained off; consequently the want of drainage renders the air both colder and more liable to the formation of dew and mists, and its dampness affects comfort even more than its temperature. It is easy then to understand how local climate is so much affected by surplus moisture, and so remarkably improved by drainage. A farmer being asked the affect on temperature of some new drainage works, replied that all he knew was, that before the drainage he could never go out at night without a great coat, and that now he could, so that he considered it made the difference of a great coat to him. Mr. Willlam Tilley, head gardener to the Duke of Portland, stated to Mr. Lee, Superintendent Inspector of the Board, that the local climate was improving, that in consequence of the drainage of part only of the district there had been a rise of one degree in the temperature of the whole district on the average of ten years. As the evaporation is greatest in the summer, the rise of temperature is greatest at that season. Dr. Madden has observed a difference of 6½ degrees in the summer temperature of drained and undrained land, and of course there would be a corresponding difference in the temperature and dampness of the air. It appears, therefore, that an effect similar to that of removal to a more genial climate may be produced by draining, which is itself a profitable employment of capital, both to the owners and occupiers of the soil.

The following are the chief agricultural advantages of land drainage to individual occupiers or owners:—

1st. By removing that excess of moisture, which prevents the permeation of the soil by air, and obstructs the free assimilation of nourishing matter by the plants.

2nd. By facilitating the absorption of manure by the soil, and so diminishing its loss by surface evaporation, and by being washed away during heavy rains.

3d. By preventing the lowering of the temperature and the chilling of the vegetation, diminishing the effect of solar warmth not on the surface merely, but at the depth occupied by the roots of plants.

4th. By removing obstructions to the free working of the land, arising from the surface being at certain times from excess of moisture too soft to be worked upon, and liable to be poached by cattle.

5th. By preventing injuries to cattle or other stock, corresponding to the effects produced on human beings by marsh miasma, chills, and colds, inducing a general low state of health, and in extreme cases the rot or typhus.

6th. By diminishing damp at the foundations of houses, cattle sheds, and farm steadings, which causes their decay and dilapidation as well as discomfort and disease to inmates and cattle.

All these evils lower the productiveness and diminish the money value of land, as well as the comfort of suburban occupations.

Every Local Board of Health is by its surveyor charged with the duty of providing and maintaining in good action the watercourses which serve as the main *outfalls* for the drainage of land as well as houses, of the entire district both town and suburbs. Whatever amount of money a private individual, be he owner or occupier, may spend for relief by drainage, or however skilfully drainage works within his own premises may be constructed, the money and the labour will be thrown away unless the natural outfall be kept clear, or unless an appropriate artificial outfall be provided and kept open.

A duty of the Local Board, to be performed by its surveyor, in respect to suburban land drainage, therefore, is providing, adjusting, and maintaining outfalls to facilitate and complete the drainage works of private individuals within the jurisdiction, and as contributors to the rate and to the payments for the services of the officers of the Local Board, such persons are entitled to as much aid as may be given

by those officers consistently with other more general demands upon their time.

The first service which the Local Board may render to private occupiers or owners is to extend to them the benefit of the general survey, to a copy of which, with the levels of his land and premises, each owner or occupier should be entitled upon payment of the expense of the tracing. He might also, at a fixed scale of moderate charges, be accommodated by the filling in of any additional particulars in the survey which he may desire for any purpose of his own.

On any ratepayer applying to the Local Board signifying his wish to drain his premises, the surveyor should examine the plot, and determine respecting it the points that lie within the jurisdiction of the Board; namely, the depth, the size, and the direction of the outfall; and the surveyor should also see that the proposed drainage is not likely to clog the outfalls or the sewers with silt. Beyond the determination of these conditions, the Local Board has nothing to do with the modes of land drainage adopted. The owner or the occupier may drain wide or close, across or down slopes, with tile tubes or with tiles and soles, or with stones, as he may think fit. As an accommodation, however, the surveyor might be permitted (under such arrangements as the Local Board may sanction, to avoid the risk of his public duties being neglected, and at such rate of charge as they may fix,) to give any advice or assistance that may be needed. Before the drains are filled in, he should be required to see that they are of a proper fall or inclination so as to give an effectual discharge to the water.

As curators of the general system of drainage, as guardians of the public convenience and health so far as they are affected by these works, and also for the protection of the ratepayers against useless and fraudulent works,—the Local Board may beneficially exercise, by its officers, a certain degree of care as to the adaptation of private drains to the main outfalls and to the general system of the drainage under their jurisdiction. It has been determined as a principle in respect to private house drainage, that no house-drains of such a size, inclination, or description as to accumulate, deposit, and give off emanations calculated to pollute the air and injure the public health shall be admitted into the public sewers; and on the like principle, the Local Board should protect their general system of drainage from the admission of any land drainage likely to injure it by bringing into the mains detritus, mud, or soil; and the surveyor to the Board should take care that the drainage water is discharged in such a manner as not to impede the general flow, nor increase unnecessarily the expense attendant on the working of the mains. This principle of administration laid down by the Sanitary Commissioners will, in its practical application, be protective of private, even more largely than of public, interests.

It will be convenient first to describe generally the construction of the outfalls, the main or public drainage works of the area, and of the road drainage, for which the Local Board, through their surveyor, will be directly responsible; —next, the private land drainage, which these public arrangements and the general survey will facilitate. In the Appendix will be found authentic practical information, furnished by the Inspectors under the Inclosure Commissioners, gentlemen who have had very extensive experience in the superintendence of land drainage works throughout the country.

Suburban watercourses and town ditches.

In consequence of the report of the Metropolitan Sanitary Commissioners the practice of draining by covered tubular drains, instead of open ditches, has been extensively adopted. Experience has shown that drains of this kind will be of great advantage to the lands that they adjoin; but the chief reasons for the change of system, as set forth in the Second Report of the Sanitary Commissioners, namely, that covered tubular drains, if properly laid down, carry water away more rapidly and are less expensive for the drainage of roads than open ditches, are equally strong for the abolition of field ditches, and the substitution for them also of covered drains. The sanitary advantages consist in the diminution of stagnant water surface and the prevention of unwholesome evaporation. These points are thus illustrated in the report referred to:—

"The field and road ditches existing everywhere over the suburbs have been a subject of special investigation by the Commission. We have received regarding them such reports as the following, which is drawn up by Mr. George Donaldson, Assistant Surveyor to the Court of Sewers, who was requested by us to examine various portions of the suburban lands.

"'The marsh land east of Greenwich is divided into fields by ditches filled with water let in from the river by small sluices under the care of the wall-reeve. These ditches are on an average nine or ten feet in width and about three feet deep of water. They answer the purpose of fences, as well as watering places for cattle, and serve in some degree for drainage.

"'Some of the workmen upon the marsh attending to cattle, &c., stated that in some states of the weather, where the ditches are not kept well scoured, they smell very much, or, in their own words, 'stink terribly,' when the water is low. The smell arises from the rotten weeds about the sides of the ditch. They stated, that at this season there is little or no smell from the ditches, but to me it was quite perceptible at the time I was speaking to them, although they seemed unconscious of it.

"'These ditches are a bad substitute for fences. Neat hedges would take much less land and they would give shelter, which is much wanted. For the purpose of providing water for cattle not one fourth of these ditches are necessary. The drainage could be much better effected in a different manner.'

"Similar accounts are given in respect to portions of other suburban districts.

"It must be recollected also, that the occupiers of the new suburban dwellings have often no other means of drainage than the common ditches, and that these ditches frequently perform the office of sewers as well as of land-drains and watering-places for cattle.

"From examinations which we have directed to be made we find that in subservience to the larger drainage arrangements, and with proper outfalls, the road-drainage by open ditches may be superseded by means of tubular tile-drains put in at proper depths and inclinations, which the officers of the Commissioners of Sewers, who will have charge of the General Survey, may, with the aid of that survey, determine accurately.

"The objections to the present road-drainage by ditches of the common forms and sizes are analogous to those we have made to the common forms and sizes of sewers; namely, their unsuitableness to small runs of water; wide bottoms intended to be flat, but so irregularly shaped as to impede effectually the current of all but very large floods of water with considerable flows.

"If the road-drainage were placed in its proper subordination as part of a system of drainage, the ditches, which are usually only about two feet deep, might be filled up, and the roads drained into pipe-drains of from four to five inches in diameter and upwards, according to the length of the road and its position in serving as an outfall for the land-drainage.

"We are assured by persons engaged in carrying out agricultural improvement by land-drainage, that the roadside ditches commonly form the most serious obstructions to their work. Covered tubular drains, such as we propose as substitutes for the open ditch, would of themselves effect extensive land-drainage; and in some suburban lands, closely intersected with byways and public footpaths which should be deep-drained, would sometimes supersede the necessity of any other drainage.

"Mr. Smith of Deanston long since abolished all open ditches in his own farm and the roads adjoining with great advantage. Mr. Josiah Parkes concurs with other practical witnesses in our view, that the drainage of the roads by covered drains would greatly benefit the adjacent land. The extent of this drainage by the covered drains would, of course, be dependent on the depth of the road-drain and the permeability of the adjacent land. On a very stiff clay soil a road-drain might not act more than from twelve to fifteen feet on either side of it. But in freer soils several practical witnesses agree in stating that a single drain would frequently drain from one to two chains. Mr. Parkes mentions an instance of one drain, from five to seven feet deep, which drains a field of about twenty acres. The road-drains would commonly serve as excellent outfalls for the drainage of the land; and Mr. Parkes and other land surveyors think it would be of great advantage to the farmers if they had the right of carrying drains into them.

"Mr. Parkes attests the fact (in which other experienced drainers examined by us concur), that a proper covered drain of the same depth as an open ditch will drain a greater breadth of land than the ditch can effect. The sides of the ditch become dried and plastered and covered with vegetation, and even while they are free from vegetation, their absorptive power is inferior to the covered drain. A mile of double road-drains would drain from fifteen to twenty acres of the adjacent land; and the increased value to the land itself would, considering the common rates of charge for land-drainage, be worth the expense. A piece of land surrounded by roads, as often happens in the suburbs of towns, might be completely drained by the road-drains.

"On a mile of road, having ditches on both sides, the extent of evaporating surface of stagnant moisture with decomposing vegetable and animal matter would be from three quarters to an acre per mile; that is, three quarters of an acre in extent could be gained as dry road or as cultivable land.*

* The abolition of ditches at the road-side is the removal of a frequent cause of overturns and other accidents

"The Wall-reeve of Poplar Marsh states to us, that the area of open ditches or sewers within the open part of his district of 520 acres is twenty-one acres, or in the proportion of one acre of water to twenty-five acres of land. He states that he is of opinion that the whole of the twenty-one acres of open ditches and sewers might be made available for grazing and other purposes, if pipes were laid and the ditches covered in.

"If stagnant and open ditches were abolished and suitable hedges substituted in their stead in places where agricultural improvement is backward, as it generally is in the marshy districts, the good that would be seen to arise from the drainage of the land situated near the road-drains would, with proper facilities, tend to the voluntary extension of general land-drainage, for which the new and extended surveys that have been proposed would be of very great importance.

"Mr. Stewart, a land surveyor and land agent, who has been extensively occupied in the draining of land, and has been recently engaged in the drainage of some lands between Greenwich and Woolwich, states, that the lands in the suburbs of the Metropolis are all very full of water and excessively in want of drainage.

"Being asked—

"How far do you believe the suburban lands may be improved for vegetable production or for the health of stock, not to speak of the health of the population, by suburban land-drainage?—I can give an idea of the improvement as respects the value of land. About five years ago I cut only one drain through the river bank and took in about twenty acres. The land has been recently let to a gardener at double the former letting. Generally speaking, by proper drainage, the low and wet lands may certainly be advanced in value from twenty-five to fifty per cent.

"The Commissioners have been led to inquire as to the practicability of superseding the road-drainage by open ditches, and substituting drainage by covered tubular tile-drains. Do you concur in the eligibility and the practicability of the proposed substitution?—I do indeed, most fully; there is no doubt of its answering perfectly, by proportioning the pipes to the quantity of water which they will have to carry; but I do not think that it will be requisite to have very large pipes in any one case for the purpose.

"What do you expect would be the effect of such drainage, independently of other land drainage, in the districts with which you are acquainted?—I do not think the other drainage would be complete without it. If you are about to drain the land in any district it would be inconsistent to leave the ditches as they generally are, say about two feet deep.

"On the low-lying lands you would drain very deeply, would you not?—Yes, where there is the means of sufficient outfall; in some of those lands I have found it necessary to drain as deep as from six to eight feet.

"To what depths have you been accustomed to drain agricultural land?—I never sink the drains of the outside of fields less than four feet, if I can get an outfall to that depth. I often go double and sometimes three times that depth.

"How long have you practised this deep draining?—All my life, where I have had the power.

