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DRAINAGE SCHEME

FOR

CHRISTCHURCH

AND THE SUBURBS.

WITH PLAN,

AND EXPLANATORY DIAGRAMS.

BY WILLIAM CLARK,

MEMBER OF THE INSTITUTE OF CIVIL ENGINEERS.

Christchurch, New Zealand.

1878.

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Christchurch, March 4th, 1878.

W. Clark, Esq., C.E.

Sir,—The Christchurch District Drainage Board have had under their consideration, the question of the precise terms of the reference to be made to you in the matter of the improvement of the District Drainage.

I have now the honour to inform you that instead of submitting to you one or more designs and inviting your opinion with reference thereto, as intended at the date of Mr. Tancred's first letter to you (June 25, 1877), they have decided to leave you entirely unfettered in advising the Board as to the best system for the Drainage of the District.

The services of the Board's Engineer will be at your disposal, and the Board will lay before you not only the plans which have already been submitted to them; but in addition every other information which may be in their possession. If you should require further information, or returns which may not be at present in hand, the Board will do their best to obtain them in such a shape as may be most convenient for your purpose.

I have the honour to be,

Sir,

Your obedient servant,

R. J. S. Harman, Acting Chairman.

TO THE CHAIRMAN AND MEMBERS

OF THE

DISTRICT DRAINAGE BOARD, CHRISTCHURCH.

GENTLEMEN,

Having been honoured with your instructions to enquire into the circumstances and conditions which have reference to improving the drainage of the city and its suburbs, I have carefully considered the subject, and now beg to submit my report.

1. Christchurch is situated on an extensive plain, which has been formed by material washed down from the mountains under the influence of the weather, acting through long periods of time. *Situation and character of the site of the city.*

Above the city, the plain rises towards the mountains at a slope of about 20 feet per mile; while below and towards the sea, from which the city is distant 5 miles, the inclination is at the rate of $3\frac{1}{4}$ feet per mile.

Thus at a distance of 9 miles above Christchurch the water level in the Waimakariri is at an elevation of 145 feet above the city, the river-bed is strewn with boulders and pebbles which travel down stream in times of flood, and have thus been spread over the plains. At the point above mentioned, and below towards the sea, the river has no proper banks, and the constant vigilance of the Board of Conservators is required to keep it within its channel; on one occasion its waters escaped, and a portion passed through Christchurch on its way to the sea; to prevent the recurrence of this, the Board of Conservators was established, and the protective works they have carried out to resist the current in the river have so far been, and promise in the future to be, successful.

2. About 4 miles above Christchurch several large springs of water occur, these are the sources of the River Avon, which flows through the city and suburbs; these springs are about 34 feet above its level. Within the north-east quarter of the city, and also in the suburbs, other springs arise, and the area is intersected by the channels in which they flow to the Avon. A dam is erected across the river within the city area by which the waters are held up 4 feet, and power is obtained for working a corn mill; the level to which the water is thus held up is 9 feet above high water in the Estuary, where the maximum range of tide is 5 feet 9 inches. *Source of the Avon.*

3. The entire fall of the surface of the river in its course of $4\frac{1}{4}$ miles within the city and suburbs is from 16 feet to 1 foot over high water level, while the average level of the surface of the land lies between 26 feet and 8 feet over the same level. Some of the creeks within the *Levels of the river and surface of the city.*

suburban area which are fed by springs, and which doubtless have an effect on the level of saturation of the site of the city, are 13 feet above high water level. The borings which have been made show beneath the surface soil an irregular succession of beds of clay, sand, and gravel, generally filled with water.

Nature of the sub-strata.

Tube wells.

4. The above conditions are favourable to an abundant supply of water, which is obtained over the entire area of the city at depths of from 80 to 160 feet, through which pipes are driven, and the water rises a few feet above the surface.

The generally accepted theory is, that owing to the great fall of the River Waimakariri, the water exists in the permeable beds of boulders and shingle beneath the city, under pressure, and these, when perforated by the tubes, furnish an artesian supply. It is estimated that there are about 1600 such tubes within the city alone, and that they furnish a supply equal to 150 gallons per head of the present population; the water is said to be very pure and soft, and suitable for domestic purposes.

These tube wells, which are generally $1\frac{1}{2}$ inches diameter, are for the most part left to run constantly, the water passing away by the street channelling to the river and creeks, and carries with it the house slops.

Few towns have so abundant a supply of water; it has, however, to be pumped or carried for use on upper floors of buildings, for extinguishing fires and all other purposes where pressure is required.

Population.

5. The population of the city is 12,370 persons, residing on 950 acres; in the suburbs, it is estimated at 10,000 persons, residing on 1500 acres; total, 22,370 persons, residing on 2450 acres. The population is thus at the rate of 13 per acre in the city, and 7 to the acre in the suburbs.

