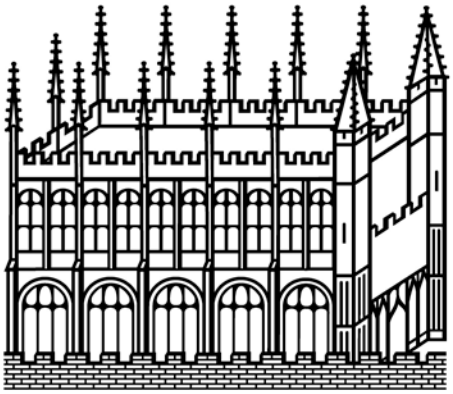

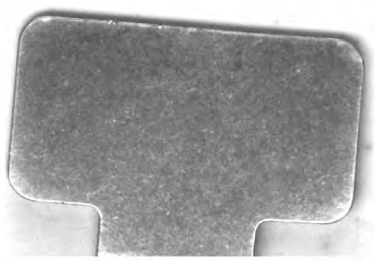

MAIN DRAINAGE.

THE DISCHARGE DIFFICULTY OVERCOME,

BY THE

ABOVE-GROUND TUBULAR SEWER SYSTEM,

INVENTED BY

WILLIAM RICHARDSON, C.E.,

AND ADAPTED TO THE METROPOLITAN DISTRICTS BY

GEORGE CLARK.

WITH PLANS.

LONDON:
JOHN WEALE, 59, HIGH HOLBORN.

1857.

MAIN DRAINAGE.

ABOVE-GROUND TUBULAR SEWER SYSTEM,

INVENTED BY WILLIAM RICHARDSON, C.E., AND ADAPTED TO THE METROPOLITAN DISTRICTS BY GEORGE CLARK.

INTRODUCTION.

THE following pages contain a description of a system of above-ground high level drainage, and of an iron tubular sewer, of which Mr. William Richardson, C.E., is the inventor.*

On the 28th February, 1857, in compliancc with the public invitation of Capt. Douglas Galton, R.E., James Simpson, Esq., C.E., and Thomas E. Blackwell, Esq., C.E., the referees appointed by the Chief Commissioner of Her Majesty's Works, &c., to consider the plans for the main drainage of the metropolis, a plan on the above-ground system was submitted to those gentlemen. The documents here printed comprise that plan, as well as a description of the construction of the tubular sewer, and estimates of the expense of its application under various circumstances.

There is something startling, it must be allowed, in the novelty of an above-ground main sewer. The idea of conveying the metropolitan sewage miles across the country, and over the heads of the population, at first strikes the mind with surprise, because it inverts the habitual order of ideas. But that is the fate of all new inventions, when the application of them is subversive of preconceived notions.

The present generation is familiar with examples of that kind. When the rail and the locomotive were first proposed as competitors to turnpike roads and mail coaches, and ocean steamers to sailing packets, great were the scientific doubts and strong the predictions of failure. But where are those doubts and predictions now? Mail

* In 1852 Mr. William Richardson presented a memorial to the Commissioners of Sewers, proposing his above-ground plan for the drainage and sewerage of the south side of London.

coaches have disappeared, and the days of sailing packets are numbered. The locomotive and the ocean steamer are triumphant, the opinions of some of the leading men of science are falsified.

It is not safe to pass a sweeping condemnation on any untried system. Reason and prudence recommend a patient hearing and a fair trial for a new plan, which *primâ facie* holds out a prospect or even a chance of success, and which, if successful, would become a great social and national benefit. Such is the character of a plan which proposes to relieve large towns of their sewage, and at the same time make it available for agricultural purposes.

The true view of the case, as to the impression produced by the first communication of the above-ground system, is well put in the words of a letter from the late eminent engineer, John U. Rastrick, Esq., F.R.S., dated October 31st, 1855. "The plan is such a bold and unique one, that it necessarily strikes every one with surprise, and consequently, without it had been carried into execution upon a smaller scale, and proved by its practical application, I am afraid you will find great difficulty in getting it adopted." Since that date, the plan has undergone great improvements, and its practicability can be proved.

Admitting the reasonableness of the above opinion, the object of publishing the following paper is to bring the subject under the notice of the public, that it may be understood, canvassed and made familiar to the mind.

In their report, the Government referees make no mention of the proposals submitted to them for the application of the above-ground system to the metropolitan drainage; they only refer to it in these words (Referees' Report, page 26):—"The fourth class, viz., plans which propose to run the sewage by conduits into the country, is inadmissible, because it requires that arrangements should be previously made with persons who cultivate the soil over very large areas, by which they must bind themselves to receive large supplies of liquid sewage, and to apply it to their land permanently, and with but little possibility of intermission. The Metropolitan Board of Works could not, with any prudence, be recommended to purchase and farm out land to the required extent; and it is probable that, if negociations were opened with proprietors in districts round London, they would rather urge claims for compensation than offer to pay for the aforesaid benefit."

This view of the above-ground system, which is completely erroneous, shows a strange misconception of its character, and assumes propositions which certainly would render it inadmissible, if, as sug-

gested by the referees, "arrangements with persons who cultivate the soil were required to be made, or the Metropolitan Board of Works should be called upon to purchase and farm out land." No idea so unreasonable or impracticable is expressed or referred to in the papers addressed to the referees. On the contrary, those documents show clearly that the main characteristic and chief merit of the system is, that whilst it affords the certain means of carrying the whole of the sewage away to the outfalls in close tubes, and the mains, traversing the country, offer the facility of drawing off the liquid sewage on its passage, and distributing the whole or part of it in service-pipes for irrigation, at any point of the line, if and when wanted;—still the system imposes and requires no condition for using any portion of the sewage for agricultural purposes, and is perfect in itself, as a conduit, for the continual discharge of any quantity of sewage into the sea with great velocity. The sewage would be at all times ready for use, and convenient to be got at, either for irrigation or collection in tanks, or for deodorisation and conversion into solid manure, but there would not, as assumed by the referees, exist any necessity for using it.

It would appear that the referees considered the iron tubular sewer worthy of some attention, for by their letter of the 12th of May (see page 28), they applied to its authors for a description of the mode of construction and estimates of expense. It might have been well if they had expressed an opinion on the proposals submitted to them; but probably their time did not admit of their investigating a plan, which, from its novelty and character, required, if examined at all, a careful and minute examination of the details.

Under these circumstances, the authors of the plan consider they owe it to themselves to make it known; and they feel convinced that the more it is examined and canvassed, the more correctly it will be appreciated, and if it possess the merit, as they believe, of affording the means of *overcoming the discharge difficulty*, it will ultimately be adopted.

In order to show the capabilities of the above-ground tubular sewer, and the remedy it supplies for the difficulties in the way of a perfect system of main drainage, it may not be out of place to call attention to the requirements and conditions of such a system, as applied to the metropolis, on the authority of the Government referees.

In their Report it is laid down:—

1. That "the scheme of drainage must relieve the low lying districts from floods, and from the evils attendant upon a tide-locked drainage."

2. That "artificial means for raising the sewage must be resorted to for the low level districts, because its removal by gravitation is only possible by retaining the present system, in which the sewage flows through tidal outfalls; but this necessitates its being discharged into the river at low water, and is therefore incompatible with the purification of the river."
3. That "for the application of sewage to economical purposes, an outfall channel along each bank of the Thames would admit of more extensive application, and would offer greater advantages than the concentration of the whole in one stream."
4. That "the sewage of a large area (from the high level districts) should flow by gravitation from outfall sewers at the river Lea in the north, and the Ravensbourne on the south of the Thames, to collecting channels commencing near Barking on the north, and near Woolwich on the south side."
5. That from the collecting channels "the sewage should flow into main outfall channels."
6. That "to prevent impediments to the flow of the sewage in the line of the main outfall sewer, the heavier and more solid matters should be separated in some convenient place, and be removed before entering the main outfall channels."
7. That the sewage being collected in outfall channels, "private enterprise, under proper control, should be at liberty to utilise it."
8. That "when not required for purposes of utilisation, the outfall channels should provide for the flow of the sewage in the most expeditious manner into the sea."
9. That "the best outfall to the sea, on the north side, is in Sea Reach; and the best outfall on the south side, is in the Lower Hope."
10. That a complete system of irrigation with liquid manure would require provision to be made for "the sewage being placed in the river, at some unquestionable point, where not required for irrigation."
11. That "it would be very inexpedient to provide for conveying to distant points large amounts of storm-water, in addition to the sewage, because it would involve not only mechanical difficulties, but very large and expensive engineering works."

These are the conditions prescribed by the referees for a perfect system of main drainage of the metropolis; and it must be admitted that they afford satisfactory evidence of the great care and ability

with which these gentlemen have conducted their investigations. They constitute in fact the principles on which alone a sound and practicable system of metropolitan drainage can be founded. By a perusal of the following pages, it will be seen that those identical conditions are laid down in the proposal to the referees for the adoption of the above-ground sewer system; and that, by a remarkable coincidence, as explained further on, the sites of the heads of the outfall channels, and their outfalls or points of discharge into the sea, selected for that system, are the same as those adopted for the plan of the referees, and recommended by them as "the best that can be found."