"Then to allow the ditches to remain along with such land-drainage would only be leaving stagnant surface moisture?—Nothing more.

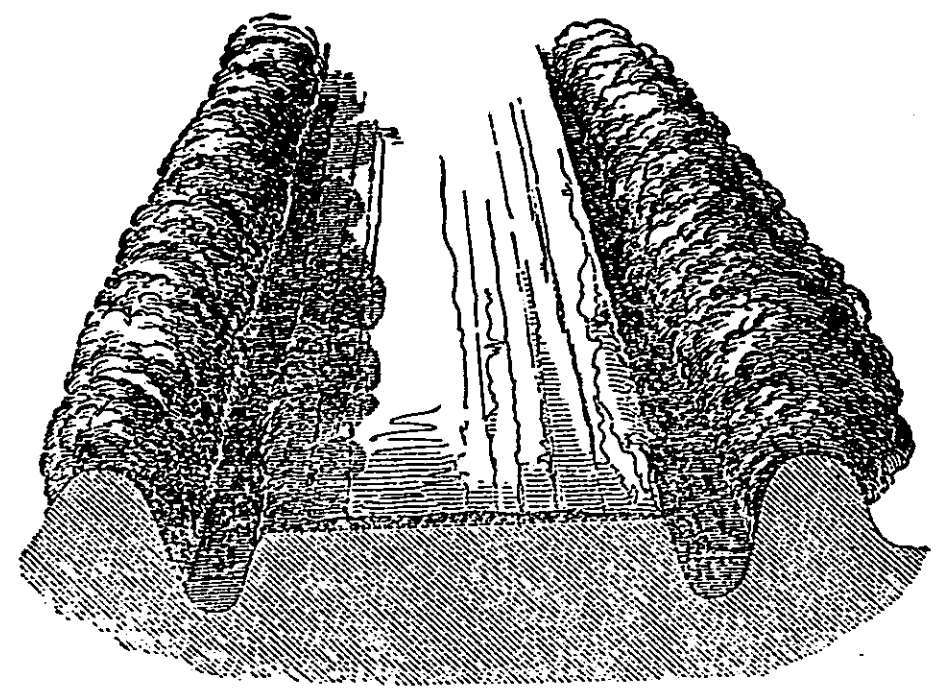
"What would be the effect of stopping up the open ditches in the district between Woolwich and Greenwich, on which you have been engaged?—The effect of deep tile-drainage of the roads in those parts would be, first, to get rid of the dreadful stench of the stagnant water and rotted vegetables in the ditches, which is at times enough to make any man sick, and does so. The health of the population would therefore be greatly improved by it. In the next place, the roads would be easier kept in repair because they would become more solid. At the height at which the water stands in these ditches, very often within a foot of the surface of the adjoining land (sometimes higher), it keeps the road soft and the land adjoining much wetter than it ought to be, often a quag.

"Where the fields are small and the roads very near, would not the deep tile-drainage of the roads very often suffice for the land-drainage?—Very often it would, provided the sub-soil is composed of gravel, sand, or matter pervious to water. I have now in hand some land where one roadside drain, if it were laid deep enough, would drain the whole field, the sub-soil being shingly gravel.

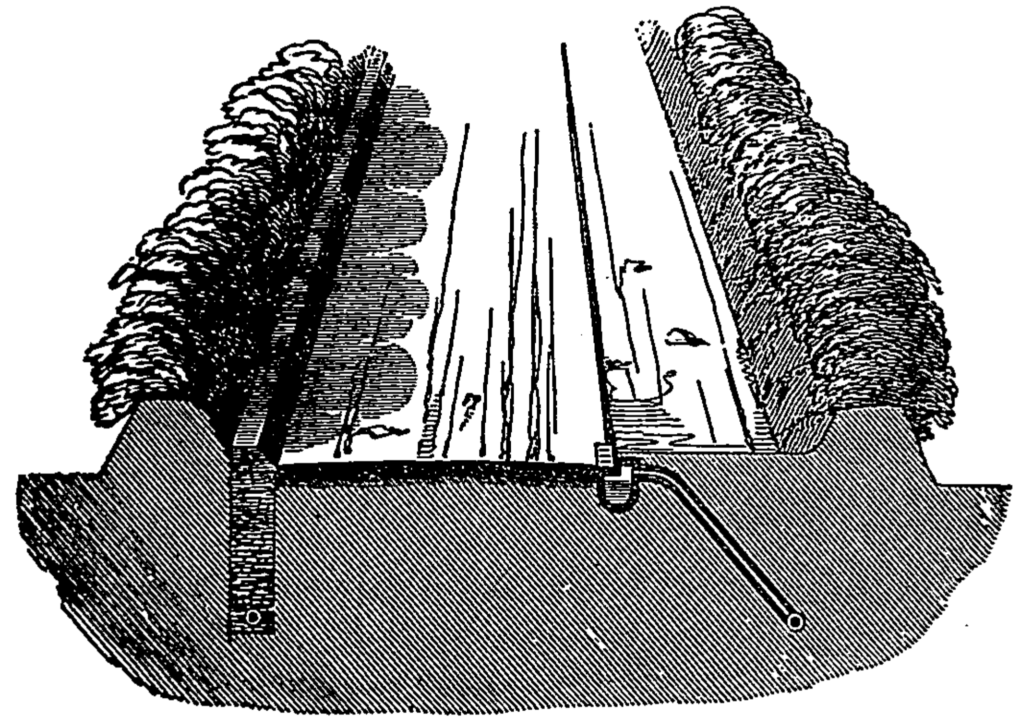
"Will not the extension of the road-drainage be of peculiar advantage in the case of small ownerships or small occupiers?—No doubt it will be of very great advantage.

"The following diagrams represent the appearance of the ditches along with hedges, which sometimes have ditches on both sides. The lower diagram gives the view of the position of the tubular drains. The road-water may be discharged either through a layer of broken stones or permeable gravel, to stop any silt, as at A, or through a small earthern vessel as at B, (into which silt would fall and be arrested, and which could be cleaned out conveniently by hand, from time to time,) and enter the drain below by a drain-pipe acting as a gully-shoot. In general the space occupied by the ditch may be advantageously added to the road, as at B. In other cases where there is a sufficient width of road it might be given to the land."

Section of road, with open ditches.



Section of road, as proposed, with covered ditches.



For conveying the surface water to the drains, gully-shoots placed at intervals with gutters running along the sides of the road, and entering the gullies, are to be preferred to gravel drains such as that figured in the cut at A. It has been estimated by experienced surveyors that with two-inch tubular drains the subsoil drainage of a road may be effected at 36*l.* 5*s.* per mile, and with three-inch drains at 42*l.* 17*s.* per mile. To take the surface water, the size, and, consequently, the cost, would be increased. But by this means the roads would be maintained dry and in good condition, and the adjoining fields would be drained to a considerable distance without any other drainage works, as well as provided with mains to receive the outfalls of the field drains.

The above descriptions refer to the cases of road drainage by ditches, which would serve as branch drains for the district generally. There are also larger main lines of natural watercourses to be dealt with, and which being lower or valley lines would generally receive, as tributaries, the pipe drains of the common ditches.

Near the Metropolis there are, besides the common ditches above described, large open watercourses which serve to carry away flood waters. When there are no floods, the water in the shallow streams or threads of water moves sluggishly over the uneven bottoms, or lodges in stagnant pools in these ditches, giving off offensive and insalubrious effluvia; for many of these ditches are used as outfalls for the drainage of suburban houses, and with the addition of such house drainage the effluvium becomes at times highly noxious and even fatal. The courses of these open watercourses were marked by excessive ravages of the cholera amongst the population living near them.

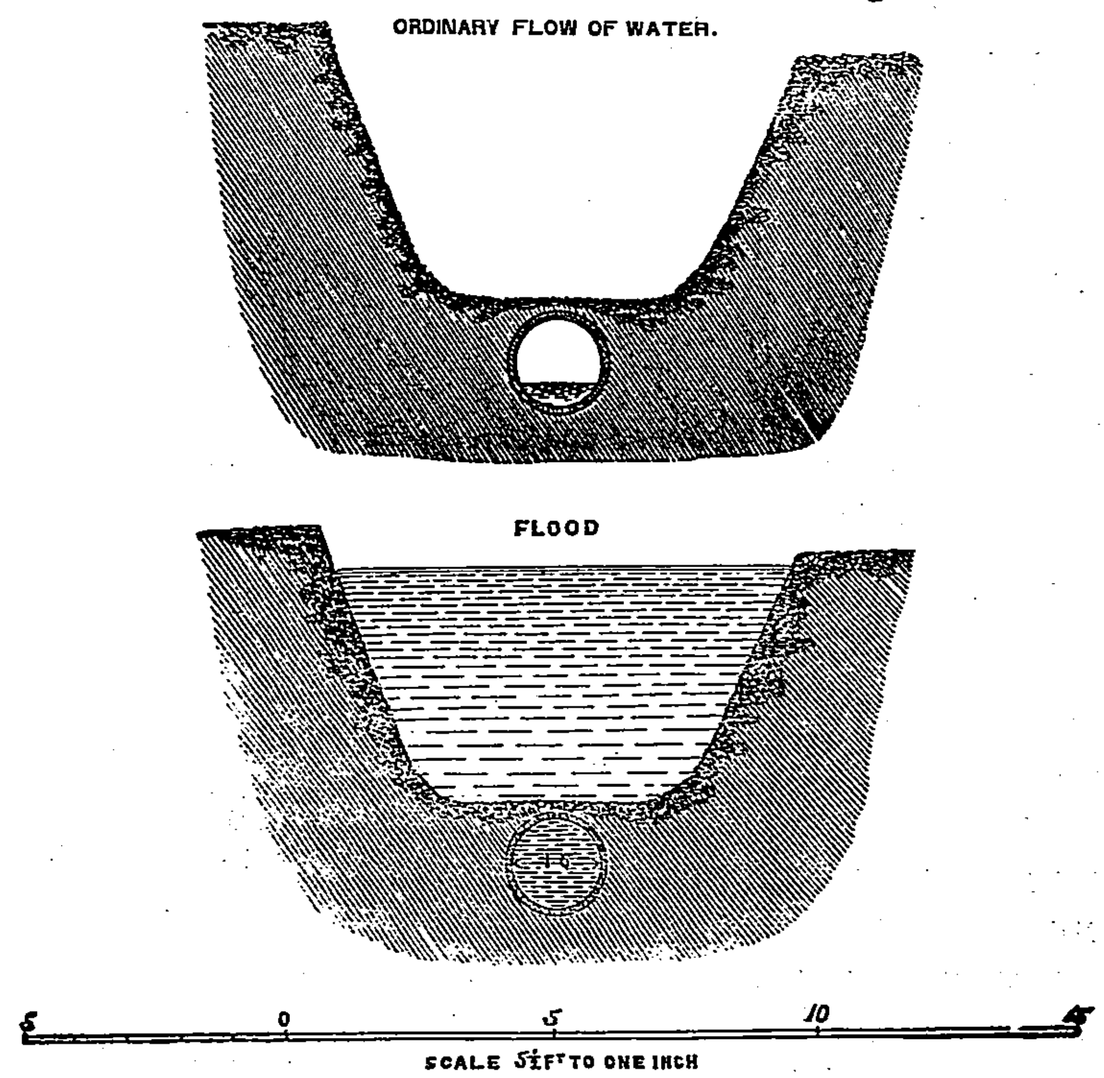
The common remedy recommended (and often practised in these cases near houses) was arching over these watercourses. But this would only have masked the evil, and the expense which would have been incurred by constructing large culverts in all these lines, which would seldom be chosen for permanent works, would have been enormous.

In some cases the course was taken of laying down tubular drains of about 18 inches diameter below the bed of the natural watercourse, and (leaving openings at intervals for junctions of side drains) covering over the tubular drain. The bed of the stream being re-formed with clay and gravel, so as to form a better channel, such extraordinary flood water as will not pass through the pipe beneath is taken on that bed. In this mode a better fall is got, the flow and the sweep of water is accelerated, and comparative cleanliness and salubrity obtained, at from one eighth to one fourth the expense which would have been required to have covered the culverts of sufficient capacity for extreme floods. So great is the acceleration of the flow through the pipe in the watercourses that it is only on comparatively rare occasions, perhaps not more than two or three times a year, that there is any overflow above them, and the surfaces usually present the appearance of a dry and clean narrow road. The cost of this work was from 2*s*. 6*d*. to 4*s*. 2*d*. per foot of run complete; to have arched over such a stream would have cost about 12*s*. per foot of run. In some cases the foul water of open streams may be diverted into neighbouring sewers, when no further expense need be incurred except for re-forming the bed of the brook for the conveyance of flood-water.