Present drainage.

6. The drainage works of the city are at present chiefly confined to the street channels, and a long outfall sewer partly open and partly covered which has been constructed from a point in Selwyn street along the South and East Belts to Tuam street, and thence to the Estuary, its total length is $4\frac{3}{4}$ miles; the fall varies from 2 to 7 feet per mile, and its depth from 3 to 7 feet.

Existing outfall sewer.

The construction of this sewer was, it is said, attended with considerable difficulty, owing to the quicksands met with, and it is now in a somewhat ruinous condition. Various small works have been done, for the purpose of improving the drainage and removing the surface water, and it has been found necessary to dig a deep ditch along the Ferry Road to the Heathcote river, for the purpose of removing storm-water; this ditch carries also the sewage from a portion of the town and suburban area, and has been a subject of complaint in the district through which it passes.

Removal of the excreta.

7. The fœcal matters are collected from about one half of the houses in the city by what is known as the pan system, and these are removed under the supervision of the Authorities, at a cost of 7d. per closet per week. It is intended to carry out the system over the entire area, and the cost will then amount to about £4000 per annum for the city area alone. In other parts of the city and in the suburbs, cesspits are in use; these are simply holes in the earth, and I am informed, without lining of any kind to prevent the saturation of the surrounding soil with filth.

Cesspits.

Mortality.

8. I am indebted to Dr. Powell for the annexed statement* of the mortality in the various districts and towns in the Colony for the year 1876, which shows that whereas the mortality for the entire district of Canterbury was at the rate of 12.41 per 1000 inhabitants, in Christchurch the mortality was 22.63 per 1000, or, in other words, out of the total 280 deaths, 127 were due to residence in the city, that being the number in excess of the general average rate of the district. This very considerable mortality was not, I am informed, due to any epidemic or other special disease. The returns for 1877 are not published, but there is said to be a considerable improvement. No separate returns for the suburbs are available, but judging from the foregoing facts I should not expect to find the mortality there to be less than in the city, considering that the soil is there more or less impregnated with fœcal matter in near proximity to the houses.

Present immunity from sickness probably not permanent.

9. Such are the principal facts which I have ascertained as affecting the question of the drainage of the city, and its present condition. The city is still in its youth; pollution is a cumulative process, the number of inhabitants is at present very small for the area occupied, and the usual results of long occupation on an undrained site have not been developed, therefore the necessity for remedial operations is not so evident as in older cities; and it is a question with many persons whether any measures are now necessary to prevent anticipated evil; and among those who do recognise the necessity, there is a great diversity of opinions as to what the measures should be.

Saturated condition of the subsoil.

10. I would therefore point out what is to me the most prominent feature in its condition, as affecting the public health of Christchurch and its suburbs. This is its water-logged site. Over a large area of the city, especially in winter, water is met with at from 4 feet to a few inches only below the surface of the ground, and at Waltham the water during winter time is stagnant on the surface; while, therefore, the

YEAR 1876.*

Provincial Districts.	Estimated Population.	Annual Total Deaths.	Annual Deaths per 1,000.
Auckland	80,934	1,141	14·09
Wellington	41,591	654	15·07
Nelson	25,100	279	11·11
Westland	16,655	166	9·09
Canterbury	81,389	1,018	12·41
Otago	112,624	1,302	11 56
Towns.	**Estimated Population.**	**Annual Total Deaths.**	**Annual Deaths per 1,000.**
Auckland	12,156	303	24·93
Wellington	15,145	299	19·74
Nelson	5,573	98	17·58
Hokitika	2,983	53	17·77
Christchurch	12,371	280	22·63
Dunedin	22,567	389	17·24

General returns for 1877 not yet published.

Mortality of Christchurch, as gathered from monthly returns, under 17 per 1,000.

present imperfect removal of filth is a growing evil, the exhalation from a very damp soil is abundantly present, and the combination of these causes of mischief is really a present question, and one of degree, rather than one which may be deferred for future consideration with safety to the present population.

Whatever may be the divergence of opinion as to the actual causes which give birth to the various forms of zymotic diseases, there is a general unanimity as to their greater development under the influence of an impure and moist atmosphere.

Drainage works should lower the level of saturation.

11. Under these considerations, it appears to me indispensable that the measures to be adopted should not only comprise the removal of filth and surface water, but should, as far as it is possible, aim at lowering the level of saturation of the subsoil beneath the city, and insure a greater depth of dry soil over its entire surface.

Impervious footpaths and channels now constructing.