The difference between the two plans is in the nature of the outfall conduits, and the mode of discharge. One provides open channels, with an inclination of six inches to the mile, which will discharge the sewage by gravitation from reservoirs, in which it will be largely diluted with tidal water from the Thames to increase the volume; the other provides above-ground discharging mains, with a proper gradient for velocity of flow, the sewage being lifted by pumping to the head of the main.

Replace the tidal diluting reservoirs, by collecting reservoirs, to receive the sewage from the high-level collecting conduits by gravitation; provide for the discharge of the overflow of storm-water, from the collecting reservoirs into the Thames, below the metropolitan area; substitute close above-ground tubular discharging mains, from which no effluvia can escape, for open tidal ditches; establish pumping engines to lift the sewage from the low level outfalls into the collecting reservoirs, and to lift the whole body of sewage from the latter to the heads of the above-ground mains, and the arrangements are complete, in accordance with the principles laid down by the referees, all the requirements of the report will be fulfilled.

In considering the adoption of the above-ground plan, two questions have to be examined:—

1. Adaptability, strength, and permanency of the discharging main as a structure.
3. Certainty and expense of lifting.

As to the first, the statements in this publication are referred to. The construction and actual working of a specimen sewer, of the same diameter as the main intended to be used in practice, as proposed to the referees on the 6th June (see page 36), will afford a satisfactory solution to this question.

The second question rests entirely upon the practicability of lifting the sewage into the main, on a plan which shall guarantee its continuous working without derangement. No particular description

of machinery is proposed. That best adapted to the work will be used. Pumping large bodies of water to great altitudes has of late years been brought to such perfection, the mechanical contrivances for that purpose are so complete, and have been so long and so thoroughly tested, and worked with such complete success, that perhaps no branch of mechanical science is reduced to so much certainty in practice, with so little liability to failure.

The vast operations for draining mines, which have to be kept constantly free from great bodies of water, the important pumping establishments of the metropolitan water companies, where a never-ceasing supply, at high levels, must be kept up, are familiar instances of the perfection of mechanical means for lifting fluids. The drainage of the Great Haarlem Lake in Holland is a remarkable example of the confidence, with which the appliances required for lifting enormous bodies of water and fluid mud can be calculated and provided by practical engineers :—"The area of the lake is equal to 45,230 acres, and its average depth about 14 feet, the cubic contents being equal to 800,000,000 of tons of water. Observations, continued during a period of 91 years, shew that the maximum quantity of rain which falls upon the lake amounts to 36,000,000 tons of water monthly,"* consequently 1,200,000 tons per diem, equal to 43,008,000 cubic feet, in addition to about an equal quantity of the contents of the lake, or 86,016,000 cubic feet in all, to be removed in 24 hours. This vast undertaking, of greater magnitude than the drainage of the most important metropolitan district, according to the plan of the referees, was successfully performed by means of three engines of 350 horse power, each of which discharged 63 tons of water per stroke. This shows that no real difficulty exists to prevent the execution of operations of this kind with unerring certainty.

It is admitted by the referees that to remove the sewage and rain-fall of the low level districts, comprising an area of thirty-eight square miles, recourse must be had to artificial means; and in their plan they provide for lifting this great body of fluid, amounting to one-third of the metropolitan drainage, by steam power.

Now, it is precisely this portion of the drainage which forms the real difficulty and source of danger referred to, in the referee's report, if artificial means be relied upon to remove it; for being low level drainage, which cannot, as they admit and lament, flow to its outfall by gravitation, it must be removed by pumping, for otherwise it

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* G. D. Dempsey, Esq., C.E. on the "Drainage of Districts and Lands."

would embarrass the whole system of main drainage, and under certain contingencies, as storm-rainfall at high water, would flood the low level districts, if the lifting arrangements failed to fulfil their object.

It is thus allowed that, for the low level districts, the evils apprehended from the use of artificial means may be effectually guarded against; and yet it is thought that similar means, however efficient, ought not to be relied upon for the higher levels, although in the latter case, in the event of a sudden accumulation from rainfall, or temporary derangement of machinery, the drainage on an emergency could be diverted by gravitation into the Thames below the metropolitan area, for which as distinctly proved in the referees' report, ample and ready means will be provided.

It results from this comparison of the referees arrangements for the low and high level drainage, that in the former case, where danger does exist, provision is made to overcome it by mechanical means, and no difficulty in practice is apprehended; whilst, in the latter case, where there is no danger whatever, mechanical aid is deprecated as being too precarious to be relied upon.

It would appear from the foregoing observations, if well founded, and looking at all the circumstances of the case, that the objections to the use of artificial means, for the metropolitan drainage, have been exaggerated; and it remains to be seen whether the referees' system of discharge by gravitation in open channels, will not create objections of a much more serious character.

The proposed outfall channels will be tidal ditches, in which the stream of sewage can only flow to the outfalls in the sea during ebb tide. Commencing with the flow of the tide and during its rise, the outfalls will be closed, either by flood-gates or by the flow of the tide into the channels* up to the time of high water, when the discharge of sewage will recommence with the ebb. During about five hours every tide, or ten hours in twenty-four, the sewage water in the channels and in the tidal reservoirs, if the former be closed by flood-gates, will be reduced in level, and cease to flow, and during that period the subsidence of the putrescent matters in suspension will rapidly progress. A slimy deposit will be formed at the bottom and sides of the channels and reservoirs, and will go on accumulating like the sewage mud now does in the Thames, constantly tending to choke up the channels. If, on the other hand, the rising tide be allowed to flow freely into the channels from the sea, the sewage will be turned back to the London reservoirs up to the time of high

* The Report gives no explanation on this point.

water. In either case, new quantities of sewage will be discharged into the reservoirs, for which during ten hours in twenty-four there will be no outlet, and the whole body of polluted water, in the reservoirs and channels, will become charged with putrescent matters in a more concentrated state than in the river Thames at the present time.

That this must be the case, not only during the ten hours when the outflow of sewage will cease, but also during the period of its discharge, is obvious, because the dilution in a channel only thirty-seven feet wide, and half the depth of the Thames, with a current at a lower velocity, must be enormously less than in the Thames itself, where dilution with the waters of the whole stream does not prevent offensive and noxious exhalations.

Another objection has to be considered. Will the velocity of the stream in the channels be sufficiently great to remove the sewage of twelve hours, increased in volume by dilution to the extent proposed, during six or seven hours flow each tide? The length of the outfall channels will be about 18 miles each. At the proposed mean velocity of 2 feet 6 inches per second, the stream will flow 1.7 mile per hour, consequently the sewage, at the head of the channels and in the collecting reservoirs, will take ten hours to reach the outfall, but the period of flow will be only six to seven hours. How does this correspond with the degree of velocity, which it is maintained is indispensable for the effectual removal of the sewage? How can this sluggish stream be expected to scour the channels?

The referees' report alludes to the effect of weather upon the difference of level at high water at Sea Reach and Blackwall, which, "in *ordinary* weather" is stated to be two feet. This refers to the prevalence of easterly gales at certain periods, when the flood at the mouth of the river is accelerated and the ebb retarded, so that the usual difference of levels at Sea Reach and Blackwall is disturbed; the tide at the former place instead of being 2 feet lower, rising sometimes, under such circumstances, 2 feet higher than at the latter place, and the difference of the ebb and flow in point of time being also materially altered. It would seem to be inexpedient, not to say hazardous, to allow the discharge of the metropolitan sewage to be dependant upon the state of the tides and the weather—causes beyond human control. A combination of adverse circumstances, by no means improbable, namely, a long continuance of easterly winds at spring tides, might limit the time during which the sewage could flow from the channels into the sea, for so long a period and to so great an extent, as to expose large areas of the metropolitan districts to inundation.

The obstruction to the flow of the sewage which would arise from

an accumulation of gravel, road-sand and other solid matters, has attracted the attention of the referees, who point out the necessity of preventing these bodies being carried into the outfall channels. This objection would be serious in any system where gravitation was relied upon, and any effectual mode of obviating it would be attended with considerable expense. But in removing the sewage by lifting, the ponderous insoluble substances will be separated by their own gravity, and be left behind to be removed when occasion required.

Of the foregoing conclusions, some may prove to be erroneous when the referees have more completely explained the details and working of their plans. For the present there are no elements of calculation but the data furnished in their report.

In the description of the above-ground sewer system, addressed to the referees on the 28th February, 1857 (page 17), it will be seen that all the objections to the gravitation plan here pointed out will be obviated by the adoption of the former. Those to which the above-ground plan is liable, in the opinion of the referees, have been already examined. The practicability and efficiency of the peculiar mode of construction will be set at rest by establishing a specimen sewer, as before explained. As to the pumping operations, it has been shown that no serious doubts can be entertained of the possibility of their being accomplished successfully.