In all cases of drainage by natural streams important opportunities will occur to a competent local surveyor for diminishing the friction and accelerating the discharge of surface water, by straightening and thereby shortening the watercourses, as well as by concentrating the flow by the construction of properly formed channels.

The following is a cross section of the species of draining described as executed under the direction of Mr. John Grant, one of the surveyors to the Metropolitan Commission of Sewers.

Transverse Sections of Stream, showing



A similar plan has been followed in the treatment of some old sewers with flat bottoms, in which the ordinary shallow streams are spread out, and by being so spread out friction is increased, the flow retarded, and accumulations of deposit occasioned. The expense of periodically cleansing these sewers by flushing was in some cases as much as 56*l*. per mile per annum. At the bottom of some of such sewers pipes of 16 and 18 inches diameter were put; and with the same quantity of water, with the same inclinations, such an acceleration of flow is obtained—in one instance where it was measured the acceleration of velocity was at times three, four, and fivefold, (*vide Report on Water Supply of the Metropolis*, p. 186,)—that the formation of any deposit is prevented, and the channels kept entirely clear of the foul accumulations; and it was proved that the expense of these works was nearly paid for by the saving in expense of cleansing by flushing.

Where a district is situate below high-water mark, or where there is no sufficient outfall, it should be known that the expense of providing for the quick and complete discharge of the sewerage as well as the rain-water is inconsiderable. Extensive fen districts are, by steam-power, kept clear of surplus rain-water at an expense of from 2*s.* to 5*s.* per acre per annum, including all expenses. It was estimated that the expense of pumping out the sewerage, as well as the whole of the rainfall, from a difficult district on the Southwark side of the metropolis, of 4,000 acres, by a lift 31 feet high, and discharging it at twelve miles distance, would be about 2*l.* 15*s.* per acre per annum, or 2*s.* 8¾*d.* per house per annum, for a work which would be a great economy by preventing dilapidation from damp and excessive moisture. *Vide Report on Metropolitan Water Supply, App.* II. pp. 22–25.*

Private or general land drainage within the area of jurisdiction.

The more extensive owners will no doubt engage professional persons for their drainage works, and decide for themselves the plans and adaptations suitable to their own lands. But, for the information of the ratepayers in the districts where the land is too much subdivided and the individual holdings too small, to admit of this mode of proceeding, the following suggestions have been drawn up.

Drainage being of the nature of a permanent improvement should be executed by, or at the expense of, the owner; but it being at the same time an additional work of convenience and value not agreed upon or contemplated at the time the land was taken, it will justify an additional rent for the new outlay.

* It will scarcely ever be necessary to provide an artificial outfall by pumping for all the sewage of the most unfavourably situated district, and in very few cases will it have to be lifted so high or carried so far off as is here assumed.

Many owners and occupiers are well aware of the defectiveness of their land in respect of drainage, but do not know how to apply the remedy. In a large proportion of cases the holdings are so small and subdivided that occupiers or owners cannot separately undertake the work at any reasonable charges, or with probability of success. It is therefore requisite for the surveyor not merely to make known the facilities that may be offered for the execution of works of private land-drainage, but also to explain the principles that determine those facilities, and to furnish detailed instructions to the ratepayers for their practical application. The public interests, for the reasons stated, are indeed so closely coincident with those of private owners in facilitating all works of land-drainage, that this class of works forms an exception to ordinary cases, and it is one where the Local Board may with propriety allow their surveyor to receive extra remuneration for extra service in the preparation of plans, or in otherwise aiding in the execution of the smaller land-drainage works, beyond the main outfalls which he will have in charge, as a matter of direct public duty.

The system of road-drainage by tubular drains, proposed by the Metropolitan Sanitary Commissioners, instead of the present open ditches, will offer most important facilities for private land-drainage of every description.

And first as to the principle of *thorough drainage.*

All the older drainage was chiefly *surface* drainage by ridge and furrow. This, besides leaving the land surcharged with moisture, carried away the finer particles of earth, and along with these such of the manures and fertilizing matters as were removable from off the surface in suspension in water. On the occasion of sudden and heavy storms, the greater part of a top-dressing of manure on such lands is sometimes carried into the ditches and watercourses. The modern method, which Mr. Smith of Deanston so far systematized, instead of draining over the surface, does away with ridges and furrows, makes the surface (except where it is raised for the growth of the plant) a perfect plain, and the water drains downward through the table of land into underground channels. In thus filtering through the soil, the fine earthy powder of the mould, and the particles of manure, or loose animal or vegetable matter, are left upon it, and soluble manure is carried down into and absorbed by it, and thus retained for the sustenance of vegetation. This saving of manure and of fertile mould increases the productiveness of thoroughly drained land, apart from the permeability, increased temperature, and better condition of the soil which thorough-drainage brings about. The action of a soil made permeable to air and moisture is fully elucidated in an extract, given in the Appendix (No. IV.), from a lecture on the preparation of soils for the reception of seeds by Dr. Madden, of Penecuick, published in the Transactions of the Royal Agricultural Societies of England and Scotland.

When there happen to be two outfalls into the same main from the same description of land, the one from surface-drained land and the other from under or thorough-drained land, the water from the thorough-drained land (if the drains be properly laid so as to effect a perfect filtration) may be seen running perfectly pellucid, while the water from the surface-drained land will be thick and muddy from the solid particles which it contains. The surveyor, in the exercise of his authority, should admit no outfalls from surface-drained land into the main drains, lest they should become obstructed.

The following extracts from a Report on Drainage by Dr. Shier, the Editor of "Davy's Agricultural Chemistry," Agricultural Chemist to the colony of British Guiana, one of the ablest scientific agriculturists that this country has produced, express clearly and concisely the nature and advantages of land-drainage, and they may serve for the guidance of owners and occupiers desirous of draining their lands.

"The history of drainage in Britain may be briefly told. Till the time of Smith of Deanston draining was generally regarded as the means of freeing the land from springs, oozes, and underwater, and it was applied only to lands palpably wet, and producing rushes and other aquatic plants.

"Springs may be viewed as natural Artesian wells, and are to be explained on the same principles. Rain falling on hills and high land runs over the surface to all lower levels. If in its progress it passes over clay or impervious rock, it cannot sink; if it encounters a pervious layer, such as sand or gravel, it immediately sinks and flows in the interstices as in a pipe. When we examine the upper geological layers we find clay and sand, or gravel, interstratified, sometimes in numerous layers; hence, if each pervious layer at its out-crop receives rain-water, and if the clay layers are unbroken, we may have under a plain, or in a valley or basin, many layers containing water, capable, by the pressure of the water entering at higher levels, of rising to the surface of the ground through any natural fissure or artificial boring.

"The old method of draining springs was to form a drain or culvert of sufficient capacity to carry the water under ground to lower levels, thus preventing the water from bursting out on the surface of the land. When several springs occurred in the same field or vicinity, a main drain was laid along the lowest level with a leader to each eye.

"On this method Elkington, a most sagacious and successful drainer, introduced sundry improvements, the chief of which was the use of the auger, with which he bored through the bottoms of the drains, in suitable situations, and thereby laid dry many of the natural springs and oozes, and greatly restricted the extent of the works required.*

"Oozes, or outbursts of water, as they are termed, occur in immense numbers in all undulated and hilly countries. They are caused by various arrangements of the pervious and impervious layers, but most frequently by the out-crop, or coming to the surface of an impervious clay layer, on which rests a pervious stratum. The water conveyed in the pores or interstices of the latter being unable to descend runs over the surface of the clay, forming a marsh, or in some cases a line of springs or marshy spots. The rule followed in dealing with such cases was to cut off the water

* The Board had in view this process for the collection of the springs from the sandy districts, commencing at Bagshot in Surrey. The rain falling on such sands, like that upon gritstone formations, having passed through natural filters of insoluble silicious matter, is of the highest order of purity. The witnesses, having in view Elkington's process, called it "*drainage*" water, a term often used as denoting the discharge of mere waste and fluid impurities; whereas the process is properly one of the collection of shallow springs, of far greater purity than common wells or the deeper springs, which usually contain much mineral matter. These shallow springs are of superior quality, where available, to the common supplies from rivers. In respect to the quantities derivable from such springs, it was frequently represented by Elkington as so great, that it ought to be turned to account for working mills. In addition to the superior purity of the water, one great advantage of the derivation from these springs for towns is, that the supply is less variable, and less storage room than for surface flood water is required. (*Vide the Board's Report on the Supply of Water to the Metropolis,* p. 83 *to* p. 113.) The new supply of water for the town of Rugby, under the Public Health Act, is obtained by permeable pipe drains, 9 inches in diameter, laid 14 feet in a bed of gravel, by which means a supply of water of less than one half the hardness of the river water is obtained pure from animal and vegetable matter, clear and cool, as if from perennial springs, and fit for drinking without any artificial filtration. The water is as good as if the enormous expense had been incurred of carrying it, while fresh drawn, from a multitude of pumps sunk to the same depth, while its coolness is preserved and its purity secured. In other instances, under the Public Health Act, the same means of supply are successfully resorted to.

as near its source as possible, by running a drain along the line of out-crop, that is to say, between the wet and the dry, or a little below the commencement of the marsh. The water so intercepted was at convenient intervals conveyed to lower levels.

The principle of Elkington's drainage is thus described in his own terms, as dependent—

"1st. Upon finding out the main spring or cause of the mischief, without which nothing effectual can be done. 2d. Upon taking the level of that spring, and ascertaining its subterraneous bearings; for, if the drain is cut a yard beyond the line of the spring, you can never reach the water that issues from it; and by ascertaining that line, by means of levelling, you can cut off the spring effectually, and consequently drain the land in the cheapest and most eligible manner. And, 3dly, by making use of the auger to reach or tap the spring, when the depth of the drain is not sufficient for that purpose.

"Although the process of thorough-drainage does in most cases suffice for the removal of under-water, as well as surface-water, it is proper to state that there are cases where the old and new methods require to be combined, some special spring or ooze requiring special drainage, or more specific treatment than is provided for in the frequent-drain system. It will sometimes happen, too, that water may rest in layers below the subsoil, out of reach of the frequent drains put in at the usual depth, but may yet, under certain circumstances, prove prejudicial to the soil. No skilful drainer, appreciating the merits of both systems, will have much difficulty in dealing with such special cases.

"In regard to the construction of drains, attention is called to the following points:—

"1st. The direction of the drains, namely, that they ought invariably to run down the steepest descent, and parallel to each other.

"In directing the drains directly down-hill, there is a manifest departure from the old and sound rule observed in cutting off oozes and outbursts of under-water; but the purpose is different, and it can easily be shown (especially by models or diagrams) that by observing this rule the water has the shortest way to percolate in getting into the drain, and that when once in the drain its delivery into the mains is effected at the most rapid rate; points, both of them, of the greatest importance. To many persons the results of experience are more satisfactory than reasoning from principles, and to such it must be satisfactory to learn, that although in the infancy of thorough-drainage it was stoutly argued by many that the frequent drains should be directed in an oblique direction, and consequently at a lower inclination than the 'right down-hill' direction gave, the practice is now universally in favour of the rule laid down by Smith.

"The parallelism of the frequent drains is only departed from when the nature of the surface or the direction of the boundary lines of fields renders it necessary. In Britain the irregular undulation of surface is the chief cause why thorough-drainage is not always well planned.

"The direction of the mains and sub-mains depends entirely on the nature of the ground and levels. When the surface is undulating, the rule is, to lay a main of sufficient size along the principal hollow, with sub-mains along all the secondary hollows, the small drains opening into these generally at right angles. Mains require also to be introduced whenever the length of the small drains becomes as great as would give them more water to deliver than they are capable of.

"2d. The frequency of the small drains. The distance at which the small drains are placed apart depends on several circumstances, such as the nature and texture of the soil, the depth at which the drains are to be put in, and whether it is surface-water alone they have to deliver."

In regard to the depth and frequency of drains, the following statements are made by Mr. Josiah Parkes:—

"I gave several instances of this practice (deep drainage) in Kent in the Report of last year, already alluded to, and it is rapidly extending. Mr. Hammond stated to you (Journal, vol. iv. p. 47.), that he drained 'stiff clays 2 feet deep, and 24 feet between the drains, at 3*l.* 4*s.* 3*d.* per acre,' and 'porous soils, 3 feet deep, 33½ feet asunder, at 2*l.* 5*s.* 2*d.* per acre.' I now find him continuing his drainage at 4 feet deep, wherever he can obtain the outfall, from a conviction, founded on the experience of a cautious progressive practice as to depth and distance, that depth consists with economy of outlay as well as with superior effect. He has found 4-feet drains to be efficient at 50 feet asunder, in soils of varied texture, not uniform clays, and executes them at a cost of about 2*l.* 5*s.* per acre, being 18*s.* 4*d.* for 871 pipes, and 1*l.* 6*s.* 6*d.* for 53 rods of digging.*

* The cost above given can only be taken as that of the particular case.