12. And here I would remark, that the operation in which the City Council is engaged of making impervious footpaths and surface channels is entirely in the right direction, as it will diminish the amount of soakage into the soil, which occurs when the rain and surplus artesian water with its load of sewage is made to flow through leaky channels, and will, I have no doubt, assist in promoting the public health, as well as the comfort of pedestrians.

Measures which have been proposed for sanitary improvement

13. In the course of my inquiries I have been provided with every information as to the measures which have been proposed to improve the sanitary condition of the city; these, with the exception of a few suggestions from various persons who have interested themselves in the subject, are confined to the two schemes prepared by J. Carruthers, Esq., C.E., the first of which was a Pumping scheme, with two pumping stations; the second, a Gravitation scheme. By both of these it was proposed to remove the rain water to the extent of $\frac{1}{4}$ inch of rain in 24 hours from the entire area drained, with the artesian supply, by pumping it into the existing outfall sewer, and as a temporary arrangement discharging it into the Sumner Estuary. This Estuary is very shallow, and for the most part dry at low water; subsequently, in order to avoid the necesity for pumping, he revised the scheme, and proposed to effect its removal to the same place on the Estuary as a permanent arrangement, by constructing a very expensive outfall sewer with a fall of 1·4 feet per mile, and at a cost of £57,000.

All the proposed schemes discharge filth into the Sumner Estuary.

I am quite aware that these proposals have been strongly opposed; in the discussions on the subject which I have read, there appears to be no other scheme which has passed the stage of mere suggestion. They include: one, to continue the river as the receptacle for the fluid filth of the city—the night-soil being excluded; another, the cutting of a ship canal for the same purpose; and a third recognises the necessity for covered sewers, but at gradients so small as would inevitably make them sewers of deposit; while all the schemes recognise the necessity for the filth to flow through the street gutters for greater or less distances; and moreover, it must be noted, that in every case the filth is by some channel or other removed to the Estuary. Had more searching inquiry been made into these proposals, had the quantities to be dealt with and the cost of the work been estimated, it would then have been ascertained how very imperfect are the results obtained in proportion to the expenditure.

Surface Drains inefficient.

14. Surface drains have their advocates, because they can be easily cleaned; but the necessity for this cleaning not only involves labour, but it recognises also a filthy condition requiring it. Surface drains are seldom watertight, and when they are not, they assist in keeping the soil in their vicinity saturated with the urine and house slops which they are intended to convey. However well constructed, surface drains facilitate the evaporation of filthy matter, and the consequent pollution of the atmosphere.

15. The night-soil it is proposed to deal with by hand, as at present; but no greater mistake can be made than to suppose that the omission of this would leave the slops (which include a large portion of urine) sufficiently pure to render their presence anywhere near the abodes of man unobjectionable, either in the street side channels or in the Estuary. All this has been very well pointed out by Mr. Carruthers.

Character of the outfall required.

16. Undoubtedly, one of the most important points in connection with the subject is the character and position of the outfall. It may generally be stated that the flow of sewage matters should be constant, they should not cease to move from the moment of their production to that of their discharge beyond the limits of the drainage area. If these conditions be observed, there is no time for decomposition to take place, and the generation of gases within the sewers is prevented. The outfall being thus constant, it should also be such as to allow sufficient inclination within the system of sewers to secure a certain velocity of flow, and the perfect discharge of all matters admitted thereto—to prevent deposit within the sewers. The inclination may be, as a minimum, 1 in 100 in house drains, and from 14 feet in the smaller sewers to $3\frac{1}{2}$ feet per mile in the sewer which conveys the entire discharge of the city.

Natural outlets for the sewage.

17. The natural drainage outlets from the area may be considered to be the Rivers Avon and Heathcote, the Estuary, and the sea. The Avon has a course of $7\frac{1}{2}$ miles through the area; it is naturally a very pure and clean stream, and except where the drains fall into it, the pollution is not at present apparent. It is, however, to be borne in mind that the population of 13 per acre in the town area will probably increase to more than three times this number, as is the case with other cities; while it is also probable that the present abundant supply from the artesian source will not greatly increase, as it is sufficient for the wants of three times the present population. When this time comes, I think there will be few who would advocate the discharge of house slops into the river, as it would be the conversion of the most beautiful feature of the city into a foul stream.

Pollution of river not recommended.

Moreover, the surface level of the water is not sufficiently below that of the city to afford a sufficient fall in the sewers.

I am of opinion that the use of this river even partially as the main sewer of the city, should on no account be entertained.

The same may be said of the Heathcote, which could only be made available for a comparatively small part of the area. The tide also flows up this river to a point near to the city. This would check the flow, and render it undesirable as an outfall for the sewage. The same objection exists as in the case of the Avon; the surface level of the river does not afford sufficient fall for the removal of the drainage.