In its architectural character externally the above-ground main would be ornamental, presenting the appearance of an aqueduct, supported on columns, and would be an object rather pleasing than offensive to the eye. Decorative shafts of sufficient altitude would maintain a thorough ventilation.

The question of the expense of lifting remains for inquiry; but it is unnecessary, at the present time, to go into it further than to state that it can be shown that the reduced amount of capital to be expended, the economy in maintenance and repairs, and the revenue to be derived from the sale of sewage water, will not only compensate the expense of lifting, but will render the above-ground plan the cheapest, as well as the best, to overcome the difficulties of the main drainage of the metropolis.

For the general application of the irrigation system, the referees assume that a large previous outlay in preparing the ground is required to be undertaken by the Metropolitan Board of Works. This is a mistaken view—the Board will have nothing to do with arrangements of that kind, which will be made by the owners and occupiers of land, just as ordinary drainage works are executed. The expense of making catch-water meadows, or ridge and channel lands,

or terraced plots, and of under-draining when necessary, will be so much capital to be expended by the landlord for the improvement of his estate.

So far from irrigation with liquid manure being in a theoretical or even an experimental state, as maintained by the referees, it has been in practice for centuries in Lombardy and Belgium, and carried out successfully on a large scale in various part of this country with most profitable results. In combining this mode of manuring lands with the above-ground sewer system, it must be borne in mind that the outlay of capital for lifting, which is usually a half to two-thirds of the expense of the preparatory arrangements, will not fall upon the landlord, as the sewage will be elevated in the main to a level above the ground to be irrigated, and always ready for distribution. This is an important economical feature of the scheme. At one expense, the liquid manure of the metropolis will be elevated to a level, from which it can be delivered by gravitation over a vast extent of agricultural districts.

This is not the place or the time to go into further details on irrigation, but before concluding these introductory remarks, it will be to the purpose to quote the following passages from the report of H. Austin, Esq., C. E., the superintending inspector of the Board of Health, which affords an appropriate commentary on the mistaken opinions of the referees on the use of sewage in agriculture, aswell as on their plan itself, and confirms the view of the advantages of the above-ground sewer as a means of distributing liquid manure.

"That the practical experience obtained during many years at Edinburgh and Milan, has shown the great value of sewer water on grass lands, although applied in a state of great dilution; while valuable experiments have shown the power of soils *to remove from solution, and retain for vegetation, the fertilising elements.*

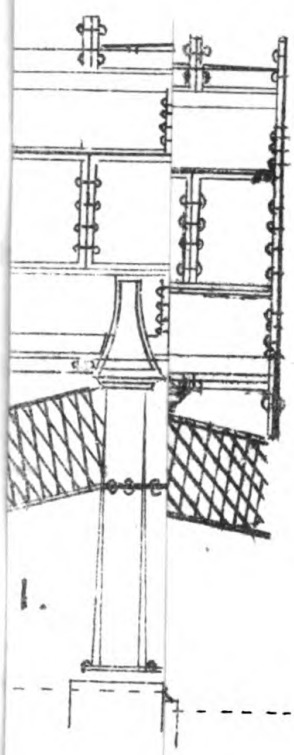
"That although immense agricultural results have been obtained from irrigation with sewage water at Edinburgh, the method employed has given rise to much complaint of nuisance. That this arises, for the most part, from *foul deposits in wide ditches,* and from the large evaporating surfaces of the sewage constantly exposed in the channels of irrigation.

"That all such sources of nuisance and danger are preventible, and should not be tolerated. That no ditches should be used, and that the sewage should be exposed only during the act of irrigation of each portion of the land, where it would be *immediately abstracted and deodorised by the soil.*"

London, August 20, 1857.

C H L

CLA.



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MAIN DRAINAGE.

RICHARDSON AND CLARK'S ABOVE-GROUND SYSTEM.

To Captain DOUGLAS GALTON, R.E., JAMES SIMPSON, Esq., C.E., and THOMAS E. BLACKWELL, Esq., C.E., the Referees of Her Majesty's Government for the examination of the Plans proposed for the Main Drainage of the Metropolis.

GENTLEMEN,—

In submitting to your notice the enclosed description and plans of our system of "Above Ground High Level Drainage," we have, in the first place, to state that it is not our object to propose any plan of works for the arterial and intercepting drainage of the metropolis.

Our attention has been directed to the disposal of the drainage matters, after their delivery at the metropolitan outfall, on a plan calculated to prevent any pollution of the Thames, and render the sewage easily available in a liquid or a solid state for agricultural purposes.

As a mode of attaining these objects in the most efficient way, we offer for your consideration a proposal for disposing of the metropolitan sewage, by means of an aqueduct or above-ground discharging main, from the metropolitan points of outfall to the sea.

Referring to the enclosed description of the plan in question, we will not here enlarge upon its character and advantages, but at once proceed to state our views on its application to the metropolitan drainage.

The plans for the arterial and intercepting drainage works of the metropolis, with the extensions recommended by the government engineer (Capt. Burstal, R.N.) as approved by the Metropolitan Board and the first Commissioner of Her Majesty's works, have been so maturely considered, and are so dependent on natural causes, many of those plans have been so extensively executed, and the whole system so indispensably connects itself with stupendous works already con-

structed, that any modifications that might result from the investigations about to be instituted, under the authority of Government, would probably be limited to minor details; unless the necessity, which appears now to be admitted, of discharging the sewage at a great distance from London, should become a disturbing cause, interfering with the levels of existing sewers and of others in progress or to be constructed.

Any disturbing cause of that nature would create an enormous amount of wasteful expenditure, loss of time, and public inconvenience.

To obviate these evils is our aim, and we therefore propose so to adapt our system to the drainage plans, whatever they may be, when further improved and finally adopted, that it shall be ancillary to those plans and conducive to their better execution, by affording the means of taking up the drainage matters at the metropolitan outfall, and discharging them at any distant places that may be fixed upon.

With that object, we conceive that the adoption of the proposal we have the honour to submit, would not only obviate any difficulty that might exist in carrying out the plans of the Board, but would afford remarkable facilities for rendering them more perfect and their execution more easy.

Should it be adopted in principle, the restoration and maintenance of the purity of the Thames water would cease to be a question for consideration. That point would be settled in the most satisfactory way, for no part of the London sewage would be discharged into the river.

In that case the original plan of the Metropolitan Board, with the points of outfall at B, might be reverted to with advantage. In reviewing that plan, as connected with the intention of discharging the sewage from the outfall reservoirs into the Thames, it was found that, to comply with the act of Paliament, regulating the Metropolitan Drainage, it would be requisite to remove the points of outfall lower down the river to B*. But if the sewage should be carried away to the sea by an above-ground main, the objection which suggested the removal of the points of outfall from B would cease altogether.

It would be premature, at the present time, to propose the precise mode of applying our system to the metropolitan drainage. Its chief merit is its applicability to any circumstances, and we are now mainly desirous to draw attention to the subject, that it may be understood and appreciated.

When called upon, we shall be ready to submit a comprehensive scheme for disposing of the drainage of the districts on both sides of the Thames, with plans and estimates of cost. In the meantime we are able to state, that, for the construction and maintenance of the works on the above-ground plan, considering the many advantages connected with it, the expense will be less than for a subterraneous sewer, whilst the revenue to be derived from the distribution and sale of sewage manure will be much greater.

As an illustration of the mode in which our system may be applied to the metropolitan drainage, after a careful survey of the ground lying between Erith Marshes and the Medway, we are enabled to present a plan for taking up the sewage of the south side of the Thames, at the point of outfall B*, and discharging it into the sea at Yantlet Creek.

The projected line of discharging main would commence at the outfall at B*, at an elevation of 45 to 55 feet above the level of the collecting reservoir. After crossing Erith marshes, it would pass the town of Erith along the bank of the Thames, and from that point would take a direct course to Greenhithe, passing over the river Darent, at an elevation which would not obstruct the navigation. It would be carried in front of Greenhithe, along the bank of the river. From thence it would take a direction parallel to, and on the north side of the North Kent Railway to Northfleet, passing inland behind that town, and under the high road through a cutting, along which the sewer would be carried under the railway, at a point near the windmill, and pass round the town of Gravesend on the south side, still proceeding along a cutting, which would follow the direction of the high road near the cemetery, and south of Windmill Hill. Emerging from this cutting, the aquednct would reach the railway a little to the east of Milton, at a point where it would cross the railway and the canal, at the required elevation. From this point the sewer would be carried over the marshes, as indicated on the plan, until it approached within half a mile of Dagnam, passing from thence through a short cutting to the outfall reservoir near Slough, from which the discharging branch would be carried to the shore, on the west side of Yantlet Creek, and continued on a jetty to the outer edge of the sand, bringing the outfall of the sewer to deep water, at 2 to 3 feet above Trinity high-water mark.