"Communications have been recently made to me, by several respectable Kentish farmers, of the satisfactory performance of drains deeply laid in the Weald clays, at distances ranging from 30 to 40 feet, but I have not had the opportunity of personally inspecting these drainages.*

"The following little table shows the actual and respective cost of the above three cases of under-drainage, calculated on the effects really produced, *i. e.*, on the masses of earth effectively relieved of their surplus water at an equal expense. I conceive this to be the true expression of the work done, as a mere statement of the cost or drainage per acre of surface conveys but an imperfect, indeed a very erroneous idea of the substantive and useful expenditure on any particular system. This will be apparent on reference to the two last columns of the table, which give the cost, in cubic yards and square yards, of soil drained for one penny at the above-mentioned prices, depths, and distances:—

Depth of the Drains in feet.	Distances between the Drains in feet.	Mass of Soil drained per acre, in cubic yards.	Mass of Soil drained for 1*d.*, in cubic yards.	Surface of Soil drained for 1*d.*, in square yards.
2	24	3,226½	4· 1	6·27
3	33½	4,840	8·93	8·93
4	50	6,453	12·00	8·96

"I may observe, that Mr. Hammond, when draining tenacious clays, chooses the month of February for the work, when he lays his pipes (just covering them with clay to prevent crumbs from getting in), and leaves the trenches open through March, if it be drying weather, by which means he finds the cracking of the soil much accelerated, and the complete action of the drains advanced a full season. The process of cracking may, doubtless, be hastened both by a choice of the period of the year in which drains are made, and by such a management of the surface as to expose it to the full force of atmospheric evaporation."

On the same point, Mr. Smith of Deanston expressed himself thus:—

"Estimating the thorough-drainage of land by the cubic contents of the soil, reckoning from the level of the bottom of the drainage to the surface of the ground, can give no exposition of the agricultural effect; because it

* For illustrated diagram, *vide* p. 64.

has not yet been fully determined by experiment or in practice how far it is beneficial to the growth of plants to remove the *free* water from the lower regions of the subsoil. One set of experiments over a course of three years has been furnished by Mr. Hope, of Foreton Burn, in East Lothian, from which it appears that the results were in favour of moderate depths of drains; and the practice in the Fens of Lincolnshire shows that the most beneficial distance from the surface for the free water is about two feet. In dry seasons, when the water in the level ditches falls below two feet from the surface, the crops are found to suffer, and it is customary to dam up the water to that level.* Water will rise some inches in soil by capillary or molecular attraction; but in such cases the water never fills the fissures or interstices of the soil to such an extent as to exclude the atmospheric air, but merely attaches itself to the surface of the particles of soil and of the smaller cells and channels in the soil, where it remains available to the roots of plants, and without any of the bad effects resulting from stagnant *free* water. Until the great point can be fully and practically determined as to the proper distance for retaining a supply of water, the depth to which land should be drained cannot be pronounced. The rule when ascertained will probably be found to vary with the nature and condition of the soil. In removing water falling on the surface it has been found in practice, and which agrees with a great theory, that having the artificial channels at near distances, and not over deep, is most effective in the immediate and complete removal of the free surface water. Distances of from 18 to 24 feet, with depths of from 2 feet to 3 feet, have been found over extensive tracts and in soils of various texture to effect complete thorough-drainage for agricultural purposes."

In regard to this disputed part of the subject of drainage, Mr. Stephens, the author of "The Book of the Farm," and of an able "Manual of Practical Draining," lays it down as a principle that the drains should be, at the very least, so deep as to place them beyond the reach of subsoil ploughing, which may penetrate 16 inches below the ordinary furrow of 7 inches, or 23 inches below the surface; that is, allowing 3 inches in addition to the depth of the subsoil furrow, the top of the drain ought to be at a depth of not less

* J. A. Clarke, Esq., the author of an elaborate report upon the farming of Lincolnshire, questions the real expediency of this practice. *Vide* Journal of the Royal Agricultural Society, vol. 12, p. 326.

than 26 inches. How much deeper than this it should be depends on the nature of the soil; a porous soil with a rapid discharge does not require much more depth; but if the soil be tenacious and less permeable, a greater depth will be required to give discharging room to the water coming from each side of the drain. On these grounds Mr. Stephens gives the following table for three different kinds of subsoils.

	Porous Subsoil.	Tilly Subsoil.	Clay Subsoil.
	Inches.	Inches.	Inches.
Ploughed surface - - - -	7	7	7
Depth of subsoiling, &c. - -	16	16	16
Thickness of earth above the filling materials - - - -	3	3	3
Height of tiles and soles, say -	6	6	6
Depth of discharging effect of subsoils	1	10	18
Hence the *minimum* depth of drains in porous subsoils is - -	33	—	—
" tilly " " - -	- -	42	—
" clay " " - -	- -	- -	50

To return to the extracts from Dr. Shier:—

" 4th. The materials employed.—The best materials for the construction of the water-way of the frequent-drains are tubes, tiles and soles, water-worn pebbles from the sea-beach, harped gravel, or broken stones.

" A decided preference should be given to tubes over tiles and soles. They are cheaper, occupy less space in the kiln as well as during transport, and are much less liable to breakage. They are easier laid, effect as complete drainage, and are less liable to silting or sediment, or, indeed, to accidents of any kind."

The action of thorough-drainage is illustrated as follows:—

" That in thorough-drained land it is intended that every drop of rain should sink on the spot on which it falls, and pass through the fissures of the soil and subsoil till it enters the drain laterally or by the bottom.

" When the drains are constructed so as to effect this, it follows:

" 1st. That all the water is filtered before it enters, and, consequently, that no silting can occur.

" 2d. That no loss of finely-divided matter can occur.

" The finely-divided portion of the soil contains its most active and valuable parts. But land drained on the open-

drain and round-bed system is constantly deprived of this finely-divided portion, by its being carried over the surface into the open drains and deposited there.

" 3. It is now obvious why the drains should not draw downwards, especially at first.

" II. That it is essential to the success of thorough-drainage, that whenever there is excess of water present in the soil, it should be constantly sinking.

" The accuracy of this principle might be inferred from the fact, that in all the cases that occur of soils naturally of high fertility, and to which man has had to do nothing but till them, there is uniformly found effective drainage. Direct experiments on the effect produced on soils of the same kind when treated with water, allowed in the one case to percolate through the soil, and in the other to stagnate on the soil, are in progress, and may lead to instructive conclusions.

" III. That the fissures and water-ways that occur in thorough-drained land are caused by the shrinking of the soil as it dries.

" IV. That after a series of years the subsoil of a thorough-drained field changes into the nature of soil as far down as the level of the water in the drains.

" Those who are not familiar with the reality of this change will be most effectually convinced of it by inspection. It will be found to occur in the most marked degree when, as very often happens in clay lands, the original inorganic constituents of the soil and subsoil are not widely dissimilar. This change is accounted for—

" 1st. By the ameliorating effect of air and water, as has already been described, producing healthy decomposition of the organic and inorganic constituents, and thereby eliminating substances which constitute the food of plants.

" 2d. By the washing out of deleterious ingredients.

" 3d. By the loosening of its texture.

" 4th. By the penetration of roots, and by their ultimate decay in the subsoil.

" 5th. By the penetration of earth-worms and insects.

" It is now obvious, that when the subsoil has been thus changed it becomes fit for being mixed with the soil, and of greatly improving it, by supplying such principles as in the course of cropping may have become deficient.

" There are cases, too, where, from the very dissimilarity of the texture of the soil and subsoil, great benefit may accrue from their admixture: thus, for instance, a sand layer, did such occur under the surface of stiff clay, would obviously improve the texture of the clay were it ploughed up and intermixed with the soil.

"V. That the increased fertility of thorough-drained land is in a great degree due to the increase of feeding surface, to which the roots of plants obtain access.

"Thus, were an undrained soil that could never before be tilled with advantage deeper than six or seven inches to become deepened by thorough-drainage and subsoiling to eighteen or twenty-four inches, it would not be wonderful although its crops were doubled.

The following is Dr. Shier's enumeration of the results of thorough-drainage:—

"Induction from a copious number of facts is always desirable in coming to important practical conclusions. Fortunately the process of thorough-drainage has been so extensively adopted in Britain that the advantages are known to nearly all. A brief enumeration of the leading advantages will suffice.

"1st. When properly executed, it always proves remunerative.

"Many cases have occurred where heath or moorland, dear at a rent of 5*s.* per acre, has, when thorough-drained and sub-soiled, become worth 30*s.* or 2*l.*; and of clay land, dear at 7*s.* 6*d.* per acre, becoming worth 3*l.*, or, in good localities, even 4*l.*

"That it is a remunerative improvement is, if possible, more strongly shown by the fact, that Scotch tenants on a nineteen years lease have been frequently known to thorough-drain their farms at their own expense when no aid could be obtained from their landlords.

"2d. That by thorough-drainage and subsoiling the quality as well as the amount of the crops is improved.

"3d. That clay lands which, in the raised-ridge form, could produce only wheat, beans, and clover, have, when thorough-drained and subsoiled, been found capable of producing root crops, such as turnips, beetroot, and potatoes; thus enabling the naked fallow to be dispensed with, and permitting the adoption of a much safer and more profitable system of farming, in which the rearing and feeding of stock are combined with the growth of valuable grain-crops.

"4th. That thorough-drained fields stand wet and drought better than undrained fields naturally of the same sort of soil.

"That they should stand wet better from being drained was to be expected; but it is not, at first sight, so apparent that they should also stand drought. Those who in travelling through districts of England or Scotland into which thorough-drainage has recently been introduced, have felt an interest in marking the effects, know well how, during protracted droughts, the thorough-drained fields call attention to themselves by their superior verdure. It follows, from the principles already laid down, that it should be so. It need only be mentioned that thorough-drained soils have been greatly deepened, that they do not bake, and that it is merely of superfluous water that the drains free them.

"5th. That thorough-drained fields are more easily tilled and are in a fit state for the operations of tillage a much greater number of days per annum.

"In variable climates this is a very great advantage. There is not merely 'a time to sow,' but a time for every other operation of the field; and when the state of the soil forbids an operation till the proper time is past, the result is seldom favourable.

"6th. That all manures produce a much greater effect on thorough-drained fields than on undrained ones."

Among the beneficial effects of drainage are reckoned the admission of air into the soil from below, or by an underdraught through the drains. Common air and water are the two substances most important for plants, and both require to be supplied to the roots in proper measure; and it is considered to be a great advantage to supply air from beneath as well as from above. But the effects of different methods of land drainage, in this respect, have not yet been sufficiently observed for the enumeration of any practical conclusions in relation to them. It is now, however, a practice with florists to make several holes at the bottom of flower-pots instead of only one, expressly with the view of admitting a more abundant supply of air.

The object of drainage is not to deprive the land of moisture, but to adjust the quantity so as to produce the highest degree of fertility; and although the very best systems are far from being perfect in this respect, yet, under every mode of drainage that has been tried when gross errors of construction have been avoided, the returns have always been found to be a very high remuneration for the outlay.

It is presumed, however, in regard to suburban land and villa occupations, that the chief thing sought is the immediate drying of the soil; so that in their case closely-laid drains will be requisite to ensure a rapid discharge of surface water, particularly from the footpaths.

It should be kept in view that roads and footpaths cannot drain downwards by percolation, but over the surface. Once at the sides of the road, the water may either percolate into the drains or be received into them by gully-shoots properly trapped to prevent the ingress of sand or silt. The same remark applies to court-yards.