The total length of the aqueduct would be about 23 miles. The inclination would be continuous, averaging 2½ feet per mile; but for the first 5 miles from the head at B* it would be 4 to 5 feet per mile.

By this arrangement, when the body of liquid was much increased by rainfall, the upper part of the sewer being full, the stream, impelled by hydraulic pressure, would flow with great rapidity.*

For a general notion of this line of "above-ground discharging sewer," and of the manner of executing the work, we refer to the enclosed description, and to the annexed sheet of plans and drawings, exhibiting—1st. The line laid down on an ordnance map; 2nd. An elevation showing the arrangement at the pumping station, at the head of the sewer; 3rd. Plan and elevation of a section of the line, at the outfall to the sea; and 4th. A view of the sewer above ground, supported on columns.

We offer this project as an indication of what may be done with the above-ground drainage plan, and for the purpose of rendering it more intelligible. But before leaving the subject, we have to point out that by removing the metropolitan outfall to a point near Deptford, or Woolwich, nearly 3 miles of sewer might be saved, and a better natural fall obtained.

As to the north side of the Thames, by the application of our plan, a discharging main would be carried to the sea in a more direct line than would be possible with a brick sewer, and the distance would be shortened.

For our views on the question, whether it be preferable to adopt two discharging mains, one for each side of the river, or one only for both sides, and for more ample details on the subject generally, we beg to refer to the statement and to the plans and drawings which accompany this letter, and

We have the honour to be, gentlemen,

Your most obedient servants,

(Signed) WM. RICHARDSON.
GEO. CLARK.

5, Ranelagh Grove, Pimlico,
London, 28th February, 1857.

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* In this computation, as in some others, *maximum* data were assumed. From more precise data since obtained, it results that a fall of 18 inches per mile will, with a volume of water filling the tube, give a flow of sufficient velocity to carry off ordinary rainfall as well as sewage. This will reduce the elevation of the head of the main for a length of 23 miles to 35 feet, and sensibly diminish the expense.

MAIN DRAINAGE.

Description of RICHARDSON and CLARK'S System of "Above-Ground High Level Drainage," and of the advantages of an Above-Ground, as compared with an Under-Ground Main Sewer, for the Drainage of the Metropolis.

THE best mode of disposing of large bodies of sewage under safe, sanitary, economical and durable conditions, is one of the absorbing domestic questions of the day. It is for populous districts, next, if not equal in importance, to water supply. The extent to which it interests the inhabitants of the metropolis, it is here unnecessary to point out. Its paramount importance is fully understood and admitted, and the subject has been agitated so effectually by the proceedings of the Metropolitan Board of Works, and other public bodies, as well as by the earnest advocacy of the press, that the attention of the public, the Government, and the Legislature, is fixed upon it, with the determination, in the words of Sir Benjamin Hall, "to arrive at the satisfactory execution of a work of so important a character, from which so much is required."

It is singular that a matter of such importance to the health and comfort of an enlightened population, palpable to the senses and sensations of every individual, forced upon his notice daily and hourly, should not, with a view to the thorough reform of the means and contrivances by which it is regulated, have long ago fallen into the domain of practical science.

It would seem that the engineering views directed to the subject, although some excellent theoretical plans have been propounded, have, in practice, hardly ventured to emerge from the routine of ancient usage.

In the requisite arrangements for the disposal of the sewage and drainage of towns, there is an evident and close analogy to an organised system of water supply. The difference is, that, in the one

case, the pure fluid has to be conveyed, and for that purpose lifted to the highest level of the houses to be supplied; and in the other, the liquids, carrying with them the solids, have to be conveyed to a level lower than that of the houses. In the latter case, the presence of the solids is the distinctive characteristic, which renders some modifications in the arrangements necessary, in order to prevent obstruction in pipes and conduits from the solid matters. For water supply, the fluid having been collected in reservoirs, is distributed first through mains and then through small pipes, finding its own level. But sewage matters are collected first by small drains, and next by intercepting mains, from which they have to be discharged.

Under the last-named circumstances, the presence of the solids changes the conditions of conveyance, by limiting the application of the principle that fluids find their own level. The underground system of drainage works aggravates this evil. It fixes the levels and requires a low point of outfall, thus rendering *the final discharge of the sewage, after collection, the real difficulty to be overcome.*

These considerations have suggested to the undersigned, as a remedy for the "discharge difficulty," the simple method of *lifting the whole body of sewage substances,* in a liquid state, from the lowest level of the intercepting and collecting sewers, to such an elevation, as shall give it a certain, continuous and rapid flow, by gravitation, from the outfall of the district to be drained, to the point of discharge, making ample allowance, in the capacity, internal smoothness, and inclination of the discharging main, to prevent obstruction from the deposit or accumulation of solid matters.

Evidently such a system involves the necessity of establishing collecting reservoirs and pumping apparatus at the head of the main, precisely as at a well-organised establishment of water works.

The principle of lifting sewage no doubt has been suggested by many engineers, and plans have been proposed, and sometimes applied, for raising it by pumping to a higher level, but that method has been had recourse to as an expedient to overcome a local difficulty, or for a temporary purpose. It has not been brought into notice as the grand principle and essential basis of a perfect system of district drainage.

The universal practice of making sewers underground, from time immemorial, has rendered that method so familiar to the mind that it seems to be a foregone conclusion and fixed principle, that sewers must of necessity be subterraneous. In accordance with this settled idea, the numerous plans proposed or suggested for the drainage of

the metropolis, with the exception of a plan* of which it is the object of this statement to give a detailed description, are all based on a system of underground works.

That mode of construction is no doubt recommended by many obvious reasons, such as the ready and convenient fall, for surface and house drainage, resulting from sinking the sewer below the level of the surfaces to be drained, or of the points where the sewage is locally formed or collected,—the protection to the sewers from accident and frost by the masonry or pipes being imbedded in the earth,—the facility of construction, and the prevention of the escape of effluvia to the surface, through fissures or defects in the work, by the superposition of a thick layer of earth.

For collecting and intercepting drains and sewers, the underground system, when the difference of levels offers no serious impediment, is no doubt the best, as for constructive purposes it is the simplest. But when a sewer of large dimensions is to be used as a main conduit, 20 to 50 miles in length, to carry off the sewage of a populous district, covering an immense area, and attended with circumstances presenting innumerable objections, if the old routine be adhered to, a totally different question presents itself; and it may be asked, why, at a time when engineering works know no difficulty, the system of construction must be restricted to the routine of old experience, and a rough and ready method, in which no alteration or improvement has been made since the days of ancient Rome?

As well might the aqueduct still be the sole method in use for supplying towns with water. But in that case science has applied the two principles peculiar to fluids—their tendency to find their own level, and their capability of being lifted by pumping,—to render the supply and distribution of water in quantities proportioned to the consumption, operations simple, easy and sure in execution, remunerative to companies, and satisfactory and economical to consumers.

So in like manner is it the province of science to apply known principles and mechanical means, to render the collection, conveyance, distribution and final disposal of large bodies of sewage, operations as simple, easy and satisfactory, in every point of view, as those for the supply of water.

That desirable object, it is submitted, will be attained by the adoption of a plan similar in principle to that proposed to the Com-

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* Mr. W. Richardson's Memorial to the Commissioners of Sewers in 1852.

missioners of Sewers by Mr. William Richardson, and which it is the present purpose of its authors to bring under notice.

Just as the underground pipe or tunnel system, for the conveyance of water, has superseded the ancient aqueduct, so for the conveyance, distribution and disposal of sewage, reversing the operation, it is proposed to substitute the aqueduct, or above-ground sewer, in place of the subterraneous tunnel, as a discharging main; and to lift the sewage, by pumping, to the head of the aqueduct, to such an elevation, that it will flow by gravitation to its final point of outfall.

This is the essential characteristic of the proposed plan, of which it will be sufficient to give a general notion, in order to explain the mode of its application to the Metropolitan drainage, and point out its advantageous results. A full description of the plan itself, of the construction of the aqueduct or sewer main, and of the works connected with it, accompanied by estimates, plans and drawings, will be produced when required.

The principal feature of the invention is a new adaptation of iron, in combination with other materials, for the construction of tubes or tunnels above, or under ground, and across rivers and canals, either by bridging over, or passing under the water. These tubes, in given lengths, are formed of cast-iron plates, bolted together and strengthened by a peculiar arrangement, which comprises a lining of glazed pottery, forming an inner tube with a space between the two tubes, filled with non-conducting materials as a protection against frost. Every length, thus constructed, becomes, at the same time, an air and water-tight tunnel, and a beam of great strength, calculated, according to its dimensions, to bear any required weight and pressure, internal or external, and also well adapted, by its own rigidity and cohesive strength, to traverse considerable distances without deflection.

The annexed plans will convey a general idea of the mode of construction. Fig. 1 is a side elevation of two lengths of circular tube on a scale of one-eighth of an inch to a foot. It shows the external arrangement of the plates, with flanches bolted together, and a longitudinal rib along the top, also with its flanches bolted together, giving additional strength to the structure. Fig. 2 is a longitudinal section of a segment of tube Fig. 1, on a larger scale, showing the internal arrangement of the parts forming the tube. Fig. 3 is a transverse section of tube Fig. 1, on a scale of a quarter of an inch to a foot, and also an elevation and plan of the columns and saddles forming the supports to each length of tube, when above ground, at or near to its extremities. Fig. 4 shows the mode of connecting the

plates to each other with wrought-iron bolts and nuts. Fig. 5 is an enlarged segment of Fig. 2, showing more clearly the internal details of construction. It also represents part of a top plate with its portion of the rib; (*a a*) is the thickness of the iron plate; (*b b*) is the rib forming part of the casting of the top plate; (*c c*) is the top flanch of the rib; (*d d*) is the inner tube, or lining of glazed pottery; (*e e*) is the space between the two tubes filled with non-conducting materials; (*f f*) is India rubber between the flanches, forming water-tight joints, and an elastic medium to counteract expansion and contraction.

On this plan a main sewer can be constructed, in lengths of tubes fitted up on the spot, and bolted together at their extremities. Tubes may be made of large dimensions, varying from 6 feet to 15 feet diameter. These being properly supported, at suitable distances, with all their parts of corresponding strength, will span over spaces of from 50 to 200 feet. All the parts of the work will be sound and water tight, allowance being made for expansion and contraction. The lining of glazed pottery, by its smoothness, will materially aid and accelerate the flow of the sewage, and, in conjunction with the sufficient and uniform inclination obtained by the high level, at the head of the main, will render obstruction impossible.

It is unnecessary, here, to enter into further details of construction of the tubes. It will be sufficient to point out that this mode of building them on the spot, the parts being, when separate, portable, and, when united, of the required strength, offers obvious advantages, in facility and rapidity of execution, as well as in strength and durability, for drainage works on a large scale, and under the most difficult circumstances.

The tubes, when above ground and under ordinary circumstances, will be in lengths of from 50 to 100 feet, supported by columns and saddles at or near to their extremities; but these lengths may be increased when large spaces are required to be traversed, as in crossing rivers, railways, and valleys. In such cases, additional strength may be given to the work by a rib cast on the top plates, as before mentioned, forming a convex ridge longitudinally to each length of tube as shown in the plan. For works under or on the surface of the ground, or under water, the expense of columns will be saved; the tubes will be laid on a bed of brickwork or concrete.

From this outline description it will be understood, that a sewer on this plan, may be constructed above ground, as a *discharging main*, with any required gradient from the Metropolitan outfall to a distant place of discharge, by elevating the head of the tube, at the former point, to such a height above the level of the discharge outfall, as

shall give a sufficient fall for the continuous and rapid flow of the sewage. The system, moreover, affords great facility for carrying the main discharging conduit at a uniform inclination through cuttings and tunnels, and over or under rivers and valleys, with a degree of precision and rapidity of execution which no other mode of construction admits of. To complete and work the system, provision has to be made for lifting the sewage from the collecting reservoirs at the Metropolitan outfalls, to the head of the discharging mains. This operation, however, will be no innovation on the plan of the Metropolitan Board, which proposes to pump up the sewage from the collecting reservoirs, in order to discharge it at once into the Thames, the only difference being that the sewage will have to be lifted to a higher level. With the addition, therefore, of the engine power required by the increase of elevation, the general arrangement, substituting the delivery of the sewage into the above-ground mains, for its discharge into the Thames, will practically be the same.

In the event of the above-ground plan being applied as an accessory to the Metropolitan drainage, it is proposed to adopt the arrangements of the Board of Works, as modified by their engineer, in accordance with Captain Burstal's report, or as they may be finally settled on the report of the Government referees.

These final arrangements* would, in fact, be maintained in their entirety, and carried out, without any alteration, to the Metropolitan points of outfall. At these points, wherever fixed, the head works of the above-ground discharging mains would be established, and the sewage, instead of being pumped into the river, would be lifted into the mouth of the discharging mains, through which it would flow into the sea.

But, in its passage through the mains, the sewage may be drawn off for agricultural purposes along the line of country traversed, being at all times available for irrigation in its liquid state, or for conversion into solid manure, for both of which operations the high level offers great facility, as will be hereafter more fully explained.

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* These final arrangements refer to the arterial and intercepting sewers, and the discharge of the sewage into the collecting reservoirs near London. Adopting the principles laid down by the referees, the above-ground system would take up the sewage "on the south side in the marshes close to Woolwich, and on the north side near Barking." At these points, the head pumping stations would be established, and the sewage, instead of flowing into open channels, would be lifted to the head of the above-ground tubular mains, and carried away to the sea.

Thus not only will the river be preserved entirely from pollution by the London drainage, but the sewage and the land drainage waters of districts below the London radius, on both banks, may at a small expense be pumped up into the mains, to be used, in like manner, for irrigating and manuring lands, or conveyance to the sea.

The above-ground system, in its full development, if applied to the Metropolis, would comprise a main on each side of the river, to pick up the drainage of the north and south districts at the points of outfall fixed by the Board of Works: and if so carried out, would obviate any disturbance to or interference with the system of arterial and intercepting drainage, which forms the basis of existing works, and of those in progress or projected; and consequently would render it much more easy, and much less expensive, to adapt any new sewers, to be constructed, to those already formed, or in the course of execution.

But if, for any reason, it should be considered preferable to convey the Metropolitan drainage to the sea by one conduit only, on the north or south side, commencing at any point between London and Erith, or even lower down, this will become an operation easy of execution, by constructing a tunnel under the river, on Mr. Richardson's tubular plan, the expense of which will be much less than any other mode of accomplishing the same object. Should the plan of establishing a discharging conduit on one side of the Thames, for the districts on both sides, be decided upon, there are, perhaps, reasons for giving the preference to the south. It might be more convenient to run the drainage under the Thames from north to south than the reverse, and it has been ascertained, from a careful survey, that a favourable point of outfall can be established at Yantlet Creek. As regards the north side, an excellent site may be obtained at a point below Southend Pier. At either of these places, ground conveniently situated, and at a suitable elevation above high-water mark, can be obtained for the construction of reservoirs and other works that may be wanted at the outfall, of sufficient area for the sewage of one or both sides of the river.

It would be premature, at present, to determine the question of one or two outfalls to the sea, but it will not be out of place to remark that the value of the sewage for agricultural purposes, and the great facility and small expense with which it can be distributed from the above ground main, in a liquid state, without the expensive process and nuisance of deodorisation, will no doubt be considered powerful inducements by owners and occupiers of land, on both sides, to retain these advantages, and not to allow the manuring wealth of one side of the Thames to be diverted from its natural chanels, to fertilise the lands on the other.

The advantages of the above-ground system of drainage, if applied to the Metropolis, in accordance with our views, may be enumerated as follows:—

1. The whole drainage of the metropolitan districts will discharge itself into one outfall reservoir for the north, and one for the south side.
2. The best site will be chosen for the outfall reservoirs, without reference to their immediate vicinity to the river, a circumstance which, to a great extent, must govern this question, if the sewage has to be discharged into the Thames. A greater latitude, in the choice of the site, may remove many difficulties with reference to the level for the outfall, the character and position of the soil for the formation of reservoirs, and the best points of convergence for the intercepting sewers.
3. The outfalls for the Metropolis will, in fact, be collecting reservoirs, from which the sewage in a liquid state will be pumped up and delivered into the mouth of the discharging main continuously, as it reaches the reservoirs.
4. The outfalls being independent of tides, the constant flow of the sewage will prevent its collection and decomposition in a stagnant state in the sewers.
5. The sewers being no longer subject to be tide-locked or pond-locked, will be effectually scoured and cleansed by rain-fall and flushing from the water-mains. The foul vapours forming malaria fatal to life, will not be driven up the drains and gulleys into the streets and houses, which now is the case, and must always occur, when from the flow of the sewage and the current of air being checked at the mouth of the sewers, noxious gases are generated and pent up within them.
6. There will be no collection or accumulation of stagnant sewage at the metropolitan outfalls, nor any formation of deposit by subsidence, for the whole mass will be in a constant state of agitation, and as it flows into the collecting reservoirs, will be at once discharged by pumping up into the main, and carried away.
7. The mechanical arrangements to lift the metropolitan sewage to the head of the main, will be of the simplest character, consisting of only one pumping station at each outfall.