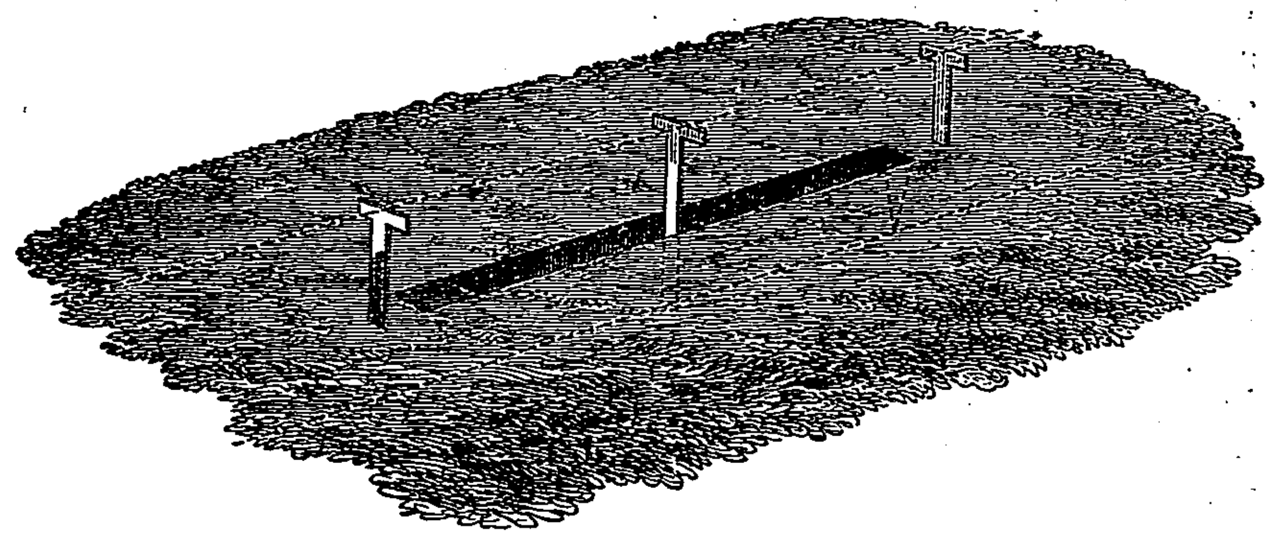
It is important, in reference to the suburban districts, to allude to the effect of drainage on the vigour and growth of trees. It has been determined by observations, that if the annual increase of trees on undrained land is 3 per cent., the increase on drained land will be 6 per cent.; and on land both drained and irrigated no less than 12 per cent., or four times the amount of the growth on the undrained land.

Those who have had no opportunities of observing the effects of drainage, and the difference between drained and undrained land, cannot judge when land is in need of drainage. The characteristics of ill-drained land have been alluded to in the previous explanations of the methods and advantages of thorough-drainage; and the following description may be given in addition. When undrained land is in the course of being dried up during the summer, the soil shrinks and cracks, and open fissures may be seen running in all directions; the surface grows hard and difficult to work, and becomes too dry for the growth of vegetation. During the rainy season of winter the cracks are filled up with water, which having no outlet remains in the soil and renders it soft and wet, and unfit for advantageous cultivation. In spring the crops are sickly, and there is a want of vigour in the plants generally; their colour is not the healthy hue; their parts are not fully developed, and they grow up and ripen very unequally. On ill-drained pasture lands the herbage is coarse, wiry, and of a sickly colour; the ground is hard and inelastic to the tread in summer, and in winter it sinks under the foot like a sponge. The more valuable species of herbage give way to a coarse bitter sort, which may, not unaptly, be termed the weeds of grass land. It has been remarked that grazing cattle prefer the best drained portions of the pasture ground.

The condition of the land and the extent of drainage that it may require can be best ascertained by proof-pits or test-holes; that is, pits dug here and there in the soil from 5 to 7 feet deep, and wide enough for a man to work in them. The water flowing out from the sides of these pits will show at what levels it is accumulated, and how deep the drains must be to carry it off. Or, instead of pits, one or more deep cuts may be made in the proper direction from one end

of a field to the other, and they will serve both as test-holes and beds for drains.*

One cause of the occasional failure of land-drains is their not having been made perfectly regular in inclination when they were first laid. If instead of a gradual and uniform fall there happen to be a slight rising in the bed of a drain, the descending water will be interrupted there till it accumulate so high as to be above the level of the rising, which will lead to a permanent stagnation or loss of fall for a certain length of the drain. Hence in laying the floor of the drains, means must be taken to make their descent to the outfall perfectly straight. This is accomplished by the use of what are called *boning-rods*, which may be described as follows:—



* It has been suggested that much useful information might be obtained from an examination of the nature and condition of lands throughout suburban districts, by means of trial-pits or test-holes, such as are made for examining the soil for land drainage. The information obtainable by this means consists of,—

1. A knowledge of the nature and capabilities of the land in each district.
2. Of the state of each district as to drainage, or the want of it.
3. The relative condition of adjacent districts, and how far the want of drainage in one district affects others.
4. How far a complete drainage of one district would affect others.
5. Whether the superfluous water in any particular locality arises from springs, or whether it be rain-water retained in the soil.
6. Whether water in any quantity likely to be useful could be collected by land drainage in any particular locality.
7. The most suitable localities for reservoirs for collecting such waters.
8. The qualities of the water found in the different localities.

In some particular spots it might for special purposes be desirable to make pits with the spade, to show the soil and subsoil; but generally an auger-bore of 3 inches to 6 inches diameter would be sufficient. And where water is found, a few small drain-pipes might be dropped into the bore to keep it open in case of any future examination of the quantity or quality of the water being desirable.

Where there are ditches filled with water, such test-holes would serve to show whether the adjoining fields were saturated to or near the level of that in such ditches. And in case of the removal of or substitution of tubular drains for ditches, the trial-pits would serve to indicate their effects upon the land.

Generally such information might be obtained as would form a record of the present state of suburban districts as to drainage, or the want of it, to which reference could in future be made, from time to time, as to the effect of any drainage executed. Together with the information so obtained should be annexed a precise account of the state of each locality, so as to form a ready book of reference on all matters relative to the state of land drainage.

Three staffs are made use of, two of them 2 feet long, and the third as much more than 2 feet as the drain is deep; that is, if the drain is 3 feet 6 inches deep, it must be 5 feet 6 inches long. The staffs are strips of wood, with cross pieces 9 inches long at the end that is to stand uppermost. The two shorter staffs are planted upright, one on the ground on a level with the field at the head of the drain, and the other at the lower end; and a person stands at one of them looking over its top, with his eye in a line with the other. A second man then takes the longest staff and holds it upright in the drain just touching the bottom, and walks along from one end of the drain to the other, keeping it in the upright position. If, while it is moved along, its top always appear in a line with the tops of the other two as seen by the person looking along the three, the fall of the drain is uniform; but if it rises above this line at any one place, the bottom is too high there and requires to be reduced; if it falls below the line, the bottom is too low and must be raised. In this way the fall may be rendered perfectly uniform.

The following are estimates of the probable cost of draining the various qualities of land under the usual general classification of light, medium, and heavy soils. The calculations are founded upon the actual cost of the drainage of lands of these qualities.* (See Table *A.*)

Subjoined also are extracts from published statements, by Mr. Smith of Deanston and Mr. Josiah Parkes, of the cost of drainage in various parts of the country. (See Tables *B.*, *C.*, *D.*)

Annexed is a diagram and statement of the comparative cost of draining a field of twenty acres on the two systems of Mr. Smith and Mr. Parkes. These estimates are rather "outside estimates," as is proper for small works. (See Tables *E.*, *F.*)

Private land-drains being liable to be opened or otherwise interfered with by the occupiers of the lands or their workmen, and to have the surface flood waters or contents of open ditches turned into them, traps or pits are necessary wherever such interference is allowed or practised; but with the drains properly constructed at first, and not afterwards injuriously interfered with, these sand traps or pits will not usually be required.

* It is thought probable that the cost of land-drainage may be considerably reduced by the operation of a recently invented drain-plough, which is described by Mr. Pusey in the Journal of the Royal Agricultural Society, vol. 12, pp. 639-641. *Vide* Appendix, No. VIII. p. 119.

Annexed also is a drawing and statement of the cost of draining plots of land for villa residences and cottages. (See Tables *L.*, *N.*) The necessity of a very complete and rapid drainage from such premises occasions a higher average cost than in the drainage of agricultural or garden ground. In general, drains for the removal of springs, or the clearance of the sites of houses from surplus water, are required to be cut much deeper than for common-land drainage, usually deeper than the foundations of buildings.

That more attention should in general be given to the condition of the suburban villas is proved by the frequent complaints of the dampness of such habitations. The dampness of their undrained soil is often aggravated by the trees that are planted about them, which exclude the action of the sun, and engender the unwholesome closeness of overgrown and neglected spots. The mosses and lichens that overspread such localities are signs of an unhealthy vegetation and a tainted atmosphere.

It is also of great importance to provide by means of suitable hedges or otherwise a shelter from the cold winds of winter, which by sweeping over the naked surface of open ground produce an excessive degree of cold, which the shelter of good hedges would tend greatly to ameliorate.

To secure the salubrity of a suburban or country residence the drainage should be deep and close. In the case of the roots of trees entering the drains, it may be remarked that they do so in order to obtain nourishment; and it is thought that it would be often worth while to allow them this facility, even though additional drains should be required in consequence; but, if necessary, the entrance of roots may be prevented by the use of collars to the drains.

The high value of suburban land in general will enable it to bear a larger expenditure with a view to secure a more productive cultivation. The space of ground near Birkenhead, now called the park, was a short time ago, like much suburban land near the metropolis, a mere marsh, over which thick mists hung at nightfall. It was thoroughly drained by Sir Joseph Paxton, with drains varying in depth from seven feet to close surface drains. The mists and fogs created on this tract have, since the drains came into operation, disappeared. The expense of that work was 20*l.* per acre; and the land, which before the drainage was worth only 1*l.* per acre, is now worth, at the least, 4*l.* per acre for pasturage; so that the work pays 15 per cent. direct profit, besides effecting its main object,—the improvement of the neighbourhood in comfort and salubrity.

(A.)

A TABLE OF THE COST OF LAND-DRAINAGE PER ACRE.

The differences in the quality of soils, that lead to differences in the depth and distance of the Drains, are also such as to affect the cost of digging the Drains. An increase of depth necessarily causes an increase of cost, from the mere circumstance of more earth having to be moved. But the same reason that causes Drains to be made closer, namely, the stiffness of the soil, renders them more difficult to dig, and hence increases the price of digging. This will explain how it happens, in the following Table, that the cost per rod is greater, not only as the depth increases, but as the distance of the Drains is less. Of two soils drained at the same depth, the expense of draining a rod will be least in that for which the Drains are farthest apart, which is where the soil is of the freest or least tenacious description.

Description of Soils.		Distance of Drains apart.	Depth of Drains.	Number of Yards of Drains per Acre.	Cost of cutting and filling per Chain.	Cost of cutting and filling per Acre.	Number of Drain Pipes of 12 Inches long required per Acre.	Cost of Drain Tiles per Acre, at 30s. per 1,000.	Total Cost per Acre.
		Feet.	Ft. in.		£ s. d.	£ s. d.		£ s. d.	£ s. d.
Heavy Soils.	Compact tenacious gravelly Clay - - -	15	2 6	968	0 1 8	3 13 4	2,905	4 7 2	8 0 6
	Stiff adhesive Clay -	16½	2 6	880	0 1 7	3 3 4	2,640	3 19 2	7 2 6
	Friable Clay - -	18	2 9	807	0 1 6	2 15 1½	2,420	3 12 7	6 7 8
	Free soft Clay - -	21	2 9	692	0 1 4	2 2 0	2,076	3 2 3	5 4 3
Medium Soils.	Clayey Loam - -	22	3 0	660	0 1 8	2 10 0	1,980	2 19 5	5 9 5
	Marly Loam - -	24	3 0	605	0 1 6	2 1 3	1,814	2 14 5½	4 15 8
	Gravelly Loam - -	27	3 3	538	0 2 4	2 17 2	1,613	2 8 4½	5 5 6½
	Friable Loam - -	30	3 3	484	0 2 0	2 4 0	1,452	2 3 6½	4 7 6½
Light Soils.	Light gravelly Loam -	33	3 6	440	0 2 10	2 16 8	1,320	1 19 7	4 16 3
	Light marly Loam -	36	3 9	403	0 2 8	2 9 4	1,209	1 16 3	4 5 7
	Sandy Loam - -	39	4 0	373	0 2 6	1 19 8	1,117	1 13 6	3 3 2
	Soft light Loam - -	42	4 0	346	0 2 4	1 16 9	1,037	1 11 1½	3 7 10½
	Sandy Soil - -	45	4 0	325	0 2 4	1 14 5	974	1 9 2½	3 3 7½
	Light gravelly Sand -	49½	4 3	293	0 3 4	2 5 0	880	1 7 4½	3 12 10
	Deep do. do. -	55	4 3	264	0 3 0	1 16 0	792	1 3 9	2 19 9
	Coarse gravelly do. -	60	4 6	242	0 4 0	2 4 0	726	1 1 9	3 5 9
	Loose do. - -	66	4 6	220	0 3 4	1 13 4	660	0 19 9½	2 13 1½

(B.)

A Table showing the Cost per Acre of Draining on Hard Subsoils, with Tiles and Soles, extracted from Mr. Smith of Deanston's Pamphlet on Drainage.