8. As the height of the stand pipe and the engine power may be fixed so as to regulate the lift of the sewage to any given elevation, the head of the discharging main may be placed at the level required to obtain a sufficient and uniform fall, and insure a continuous and rapid flow by gravitation to the discharge outfall at the sea. As this point will be above high water mark, the flow will be constant during the twenty-four hours, without reference to the tide.
9. Great facility will be afforded for draining the towns and districts along the line of the main, by local collecting reservoirs and pumping stations, to lift the sewage into the main. The Thames will thus be freed from pollution, not only within the London radius, but far below Erith and Gravesend, both on the Kent and Essex sides.
10. The peculiar mode of construction adopted comprises the elements of strength, durability, facility of execution, and adaptability to the requirements of the undertaking.
11. The nature of the works and the mode of construction, *above ground*, guarantee their sound condition when executed, and offer the certain means of their being constantly maintained in that state, owing to the facility with which every part of the works can be inspected and got at, at any time, externally as well as internally, during their execution and afterwards.
12. The immediate detection and prevention of leakage or obstruction, and the facility afforded for executing repairs by changing plates, and introducing, when requisite, diverting branches without interrupting the flow of sewage, are obvious and peculiar advantages of the above-ground plan.

The importance of the advantages Nos. 11 and 12 will become apparent, by comparison with the difficulties inherent to the existing system of underground sewers, of which the sound construction, at the time of their execution, can hardly be insured with the most vigilant supervision, or the condition afterwards be known, or tested, without enormous expense. The leakage from ordinary sewers is immense; its evil consequences, in poisoning wells and springs, and causing noxious miasma to be emitted from the adjacent soil, are incalculable.

Nor is it, in practice, possible to guard completely against these evils, which, concealed under the soil, arise and go on increasing,

unseen and unknown, to an intolerable degree; and, when discovered, can never be entirely remedied. The deplorable condition of many railway tunnels from leakage, caused by the external pressure of water, is well known. The percolation arises from the unsound condition of the brickwork, or the bad quality of the materials. The defect is visible, but the cure impossible, without taking down and re-building the tunnel. With a brick sewer tunnel the consequences of defective execution are much more serious, for the pressure of the fluid being from the inside of a cylinder, it tends to enlarge any fissures or faults in the work, which in the former case, the pressure being external, tends to close.*

With underground brick sewers the examination of the external condition of the work, above and below the tunnel, in all its length, the discovery of leakage, and the execution of repairs, are operations of vast difficulty and expense; indeed, their execution, in a perfectly efficient way, is impracticable. With above-ground sewers, on the plan proposed, these operations may be performed readily and efficiently whenever required.

In addition to the points above enumerated, not the least of the advantages which will result from the use of an above-ground discharging sewer passing over agricultural districts, is the obvious facility, already adverted to, which it will afford for employing the sewage as liquid manure.

The fertilising properties of sewage water are too well known to require many observations here. Throughout Belgium, and in many parts of Lombardy, it is the real cause of the extraordinary crops obtained in the most productive districts of those countries. In the former, the liquid manure cart may be seen traversing the fields at the proper seasons, and distributing the precious fluid, on which the Belgium farmer mainly depends for a good harvest. The experience of ages has taught him that manure is most effective in the liquid state. He collects, in a tank, his stable and farm-yard sweepings and night soil, and adds the proper quantity of water to reduce it to the strength which suits the land. Many agricultural chemists are of opinion, that even guano would be most profitably employed in a liquid state.

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* It is reported at paragraph 240 of "The Public Health Acts," by C. W. Johnson, Esq., Chairman of the Croydon Local Board of Health, that in the experiments made on the drainage of a block of 1,200 houses in Earl Street, on Lord Portman's estate, "about one-eighth of the water consumed in the houses was lost by filtration through the permeable brick house drains."

Sewage is liquid manure ready for use. If streams of that valuable fluid, amounting in twenty-four hours to twelve millions of cubic feet, which is the estimated quantity of the London sewage, and, it has been calculated, is equal in volume to the Thames at Kingston, were carried over the country, at a level and with arrangements convenient for distribution, some idea may be formed of the newly-created agricultural wealth, of which it would be the source—wealth now wasted and cast into the Thames to contaminate the water consumed by the inhabitants of the Metropolis.

Solid manure, obtained from sewage, no doubt has its value, but it has not yet been proved that it can be produced at a price which will remunerate the manufacturer; and, whatever may be said in favour of the process of conversion from the liquid to the solid state, it cannot be carried out without an enormous loss of the fertilising principle, ammonia, a volatile salt, which escapes in manipulation in a gaseous form or combined with water, in large quantities, whatever precaution may be taken. However that may be, the sewage could be drawn off at any point of the line, either for irrigation in its liquid state, or for conversion into solid manure.

Service pipes might branch off from various points of the main, and deliver the sewage water to the distance of two or three miles on both sides, with ease and regularity, at a moderate charge remunerative to all parties. The area that might thus be manured would be about 4,000 acres to a mile of sewer.

The vast importance of the question here propounded, and the extraordinary results which may be produced by a comprehensive and well organized scheme of above-ground drainage, cannot be better shown than by the following description of the improved value of the "Edinburgh meadows," by irrigation with sewage water, extracted from the useful work of G. D. Dempsey, Esq., C.E., "On the Drainage of Towns and Buildings."

"The practical result of this application of sewage water is, that land which let formerly at from 40s. to £6 per Scotch acre, is now let annually at from £30 to £40; and that sandy land on the sea shore, which might be worth 2s. 6d. per acre, lets at the annual rent of from £15 to £20."

"Although the system is irregular, and the arrangement very imperfect, the effect of the sewage water is astonishing; the meadows produce crops of grass not to be equalled, being cut from 4 to 6 times

a year, and producing from £24 to £30 per acre, one meadow even as high as £57 per acre."

W. RICHARDSON,
GEO. CLARK.

5, Ranelagh Grove, Pimlico,
London, Feb. 28th, 1857.

29, GREAT GEORGE STREET, WESTMINSTER,
May 12*th*, 1857.

MAIN DRAINAGE.—METROPOLIS.

GENTLEMEN,—I am instructed to write and inquire, with reference to some passages in your communication to the referees, dated February 28th, if you could kindly draw up a short statement, to prove that "the expense of conveying the sewage from the north to the south," in the manner proposed by you, "in an iron tunnel," will be "much less than that of any other mode of accomplishing the same object."

I am also directed to ask for a detailed account of the estimated expense of your "above-ground main sewer."

I am, Gentlemen, your obedient servant,
HERBERT C. SAUNDERS.

Messrs. Richardson and Clark,
Pimlico.

DESCRIPTION, PLANS AND ESTIMATES OF AN IRON TUNNEL SEWER UNDER THE THAMES, AND ESTIMATED EXPENSE OF AN ABOVE-GROUND MAIN.

To Captain DOUGLAS GALTON, R.E., JAMES SIMPSON, Esq., C.E., and THOMAS E. BLACKWELL, Esq., C.E., the Referees of Her Majesty's Government for the examination of the Plans proposed for the Main Drainage of the Metropolis.

GENTLEMEN,—

In compliance with your request, we have the honour to lay before you the following statement relative to the expense of conveying the London sewage from the north to the south side of the Thames.

In comparing the economy of our plan, for conveying the London drainage under the river, with that of other plans for effecting the

same object, it is to be understood that the circumstances in the two cases are assumed to be similar—that is to say, the point at which the Thames is to be crossed being determined, the question is, the construction of a main sewer under the bed of the river, the work to be of a solid and durable character, and adequate to the requirements of the case.

In this comparison, we dismiss from consideration the operation of tunnelling through the ground under the river, as one which, if attempted, would be attended with so much difficulty and so much uncertainty both of expense and success, as to be, in a practical as well as economical point of view, out of the question.

We consider the only safe mode of constructing a main sewer under the Thames is to carry on the work in an open cutting through its bed, by forming cofferdams in small sections, removable successively as the work proceeds, and not occupying more than 30 or 40 yards across the stream, at any one time during the progress of the works, offering, therefore, no serious obstruction to the navigation.

That mode of working being adopted, our proposition would be to lay down a tube of cast-iron segments, bolted together on the system described in our statement of 28th February last, cased outside and lined inside with a brick cylinder.

Commencing at either bank of the river, a cofferdam would be made, in which a section of the work would be executed, and so on by successive sections the sewer would be completed.

The annexed transverse section, Fig. 6, shows the details of construction of a sewer on our plan, 14 feet internal diameter, which probably is a capacity sufficient to convey the northern drainage to the south side. (*a*) is a body of concrete, 2 feet thick, under and around the outer brick cylinder; (*b*) is a foundation of beech planks, also encircling the outer brick cylinder; (*c*) is the external brick cylinder; (*d*) is the cast-iron tube, formed of segments bolted together; (*e*) is the asphalte lining to the iron tube; (*f*) is the inner cylinder of blue vitrified bricks; (*g*) is the inside of the sewer, 14 feet diameter; (*h*) represents a group of piles in four or five tiers tied together, forming bearings to the sewer at determined distances. The iron tube being laid inside the outer brick cylinder, and lined by the inner one, the flanches, some inside and some outside of the plates, will be built into the masonry of the outer and inner cylinders respectively, bonding the iron with both. The upper half of the outer circle might for greater security be in granite dressed smooth, which, affording no hold to ships' anchors, would more effectually protect the work from

damage. The solid nature of the combined structure obviates the necessity of sinking the sewer much below the bed of the river. Five feet of clay puddle above the crown of the arch is allowed as a sufficient protection; indeed, if the top of the sewer were bare, it would suffer no injury from anchors dragging over it.

The work, when completed, will form an unbroken continuity of cohesion the whole length of the structure, the iron tube constituting an inflexible core to the outer cylinder, and a protective shell or shield to the inner cylinder, which forms the sewer.

An important advantage, obviously, of this continuity of cohesive strength, is the equal bearing of the structure on the foundation, and the capability of considerable lengths being supported on bearings at their extremities. Thus any partial defect or sinking in the foundation, which might be fatal to a sewer of masonry, by causing fracture, for want of sufficient cohesive strength in the materials and parts, would not be a like cause of danger to the iron-cased and iron-bound tunnel. Additional security might be given to the latter by driving sets of piles into the bed of the foundation, 50 to 60 feet apart, in the manner shewn in the plan. These forming bearings, on which such lengths might be supported without any intermediate foundation, would be a guarantee against damage from the settlement of the ground. We do not consider this precaution necessary, but it might be desirable to apply it in a case, where the work being of so important a nature, and an accident might be attended with serious consequences, no reasonable source of security ought to be disregarded.

According to the estimates we have framed, we find the expense of a main sewer under the Thames on our system would be £360 per yard forward, of which £280 would be for the coffer-dams, and £80 for the sewer and its foundation. The total expense of the work complete will depend upon the depth and width of the river at the point, where the sub-fluvial sewer is to be constructed.

Your inquiry having directed our attention more particularly to the conveyance of the sewage from the north to the south of the Thames, we have, in preparing our estimate, had to fix upon a supposed point of crossing in accordance with that proposition, and also to consider the modifications the general plan might have to undergo, in the event of the above-ground system being adopted, on the same basis.

To explain our views, we annex an Ordnance map, on which the blue lines indicate the extensions and branches suggested, to connect

the drainage system of North London with the proposed above-ground sewer from Erith to Yantlet Creek, suggested in our letter of the 28th February last.

The outlet of the extension of the high-level sewer at Four Mills, West Ham Marsh, proposed by the engineer of the Metropolitan Board, appears to be the most eligible point of outfall for discharging the northern drainage into an above-ground connecting branch, which, as shewn on the map, might be carried from that point to the Thames, and thence to the discharging main on the south side, in the direction of one or the other of the following lines :—

1. Between the river Lea and the Woolwich Railway, or crossing the latter to the upper part of Bugsby's Reach, a little below Bow Creek.
2. Across Plaistow level to Woolwich Reach, and thence to Woolwich or Charlton.
3. Across the Plaistow and East Ham levels to Gallion's Reach, and thence in a direct line over Plumstead and Erith Marshes to the south point of outfall of the Metropolitan Board at B *.
4. In a direction nearly due east over Barking Creek to Barking Reach, and thence to B *, on the south side.

At or near to the lines of intersection, shown on the map, the width of the river at Trinity high-water level, and the depths at low water, 17 feet 10 inches below Trinity mark, are as follows, commencing from the Kent side :—

Bugsby's Reach.			Woolwich Reach.		
feet	ft.	ins.	feet	ft.	ins.
150.....	0	0	150.....	0	0
100.....	15	0	250.....	15	0
200.....	11	0	300.....	13	0
100.....	15	0	300.....	12	0
100.....	17	0	450.....	9	0
180	16	0	370.....	0	0
50.....	15	0			
400.....	9	0			
150.....	0	0			
1,430			1,820		

Gallion's Reach.			Barking Reach.		
feet	ft.	ins.	feet	ft.	ins.
250.....	0	0	280.....	0	0
100.....	7	6	220.....	5	6
100.....	16	6	200.....	12	0
100.....	23	0	400.....	15	0
100.....	21	0	600.....	10	0
200.....	18	0	420.....	9	0
210.....	23	0	150.....	0	0
100.....	18	0			
500.....	9	0			
150.....	0	0			
1,810			2,270		

For the construction of a sewer under the Thames, the nature of the soil of the bed of the river and the soundings and currents, for which a special survey is required, might in some measure determine the choice of the precise spot; but we do not consider there would be any absolute obstruction to the execution of our plan, at any point within the limits marked on the map. The question would be one of expense.

The same cannot be said of a brick sewer, for which the nature of the foundation and the depth to which the work might have to be carried, are more serious considerations.

So far as we are able to judge from the general plan of the Metropolitan Board of Works, the second line, intersecting the river a little above Charlton Pier, would be preferable to the others, the width of the stream and the depths, in deep water, being there the least, and the line the most direct; but for a connecting branch, on the north side, the Victoria Docks interpose an obstruction, which can only be overcome, in a direct line, by a syphon sewer under the docks and the river, exceeding a mile in length.

The first line, therefore, crossing the N. W. end of Bugsby's Reach, is suggested as that where the sub-fluvial sewer may be constructed. To this point the northern connecting branch might be brought from the outfall sewer at Four Mills, and extended to Greenwich Marsh, which would afford an excellent site for the central station of the above-ground drainage system, where the head of the main discharging sewer, the collecting reservoir and pumping engines, would be established.

The length of the line, intersecting the stream at Bugsby's Reach at high water, is stated to be 1,430 feet, or 443 yards; but as that is an average width, and we are unable to fix the exact point which might be selected, we calculate the dam and tunnel work under the river as for a maximum length of 550 yards, which at our estimated price before stated, of £380 per yard forward, will amount to £198,000

We allow 100 yards on each side of the river for the approaches to connect the tunnel with the above-ground sewer, and we estimate this expense at 20,000

Total estimated expense of the sewer under the Thames £218,000

(The use of granite for the upper half of the outer cylinder is not included in this estimate.)

The northern sewage delivered from the high-level outfall sewer at Four Mills, at a level of 9 feet 6 inches above Trinity high-water mark, might, if the proposed sewer under the Thames were used as a syphon, be discharged into the reservoir at Greenwich Marsh, above the Trinity level, without pumping.

If the syphon system should be adopted, and indeed under any circumstances, it might be desirable to construct two smaller tunnels (10 feet diameter), containing together the same area as the larger one (14 feet) already proposed. As a rule, the two sewers would be worked simultaneously, but occasionally, and at periods when one would be sufficient for the service, they might be alternately examined and cleansed. The sound state of the structure could be at any time ascertainable, and obstruction of the channels effectually guarded against. The construction of a double sewer, on our system, would add comparatively little to the expense, and tend to give greater strength to the work. The same cannot be said with equal confidence on either of those points with regard to a brick sewer.

The length of an above-ground main sewer, taking this direction, would be the shortest. From Four Mills to the central station in Greenwich Marsh the distance would not exceed 3 miles, and the distance from the station, following the course indicated on the map, to Greenhithe and Yantlet Creek would be 29 miles, making the total length 32 miles.

Our estimated expense of an above-ground main sewer of 12 feet

diameter is £85,000 per mile, at which rate 32 miles would amount to	£2,720,000
To which adding the estimated expense of the sub-fluvial sewer already stated at	218,000
The total expense would be	£2,938,000

In these estimates, reservoirs, engines, and station buildings are not included.

Until the advantages of the above-ground system, for the purposes of irrigation with liquid manure and drainage of marsh land, developed themselves, the terminus of the line might be fixed a few miles below Gravesend, with an outfall into the Lower Hope. About 10 miles of sewer would be saved, and the total expense reduced below two millions.

No doubt, adopting the same line in an opposite direction for a sewer under the Thames at Bugsby's Reach, the sewage of the south might be conveyed to the north side, where a convenient site for the central station may be found in Plaistow level, from which point the Metropolitan drainage might be discharged into the sea by an above-ground main sewer. But the length of the line would be increased 10 or 12 miles,* (as compared with a main to Yantlet Creek on the south side) and the country to be traversed would not offer the same facilities, as the south line, for the execution of the works; whilst, on the other hand, the drainage of Gravesend and other places south of the river would not be diverted from the Thames.

It only remains for us to institute a comparison between the expense of an iron and a brick tunnel under the Thames. In order to do this, with precision, we have divided our estimate of the former into two parts, the cofferdam and the tunnel works, the one being £280, the other £80 per yard forward. With reference to the first price, provision is made in the estimates for constructing cofferdams of great strength, 50 feet long and 33 feet wide inside. The external diameter of the sewer regulates the width of the dam, and the number and length of the piles, as well as the dimensions of the strutts, walings, ties, and bolts, and all the arrangements necessary to give

* This supposes an outfall into the German Ocean below Southend. It will be seen in our letter to the referees, dated the 5th July (p. 37), that Sea Reach, the point adopted by the referees, was proposed by us as the outfall on the north side.—R. and C.

strength to this important part of the preparatory works, on the proper construction of which the solidity and durability of the sewer, to be built within the dam, mainly depends.