Subsoils to which the Distances are applicable.	Distance between the Drains.	Number of Rods per Acre.	Cost per Acre of Tiles at 14*s.* and Soles at 7*s.* per Thousand.	Cost of cutting and filling at 3½*d.*	Total Cost per Acre.
	Feet.		£ *s.* *d.*	£ *s.* *d.*	£ *s.* *d.*
Clay - - -	15	176	3 0 11½	2 11 4	5 12 3
Sandy Clay - - -	18	147	2 10 9¾	2 2 10½	4 13 8½
Ditto - -	21	126	2 3 6½	1 16 9	4 0 3½
Free Stony Subsoil -	24	110	1 18 1½	1 12 1	3 10 2½
Ditto - - -	27	98	1 13 10¼	1 8 7	3 2 5¼
Porous - - -	30	88	1 10 6	1 5 8	2 16 2
Ditto - - -	33	80	1 7 8½	1 3 4	2 11 0½
Sand or Gravel - -	36	74	1 5 4	1 1 7	2 6 11

(C.)

Instances of the Cost of Draining cited by Mr. Josiah Parkes in the Sixth Volume of the "Journal of the Royal Agricultural Society," the Drain Pipes being assumed to cost Six Shillings per Thousand, being made upon the Estate.

County.	Instances cited.	Depth of Drains.	Distances between Drains.	Cost of Labour per Acre.	Cost of Pipes per Acre.	Total Cost per Acre.	Character of the Soil.
	No.	Feet.	Feet.	£ *s.* *d.*	*s.* *d.*	£ *s.* *d.*	
Kent -	1	3	33	1 0 0	7 11	1 7 11	Uniform Clay.
Sussex -	2	3	33	1 0 0	7 11	1 7 11	Ditto.
Surrey -	3	3 to 4	33	1 6 8	7 11	1 14 7	Ditto.
Ditto -	4	4½ to 4	40	1 2 0	6 6	1 8 6	Ditto.
Ditto -	5	4	50	1 6 6	5 3	1 11 9	Clay, with some stones.
Kent -	6	3 to 3½	49½	1 15 6	5 4	2 0 10	Clay—Hard Gravelly Subsoil.
Ditto -	7	4	49½	1 15 6	5 4	2 0 10	Ditto.
Ditto -	8	4	66	1 6 8	4 0	1 10 8	Various—Clay, Gravel, Sand.
Ditto -	9	3½ to 4	33	2 10 0	7 11	2 17 11	Clay, Gravelly Subsoil.

(*D.*)

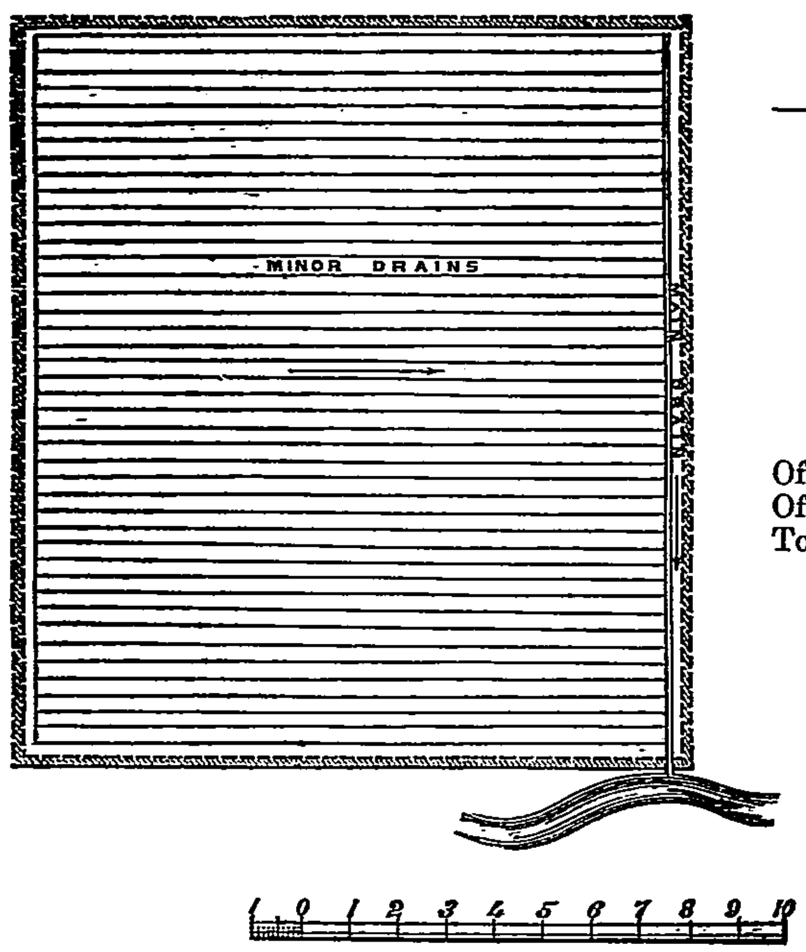
EXTRACTS from the "Gardener's Chronicle and Agricultural Gazette," 18th March 1848, of the COST of the DRAINAGE of LANDS in the County of NORTHAMPTON, by Mr. JOSIAH PARKES.

FARMS.	Extent drained.	Depth of Drains in Feet.	Distance apart in Yards.	Cost of Labour, including Mr. Parkes' Commission of 5*s.* an acre.	Cost of Tiles.	Total Cost.	Cost per Acre.	Character of the Soils.
	A. R. P.			£ *s.* *d.*	£ *s.* *d.*	£ *s.* *d.*	£ *s.* *d.*	
A	33 0 0	4	12	113 8 5	37 16 3	151 8 4	4 11 7	Heavy Clay.
B	61 0 31	4	12	152 11 0	77 12 8	230 3 8	3 15 5	Various Clay.
C	16 0 0	4	10 to 11	46 18 3	20 6 9	67 7 9	4 4 2	Strong Clay.
D	16 0 0	4	13	60 15 7	15 4 2	76 9 9	4 15 7	Strong Land.
E	20 0 0	4	10	68 16 8	25 2 6	93 19 2	4 13 11	Weak Blue Clay.
F	46 0 0	4	12	165 4 5	55 15 6	220 19 11	4 16 1	Whitish Stubborn Clay.
G	13 0 0	4	11 to 12	49 8 7	17 15 6	67 4 1	5 3 4	Strong Clay and Gravel.
H	12 0 0	4	12	36 12 7	14 3 9	50 16 4	4 4 8	Whitish Clay.

The Tiles were made upon the estate and drawn by the Tenants, who also pay to the Landlord 5 per cent. on the outlay.

(*E.*)

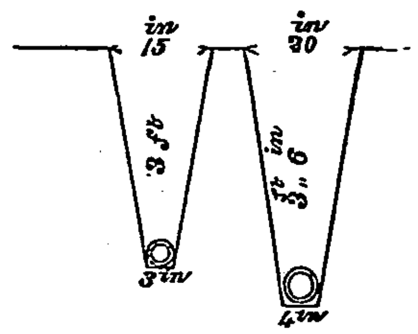
A Field of 20 acres, with the Drains 3 feet deep and 22 feet apart, upon Mr. Smith of Deanston's system.



Scale of chains.

DRAINS.

Minor. Main.



Sectional Area. In.

Of minor drain - - 324

Of main drain - - 504

To be removed in digging the drain.

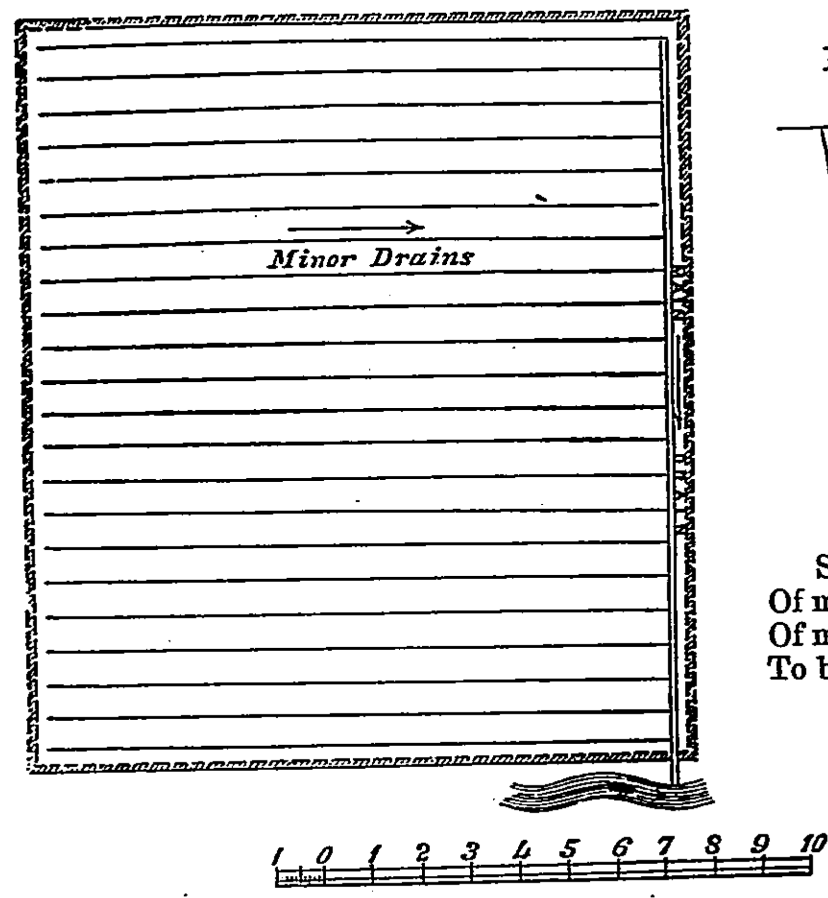
		£	*s.*	*d.*
Main drain, 60 rods, at 8½*d.* per rod	-	2	2	6
Drain pipes, 990, at 40*s.* per thousand	-	1	19	7½
Minor drains, 2,261½ rods, at 4½*d.* per rod	-	42	8	0
Drain pipes, 37,320, at 30*s.* per thousand	-	55	19	7
£5 2*s.* 6*d.* per acre.		£102	9	8½

Annual charge as Improvement Rate or Rent at 20 years, 7*s.* 7*d.* per acre.

The two fields are assumed to be alike in size and quality of soil, and the prices for cutting and filling the drains are in proportion to their depth and sectional area respectively.

(*F.*)

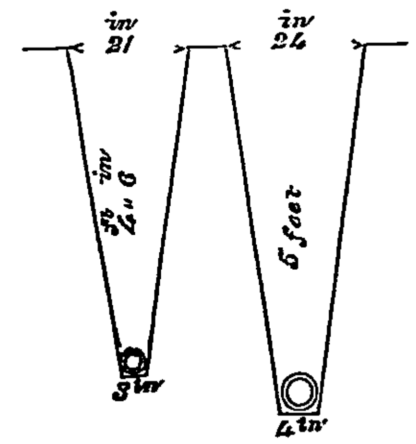
A Field of 20 acres, with the Drains 45 feet apart, and 4½ feet deep, upon Mr. Josiah Parkes's system.



Scale of chains.

DRAINS.

Minor. Main.



Sectional Area. In.

Of minor drain - - 648

Of main drain - - 840

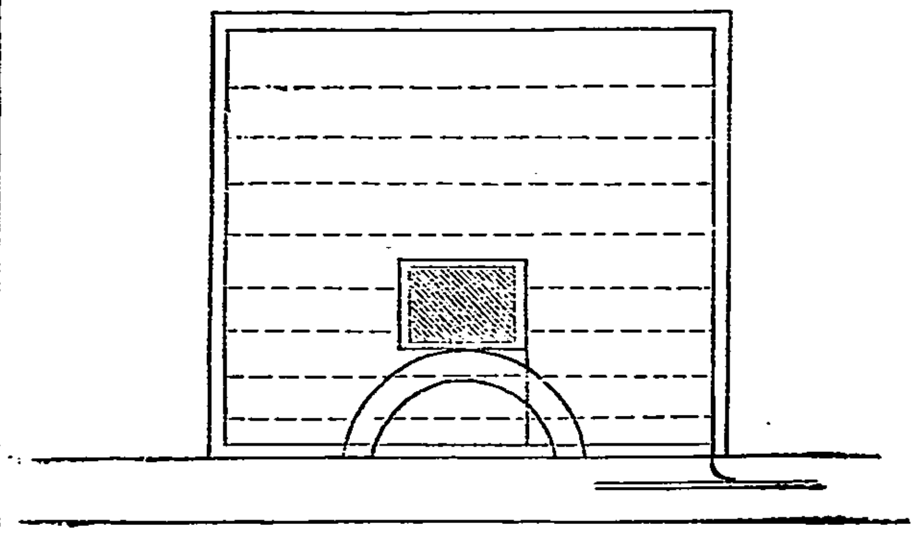
To be removed in digging the drains.

		£	*s.*	*d.*
Main drain, 60 rods, at 1*s.* 2*d.* per rod for cutting and filling	-	3	10	0
Drain pipes, 990, at 40*s.* per thousand	-	1	19	7½
Minor drains, 1,109 rods, cutting and filling at 10*d.* per rod	-	46	4	2
Drain pipes, 18,300, at 30*s.* per thousand	-	27	9	0
		£79	2	9½

£3 19 1½ per acre.