The external diameter of our 14-feet iron sewer, including a bed of concrete, is 22 feet. That of a 14-feet brick sewer, allowing for sufficient strength, with a bed of concrete, cannot be less than 28 to 30 feet. The number and length of the piles, therefore, and all the timber and iron work, and the labour and expenses of constructing the dam, must be increased in the ratio of its increased dimensions.

The total amount of this increase, in the expense of the cofferdams, we consider will not be less than one-third the estimate for our work.

With reference to the sewer, without entering into the details of an estimate of a brick sewer, when we take into account the quantity of earth-work, which will be nearly double, the great increase of strength required for the foundation, and the large amount and superior quality of the brick-work required to insure the solidity of the structure, we have no hesitation in expressing our opinion, that the expense will be one-half more than that of an iron tunnel on our plan.

We have previously referred to the probability and fatal results of accidents in a ponderous structure of this kind under the bed of the river. The necessity of building it in short sections adds to the danger, by increasing the liability of unequal settlement of the foundation—an inconvenience, from which the iron tube is protected by the peculiar rigidity and cohesive strength of its structure.

There is no doubt that a brick tunnel might be made under the Thames, combining the requisite conditions of strength and durability, but, to obtain perfect security, it would be necessary to adopt extraordinary precautions in the foundation, and descend a great depth below the bed of the river, which precisely would be causes of an immense increase of expense.

We enclose a detailed account of the estimated expense of an above-ground main sewer on our system, and have the honour to be,

Gentlemen,

Your most obedient servants,

WM. RICHARDSON,
GEORGE CLARK.

5, Ranelagh Grove, Pimlico,
London, 30th May, 1857.

PROPOSED CONSTRUCTION OF A SPECIMEN ABOVE-GROUND TUBULAR SEWER.

On the 6th of June, Messrs. Richardson and Clark addressed a letter to the referees, suggesting the expediency of having a specimen of their "above-ground tubular sewer" constructed on the scale proposed for its application to the metropolitan drainage, in order to demonstrate the permanent character and stability of the work, to prove its strength to resist external and internal pressure, and also, by actual experiment, to show its adaptability, as a main, for the double purpose of distributing the London sewage for irrigation and discharging the residue, or the whole, if not so distributed, into the sea, above high water. In reply, the following letter was received :—

29, Great George Street, Westminster, S.W.
June 10*th*, 1857.

Main Drainage.—Metropolis.

Gentlemen,

I am instructed, in reply to your letter, 6th instant, which has been submitted to the referees, to inform you, that it is not in their power, even if it were thought desirable, to adopt your suggestion, and have a portion of above-ground iron sewer constructed according to your plan, by way of experiment. I am further directed to remind you that the instructions of the referees are to report to the first Commissioner of Her Majesty's Works, &c., within the present or the ensuing month, which would quite preclude their entertaining any suggestion such as that contained in your letter.

I have the honour to be,
Gentlemen,
Your obedient servant,
HERBERT C. SAUNDERS.

Messrs. Richardson and Clark, Pimlico.

Proposals addressed to the Government Referees to establish two Above-ground Discharging Mains, one North, one South of the Thames, with a great reduction of expense.

To Captain Douglas Galton, R.E.; James Simpson, Esq. C.E.; and Thomas E. Blackwell, Esq., C.E.

Gentlemen,

In the communications we have had the honour of addressing to you, we gave a plan and estimate of an above-ground main sewer, calculated to carry the whole of the London Drainage to the sea.

The estimated expense, including a tunnel under the Thames, was about £3,000,000, with an outfall at Yantlet Creek, and about £2,000,000, with an outfall three miles below Gravesend;* the discharge level in both cases, to be two feet above Trinity high-water mark.

These estimates refer to the hypothesis of one line of sewer being adopted for the drainage of both sides of the river; but we stated that "the above-ground system, in its full development, would comprise a main on each side of the river;" and we expressed our opinion, "that the owners and occupiers of land on either side of the Thames would not allow the manuring wealth of one side to be diverted from its natural channel to fertilise the lands on the other side."

Having since directed our attention particularly to the application of liquid sewage to agricultnral purposes, impressed with the conviction, that that mode of disposing of the London sewage is a question of far greater importance, for national and private interests, than the cheapest mode of discharging it into the sea, we beg to offer the following considerations to your notice.

The dimensions of a sewer calculated to carry off the Metropolitan drainage of both sides of the Thames must be in proportion to the quantity of sewage to be discharged. From data supplied by various reports, we assumed that, on our system, a circular tube of twelve feet diameter afforded the required area; and we framed our estimate of the expense, amounting to £85,000 per mile on the basis of that diameter.

* Higham Creek, the point designated by the referees as the best outfall on the south side.

But, if separate above-ground sewers be constructed for the two Metropolitan districts, north and south of the Thames, and provision be made for the overflow of the occasional excess of storm-waters, from collecting reservoirs into the river (which offers no difficulty), the area required for these sewers would be considerably less.

The diameter, considering the continuous and rapid flow with a sufficient inclination, obtainable by the above-ground plan, might be, instead of twelve feet, only eight feet, or even less; and the expense reduced about one-third. The whole expense of a tunnel under the Thames, and of the north and south connecting branch would be saved.

Taking these reductions into account, the expense of an above-ground sewer on the north side, from West Ham Marsh to Sea Reach,* being a distance of 20 miles, may be estimated at - -	£1,200,000
And on the south side, from Greenwich Marsh to a point 3 miles below Gravesend,* being a distance of 22 miles, at - - - - -	1,300,000
Together - - - -	£2,500,000

Thus, with an expenditure of two and a half millions, which may be taken as a maximum estimate, north and south London would be provided each with a perfect system of drainage, with out-falls below Gravesend, at a level above high-water mark; and every facility would be afforded for using the sewage to enrich the lands on both sides of the river.

The London drainage question would be disposed of in a way to satisfy all parties interested, and the advantages to be derived, from applying the sewage of towns to agricultural districts, would be fairly tested. If the results corresponded to the success already obtained in some parts of England and Scotland, and in other countries, of which there can be no reasonable doubt, such would be the increase of the value of the lands in Essex and Kent, irrigated with liquid sewage, that the lines of sewer, on each side of the Thames respectively, would be soon extended to the German Ocean and Yantlet Creek, at the expense of the districts, over which those extensions would pass; for the land owners and occupiers would be only too glad to contribute their quota of the capital required.

* These outfalls are adopted by the referees.

Under the arrangement now suggested, there would be some advantages in establishing the heads of the above-ground discharging sewers at B* of the Metropolitan Board of Works (at Rainham Creek and Erith Marsh). The overflow of storm waters into the Thames, at these points, would be free from objection, as the portion of sewage they might contain during a few hours of rainfall would be so diluted as to afford no reasonable ground of complaint to the inhabitants of the districts up and down the river.

An efficient and self-acting plan for carrying off the excess of rainfall being adopted, the capacity of the above-ground sewers for the discharge of *sewage waters*, properly so called, might be reduced probably to six feet diameter, with a corresponding reduction of the expense. Supposing the points of outfall, as above suggested, to be at or near to Sea Reach, the united length of the two above-ground dischargimg sewers, north and south, commencing at points B*, would be about 26 miles, and the total expense would not exceed £1,300,000.

In a remunerative point of view, moreover, this arrangement is worthy of attention. The expense of these sewers would be under £50,000 per mile, and the revenue from the sale of liquid manure might be estimated at from £4,000 to £5,000 per mile, leaving a margin, after allowing working expenses and repairs, for a fair return on the capital expended.

We have the honour to be, Gentlemen,
Your most obedient servants,
WM. RICHARDSON,
GEO. CLARK.

5, Ranelagh Grove, Pimlico,
London, 5th July, 1857.

The foregoing letter, of the 5th July, it appears, from the subjoined answer, was addressed to the referees, at too late a date, to afford those gentlemen time to take it into consideration. It is, however, gratifying to find that in their report, dated the 31st July,

the referees adopt the outfalls above proposed at Sea Reach and the Lower Hope, as "the two points on the River Thames which entirely fulfil the necessary conditions."

29, Great George Street, Westminster, S.W.,
July 7th, 1857.

Main Drainage—Metropolis.

Gentlemen,—I am directed to acknowledge the receipt of your letter, dated the 5th inst., and to inform you that the referees are so nearly completing their report, that it is quite impossible for them to re-open the question again, which would prevent their handing it in to the First Commissioner of Her Majesty's Works, &c., as promised within a few days.

I am, Gentlemen, your obedient servant,
HERBERT C. SAUNDERS.

Messrs. Richardson and Clark,
&c., &c.

It may be worthy of notice, with reference to these letters of the 5th and 7th July, which close the correspondence with the referees, that, in their report, describing the outfalls here fixed upon (Sea Reach and the Lower Hope) as the best that could be adopted, they estimate the expense of their open sewers to these outfalls from B at Erith Reach, at* £1,719,300. *It will be seen above, that, the expense of the discharging mains between the same points, on the above-ground system, is estimated at* £1,300,000, *being a difference of* £419,300 *in favour of the latter.*