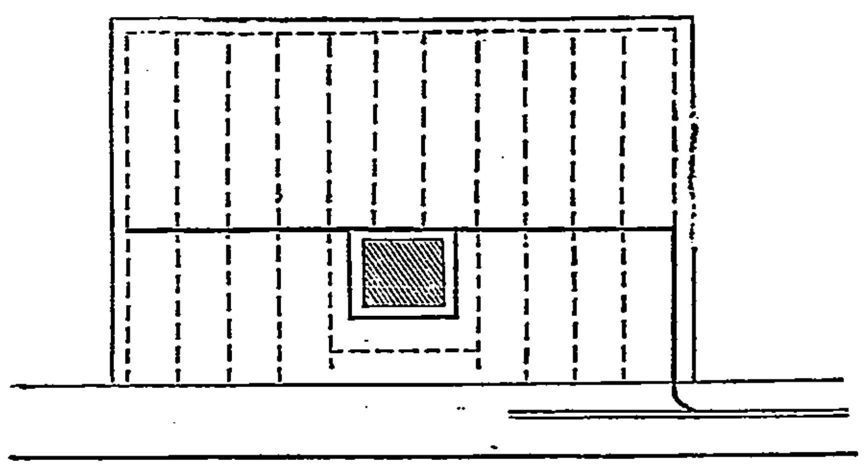
Annual charge as Improvement Rent or Charge at 20 years, 6*s.* 1¼*d.* per acre.

The two fields are assumed to be alike in size and quality of soil, and the prices for cutting and filling the drains are in proportion to their depth and sectional area respectively.



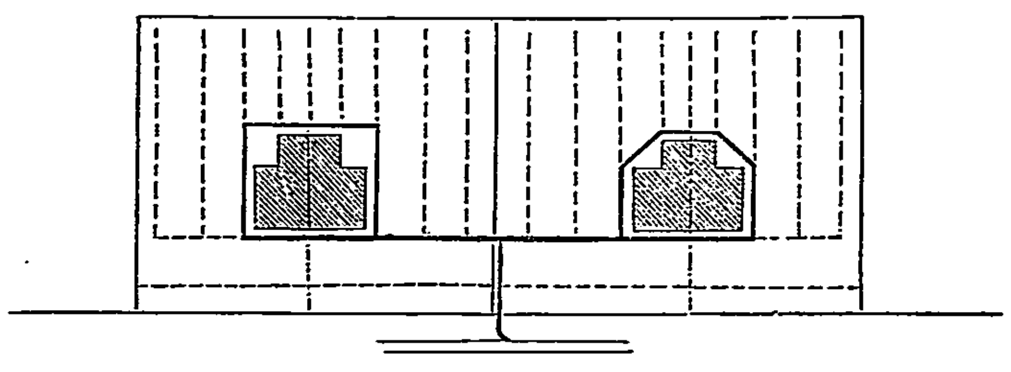
A mansion, with one acre of land isolated by a deep drain all round it. The site of the building deeply drained and the whole of the grounds thoroughly drained.

Labour and Materials.	Quantities.	Light Soils. Rate.	Light Soils. Amount.	Medium Soils. Rate.	Medium Soils. Amount.	Heavy Soils. Rate.	Heavy Soils. Amount.
		s. d.	£ *s. d.*	*s. d.*	£ *s. d.*	£ *s. d.*	£ *s. d.*
Deep (6 ft.) drain, at per yard - -	77	0 6	1 18 6	0 7	2 4 11	0 0 8	2 11 4
„ (5 ft.) drain, at per yard - -	277	0 4	4 12 4	0 5	5 15 5	0 0 6	6 18 6
Drain (1¼ in.) pipes, at per thousand -	1062		2 13 0		2 13 0	1 15 0	2 13 0
Minor (3½ ft.) drains, at per yard -	745	0 2½	7 15 2	0 3	9 6 3	0 0 4	12 8 4
Drain (1 in.) pipes, at per thousand -	2235		2 15 10		2 15 10	1 5 0	2 15 10
			£19 14 10		£22 15 5		£27 7 0
Annual charge as Improvement — Rent or Rate, for twenty years		-	£1 10 3		£1 14 8¼	- -	£2 3 2½



One acre of land and detached villa residence. The site of the buildings deep-drained, and the rest of the ground thoroughly drained.

Labour and Materials.	Quantities.	Light Soils. Rate.	Light Soils. Amount.	Medium Soils. Rate.	Medium Soils. Amount.	Heavy Soils. Rate.	Heavy Soils. Amount.
		s. d.	£ *s. d.*	*s. d.*	£ *s. d.*	£ *s. d.*	£ *s. d.*
Deep (5 ft.) drain, at per yard - -	147	0 4	2 9 0	0 5	3 1 3	0 0 6	3 14 6
Drain (1¼ in.) pipes, at per thousand -	441		0 14 5		0 15 5	1 15 0	0 15 5
Minor (3½ ft.) drain, at per yard -	622	0 2½	6 9 7	0 3	7 15 6	0 0 4	10 7 4
Drain (1 in.) pipes, at per thousand -	1866		2 6 7		2 6 7	1 5 0	2 6 7
			£12 0 7		£13 18 9		£17 2 10
Annual charge as Improvement — Rent or Rate, for twenty years		-	£0 18 3½		£1 1 4¾	- -	£1 6 0¼



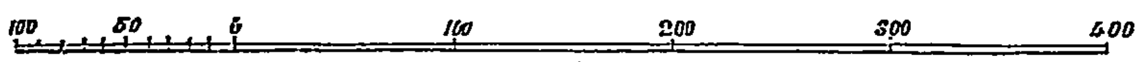
One acre of ground, laid out for four semi-detached villa residences. The sites of the buildings deep-drained, and the grounds thoroughly drained.

Labour and Materials.	Quantities.	Light Soils. Rate.	Light Soils. Amount.	Medium Soils. Rate.	Medium Soils. Amount.	Heavy Soils. Rate.	Heavy Soils. Amount.
		s. d.	£ *s. d.*	*s. d.*	£ *s. d.*	£ *s. d.*	£ *s. d.*
Deep drain, at per yard - -	151	0 4	2 10 4	0 5	3 2 11	0 0 6	3 15 6
Drain (1¼ in.) pipes, at per thousand -	453		0 15 10		0 15 10	1 15 0	0 15 10
Minor drains, at per yard - -	495	0 2½	5 3 1½	0 3	6 3 9	0 0 4	8 5 0
Drain (1 in.) pipes, at per thousand -	1485		1 17 2		1 17 2	1 5 0	1 17 2
			£10 6 5½		£11 19 8		£14 13 6
Annual charge as Improvement — Rent or Rate, for twenty years		-	£0 15 8½		£0 18 3	- -	£1 2 4¼
ditto — ditto per house - -			£0 3 11		£0 4 6¾	- -	£0 5 7

Deep drains marked ————

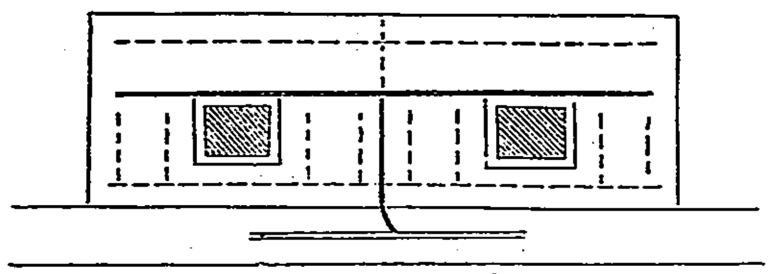
Minor drains marked - - - - - - - -

Road drains marked ═══════



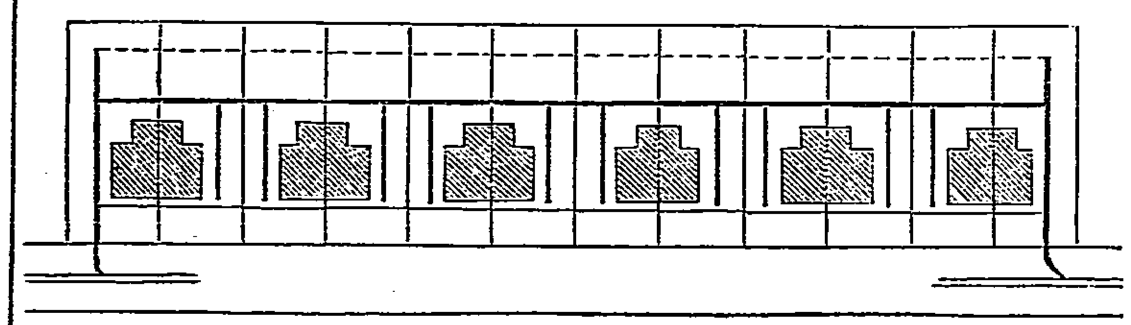
SCALE OF FEET.

G. DONALDSON,
Assistant Surveyor.



Half an acre of land, laid out for two detached villa residences. The sites of the buildings deep-drained, and the grounds thoroughly drained.

Labour and Materials.	Quantities.	Light Soils. Rate.	Light Soils. Amount.	Medium Soils. Rate.	Medium Soils. Amount.	Heavy Soils. Rate.	Heavy Soils. Amount.
		s. d.	£ s. d.	s. d.	£ s. d.	£ s. d.	£ s. d.
Deep drains, at per yard - -	161	0 4	2 13 8	0 5	3 7 1	0 6 0	4 0 6
Drain (1¼ in.) pipes, at per thousand -	483		0 16 10		0 16 10	1 15 0	0 16 10
Minor drains, at per yard - -	242	0 2½	2 10 5	0 3	3 0 6	0 0 4	4 0 8
Drain (1 in.) pipes, at per thousand -	726		0 18 1		0 18 1	1 5 0	0 18 1
			£6 19 0		£8 2 6		£9 16 1
Annual charge as Improvement. Rent or Rate, for twenty years -			£0 10 8		£0 12 3¼	- -	£0 14 11½
ditto per house - -			£0 5 4		£0 6 1½	- -	£0 7 6¾



One acre of land, laid out for 12 semi-detached villa residences, and thoroughly drained.

Labour and Materials.	Quantities.	Light Soils. Rate.	Light Soils. Amount.	Medium Soils. Rate.	Medium Soils. Amount.	Heavy Soils. Rate.	Heavy Soils. Amount.
		s. d.	£ s. d.	s. d.	£ s. d.	£ s. d.	£ s. d.
Deep drains, at per yard - -	484	0 4	8 1 4	0 5	10 1 9	0 0 6	12 2 0
Drain pipes, at per thousand - -	1452		2 10 9½		2 10 9½	1 15 0	2 10 9½
Minor drains, at per yard - -	147	0 2½	1 10 7	0 3	1 16 9	0 0 4	2 9 0
Drain pipes, at per thousand - -	441		0 11 0		0 11 0	1 5 0	0 11 0
			£12 13 9		£15 0 3½		£17 12 9½
Annual charge as Improvement. Rent or Rate, for twenty years -			£0 19 4¼		£1 2 10½	- -	£1 6 11
ditto per house - -			£0 1 7½		£0 1 11	- -	£0 2 3

Deep drains marked ————

Minor drains marked - - - - - - -

Road drains marked ════

100 200

SCALE OF FEET.

G. DONALDSON,
Assistant Surveyor.

The simple indented tube-tiles may be purchased in the country at a retail price of 15*s.* the thousand, and the double horse-shoe tiles at 40*s.* the thousand. Those who manufacture tiles themselves may obtain both kinds at a much lower cost. In the Appendix, p. 70, is given a table, showing the prime cost of making tubular drain-tiles, of various diameters, by the Ainslie tile-kiln and machine. The ordinary kilns require one half more coal. This table will furnish data which will enable those who have clay on their own lands to determine whether it will be better to manufacture or to purchase pipes.

To guard against the ingress of sand, mud, detritus, or other matters, from private land-drainage into the public mains, it is proposed that all private land-drainage shall pass through at least a chain (22 yards) of sub-main drain immediately before discharging into the mains; the sub-mains to be such as shall be approved of by the Surveyor to the Local Board; and that there be placed in each at a suitable point, not less than six yards from its junction with the main drain, a trap with a grating for intercepting any matters that might tend to choke or clog the mains.

Such traps should have a grating placed in the line of the drain pipes, with a recess for receiving the intercepted matter, the top or cover being moveable for the purpose of cleaning it out when necessary. All junctions of sub-main drains with the mains should be so constructed as to bring the line of the sub-main nearly parallel with the line of the main, so that at the point of junction the streams may flow together without collision; and in every case of junction whatsoever the same mode of connexion should be observed.

Attached to the following scales of estimated charges for the work are statements of the rates for spreading the repayment over a term of years.*

The land to be drained is taken of three classes, light, medium, and heavy. The cost of draining per acre will be—

* Appendix IX. contains tables for calculating the amount necessary for repaying any sum, with interest, by equal annual instalments in any period from one to thirty years at any rate of interest from 3½ to 6 per cent.

								Tenant's annual Charge.				
	£	s.	d.		£	s.	d.	s.	d.		s.	d.
For Light Soils, from	2	13	6	to	4	16	3	4	1	to	7	4
For Medium Soils ,,	4	7	6	,,	5	10	0	6	$8\frac{1}{16}$	,,	8	$4\frac{3}{4}$
For Heavy Soils ,,	5	5	0	,,	8	0	0	8	$0\frac{1}{16}$	,,	12	$2\frac{1}{4}$

For villa drainage the cost per acre will be from 10*l.* 6*s.* 6*d.* to 27*l.* 7*s.* according to circumstances.

The cost of drainage of a single villa will vary from 3*l.* 10*s.* to 27*l.*, according to the extent of ground and the drainage required.

A charge of 7*l.* 13*s.* 9*d.* per cent. upon the outlay would repay the cost, with interest at the rate of 4½ per cent. in the course of twenty years.

The foregoing explanations and suggestions refer to the removal from the land of the surplus water arising from rainfalls and springs. But in the case of premises not supplied with water, the occupiers may be expected not only to reserve for their own use the rain falling on the roofs of their houses and offices, but to collect part of the drainage and spring water of the fields into appropriate tanks or receptacles. The only service that could be expected from the surveyor in regard to such tanks or reservoirs would be to attend to the connexion of the overflow pipes with the main outfalls.

In respect to the house-drainage or the removal of the refuse from the water-closets, kitchens, sculleries, stables, and offices, as well as the drainage from the farm steading, it is presumed that in the case of suburban dwellings occupied by parties engaged in land-tillage, the occupiers, instead of allowing it to run to waste, will carefully retain it in tanks provided for the purpose, with the view of applying it as manure to increase the productiveness of the land.

In the Appendix will be found the answers, obtained by the Earl of Carlisle, from persons of the chief practical experience who have been consulted on land-drainage works throughout the country.

On the whole, the collection of practical information in the Appendix will be found to be the most authentic, full, and complete of any which is known to have been yet formed upon the subject; and looking to the importance of suburban land-drainage as a means of relief to the densely-populated districts, as subservient to the application of the refuse productively, as well as means for the diminution of damp and fogs, and nuisances injurious to the public health, it is to be hoped that this information will be widely circulated, to stimulate and guide private exertions for the extension of the practice of thorough drainage.

But whilst safe profitable results are now available for immediate practical application, still further improvements may, no doubt, be effected by skilful local surveyors who have studied the improved principles of drainage. The investigations of the works of town-drainage for the purpose of the sanitary improvement of the town population have elicited, on a large scale, some important results in respect to hydraulic arrangements which are applicable to land-drainage works on a small scale.

It was found that a large proportion of sewers were constructed with flat bottoms, which, when there was a small discharge, spread the water, increased the friction, retarded the flow, and accumulated deposit. It was ascertained that by the substitution of circular sewers of the same width, with the same inclination and the same run of water, the amount of deposit was reduced more than one-half. *Vide Sanitary Report*, 1842, p. 55.

By a better adaptation of the size of tubular drains to the water which they are required to convey, with the same quantities and inclinations, a velocity of discharge more than four times greater was in some important cases attained, and complete and rapid clearances effected, and heavy substances swept away which previously formed part of the accumulations of decomposing matter polluting the air of towns. (*Vide Exemplification, Report on the Water Supply of the Metropolis*, 1850, p. 185. *et seq.*) It was proved also that a great reduction of the sectional area of the system of drains was generally expedient, in many cases so great as in the proportion of 37 to 1, and that such reduction would effect a constant clearance of all deposit, and prevent those accumulations of decomposing matter which made the drains and sewers of towns only extended systems of cesspools, the cleansing of which occasioned as great an annual expense as would be required for the substitution of an entirely new set of works. (*Idem*, p. 201.)

So empirical were the first works of land-drainage, that no estimate appears to have been made of the service

required by the pipes,—the like faults of construction to those of the common town sewers were displayed. The flat-bottomed tile drain was productive of the same results as the flat-bottomed town sewer,—the flow of water was retarded and deposit was occasioned; but *safety* had been sought by the undertakers at the expense of the employer by the construction of drains of so large a size, that the process of deposit might go on for a long time before they became completely obstructed.

As might be expected, the first drainers set out with drains of this erroneous construction, as may be seen by the diagrams in Mr. Smith of Deanston's first pamphlet. Thus his minor drains were of no less than eighteen inches sectional capacity. Now, a single drain of this capacity will, when running half full at the outlet, discharge in twenty-four hours about six hundred tons of water, equal to a rain-fall of nearly six inches in depth on an acre. One inch in depth is a very heavy fall in a day, and it generally takes two days for the water after rain to drain fully from deep drained land; yet Mr. Smith provided eighteen such drains per acre, having a total sectional area of 324 inches, and capable of discharging when only half filled, 4½ inches of rain-fall from an acre in a single hour. That is in six hours more than the whole annual rain-fall of the London district.

The smaller the amount of water to be discharged, the greater ought to be the care in the concentration of the flow and in the exactitude of the construction of pipes or the channels of conveyance. Some trial works as to the flow of water through drain pipes of different materials present results which appear to be available for the construction of pipes for land-drainage. Thus it was found that with pipes of the same diameter exactitude of form was of more importance than smoothness of surface; that glass pipes which had a *wavy* surface discharged less water at the same inclinations than Staffordshire stoneware clay pipes which were of perfectly exact construction. By passing pipes of the same clay—the common red clay—under a second pressure obtained by a machine at an extra expense of about eighteen pence per thousand, whilst the pipe was half dry, very superior exactitude of form was obtained; and by means of this exactitude, and with nearly the same diameters, an increased discharge of water of one fourth was effected within the same time. (*Vide Appendix No.* 2. *to the Report on the Supply of Water to the Metropolis*, p. 184.)

The conclusions appear to be, that by a more careful construction of agricultural drain pipes, the same effects might be produced with pipes of less size than those commonly in use. The same trial works showed also that accuracy in the forms of jointing was of greater importance to the well-working of any system of small drains than is commonly imagined.

In respect to town-drainage, the practice of architects and engineers was to enlarge the area of any main pipe in the proportion of the sectional area of each junction into it; whereas it was found by the trial works, that the addition of eight junctions, each of three inches diameter, into a main line of pipe of only four inches diameter so increased the velocity of the stream, that there was no increase of its sectional area. (*Appendix No.* 2. *to Report on Water Supply, Medworth*, p. 191.)

It was a practice in town-drainage, and defended too by professional men, to make junctions of streams at right angles, and is now the common practice to form the junctions of land-drains at right angles and with projecting pieces, so as positively to impede the flow. On a large scale it was found that when equal quantities of water were running direct at a rate of 90 seconds,—with a turn at right angles the discharge was only effected in 140 seconds,—whilst with a turn or junction with a gentle curve, the discharge was effected in 100 seconds. (*Vide Sanitary Report*, 1842, p. 57.)

The hydraulic formulæ in use even among engineers of the greatest eminence who have had the direction of the largest expenditure in such works of town-drainage appeared to be erroneous as to the requirements of pipes for the discharge of water. The old formulæ were founded on experiments mostly on a small scale, and applicable only to very different circumstances, and when applied to common drainage works, they presented differences of more than one third even in the discharge through six-inch pipes; and observations preparatory to actual experiments were made which showed that the differences between the fact and the common practice, as well as the common formulæ, increased in a still greater ratio with the larger discharges of water; but the further prosecution of these trial works was stopped, and the consequent economies of structural arrangements yet remain incompleted. Though enough was shown to demonstrate the entire insufficiency of the data on which the common

practice and formulæ are founded, yet more varied trials, checked by different observers, appear to be requisite for the attainment of complete exactitude and definite limits of economy, as well as efficiency in hydraulic works of this description.

Observation of the runs of water from outfalls to sets of drains of the existing constructions and arrangements may be recommended for the improvement of land-drainage works in the better adjustment of the sizes of pipes to the discharge of surplus water and the removal of deposit, and in order to deduce, from the run through the outfall, what ought to be the size of the branch pipes. Thus, if it be observed, as it frequently has been, that a three-inch pipe which serves as the main outfall for the drainage of an area of ten acres of land is never more than half filled, it may be asked, what must be the size of the run or thread of water in the forty contributory branch pipes which the main receives? Need the sectional areas of the tributaries be so much as ten times larger than the main outfall? Will not the spreading out of the small stream or thread of water render it more shallow, increase its friction, impede the flow, and diminish its power of removing accidental obstructions?

The conclusions indicated would be, the expediency of making land-drainage pipes yet smaller, improving their manufacture, and making them more exact in form, laying them more accurately. There is no doubt that this would necessitate more skilful and even delicate adjustment than may now be readily available from common workpeople; but the question for investigation, for the improvement of these works, is, whether it would not be remunerative?

In answer to the objection of the excessive size of the pipes in proportion to any volume of water they could be required to discharge, it has been suggested, that although the additional space in the pipes might not be required for the discharge of water, it might be serviceable for the permeation of air. This object was not originally suggested as a reason for the size of the pipes, and, although it is supported by horticultural theory and practice (*vide ante*), its applicability to the pipe drainage of land has not been generally considered. Indeed no superior exit was originally or is usually provided to facilitate the free permeation of the air through the drains, and it is an operation which remains to be investigated. On the other hand, it is generally admitted that the reduction of the sizes has hitherto been advantageous, and there appears to be no valid reason why yet closer adaptation of the pipes to the quantity of water they can be required to carry may not be made with further advantage.

By Order of the Board,

HENRY AUSTIN, *Secretary.*

Whitehall,
30*th January* 1852.

APPENDIX.

No. I.

In calculating the expense of forming drains or ditches, one of the chief items is the quantity of earth that has to be thrown out, which depends on the size of the drain. The cost of the labour will necessarily increase with the weight of earth that has to be removed; hence it is convenient to know the solid contents, or the number of cubic yards of cutting, in a drain of any given dimensions. This is found by multiplying together the length, depth, and mean width of the drain. Thus if a drain is 300 yards long, and the cutting 3 feet deep, 20 inches wide at the top and 4 inches wide at the bottom, the mean width would be 12 inches (or the half of the sum of 20 and 4), and if we multiply 100, the length, by 1, the depth in yards, and by $\frac{1}{3}$, the mean width in yards, and the product would be 100 cubic yards. The following table will serve to facilitate such calculations.

TABLE showing the NUMBER of CUBIC YARDS of EARTH in each ROD ($5\frac{1}{2}$ Yards in length), in Drains or Ditches of various Dimensions.

DEPTH.	MEAN WIDTH.											
Inches.	7 In.	8 In.	9 In.	10 In.	11 In.	12 In.	13 In.	14 In.	15 In.	16 In.	17 In.	18 In.
30	·89	1·02	1·146	1·27	1·40	1·53	1·655	1·78	1·91	2·04	2·164	2·29
33	·98	1·12	1·26	1·40	1·54	1·68	1·82	1·96	2·10	2·24	2·38	2·52
36	1·07	1·22	1·375	1·53	1·68	1·83	1·986	2·14	2·29	2·244	2·60	2·75
39	1·16	1·324	1·49	1·655	1·82	1·986	2·15	2·32	2·48	2·65	2·81	2·98
42	1·25	1·426	1·604	1·78	1·96	2·14	2·32	2·495	2·674	2·85	3·03	3·21
45	1·34	1·53	1·72	1·91	2·10	2·29	2·48	2·67	2·865	3·055	3·246	3·438
48	1·426	1·63	1·833	2·04	2·24	2·444	2·65	2·85	3·056	3·26	3·46	3·667
51	1·515	1·73	1·95	2·164	2·38	2·60	2·81	3·03	3·25	3·46	83·6	3·896
54	1·604	1·83	2·06	2·29	2·52	2·75	2·98	3·20	3·44	3·666	3·895	4·125
57	1·69	1·935	2·18	2·42	2·66	2·90	3·14	43·38	63·63	3·87	4·11	4·354
60	1·78	2·036	2·29	2·546	2·80	3·056	3·31	3·564	3·82	4·074	4·33	4·584

Along the top of the table is placed the mean widths in inches, and on the left-hand side the depths of the drains, extending from 30 inches to 5 feet. The numbers in the body of the table express cubic yards and decimals of a yard. In making use of the table, it is necessary first to find the mean width of the drain from the widths at the top and bottom. Thus, if a drain 3 feet deep were 16 inches wide at the top, and 4 inches at the bottom, the mean width