Discharge of sewage into the Sumner Estuary.

18. With reference to the Estuary as a permanent outfall, experience has proved that the admixture of sewage with salt water is even more objectionable than with fresh water, and this, whether the sewage impurity be of animal or vegetable origin.

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18. With reference to the Estuary as a permanent outfall, experience has proved that the admixture of sewage with salt water is even more objectionable than with fresh water, and this, whether the sewage impurity be of animal or vegetable origin.

In all cases when near to a populous district, it is undesirable to make permanent arrangements for the discharge of sewage into salt water, if it can in any way be avoided. When it has been done, nuisance has followed, and large works have been executed in order to avoid it. Brighton, in England, is a notable case of this kind. Where, as is the case with the Estuary, it is for the most part dry at low water, the sewage discharge is even more objectionable than into the sea, as a portion is left to evaporate on the surface when uncovered by the water.

19. This may be avoided in the manner suggested by Mr. Bell, viz:— The provision of a tank to receive the sewage for 6 hours, and to discharge it at ebb tide. This would partially remove the difficulty, and the liability to pollute the Estuary, as the sewage would under these circumstances be discharged into the sea. But it would involve a stoppage of the flow for 6 hours, and, except as a temporary arrangement, I am not of opinion that the sewage should be discharged into the Estuary.

Mr. Carruthers' proposal was to use the present outfall sewer, into which he intended to pump the sewage, and the land adjacent to the outfall not being at present occupied by buildings, would for a time admit of such temporary use until a more perfect arrangement is completed.

20. The permanent use of the Estuary as proposed by Mr. Carruthers in his gravitation scheme, which also involves the construction of an expensive outlet sewer, with insufficient fall to keep clean without hand labour, appears to me to be an undesirable arrangement.

The Sea as the outfall

21. The remaining natural outfall to consider is the sea. This is even more distant than the Estuary, the latter being 3 miles, while the sea is $4\frac{1}{2}$ miles, involving the crossing of the Avon where it is wide.

An expensive work of iron pipes would be necessary to discharge the sewage so far beyond the breakers as to prevent its being thrown ashore. There is, moreover, no advantage to be obtained in the shape of extra fall, and it would still be necessary to lift the sewage in order to its effective discharge into the sea, and to a higher level than would be required to discharge it into the Estuary.

Sandhills.

22. Rejecting the sea as an outfall, the only remaining possible disposal of the sewage, is found in the suggestion to pump it on to land, and use it for the purpose of irrigation, and 400 acres of sandhills have been reserved for the purpose. These hills are situated at a moderate distance of $1\frac{3}{4}$ miles from the position in which I should propose to fix the pumping station, and are well suited to absorb large quantities of the sewage,—proper drains being laid to the nearest point of the Estuary, where the filtered sewage can pass away. Apart from the expense of the pumping operations, such an outfall possesses the advantage of overcoming every possible difficulty, and holds out some prospect of remuneration for the expenditure in the future.

23. My proposal is, therefore, to pump the sewage to the Sandhills, and it remains to be considered what should be included in this proposal, in order to limit the first cost and working expenses for the scheme intended to improve the drainage and sanitary condition of Christchurch.

Uses of sewers.

24. The following are the uses to which sewage works are usually applied:—

The removal of the surface or rain water.

The removal of the water supply after having performed its various uses for domestic and manufacturing purposes.

The removal of the excreta of the population, and the subsoil water.

All these may be accomplished by a well-designed and properly constructed system of sewers.

Removal of rain water.

25. The first of these uses, however, is attended with considerable expense. To receive the water of storms, not only must the sewers be very much increased in size, but where an outfall has to be obtained by pumping, the power to be provided is greatly in excess of that required for ordinary dry weather drainage. Thus considerable additional expense is entailed by the admission of storm water into sewers. Again, the substance which forms deposit in sewers is almost entirely road grit. This is by far the most difficult of all the matters admitted to sewers to remove to the outfall by suspension in water. Another difficulty arises from the admission of rain water, where the sewage has to be disposed of by irrigation. The farmer is bound to receive the largest quantity of useless sewage precisely at the time when it is most difficult to dispose of it, viz., during heavy rain. The value of sewage farms from this cause is seriously diminished.

Road grit.

To prevent inconvenience from this cause it has been in some cases proposed to construct a second system of sewers for rain water, and the more recent practice is to separate wherever it is possible the surface water from the sewage.

Dealing with surface water on the surface recommended.

26. For the above reasons, and because it is practicable to do so with economy, I would recommend that, in Christchurch the rain water should be removed by the street surface channels to the existing creeks and rivers—the former of which are indispensable under any arrangement, and therefore involve no extra expense—while the creeks are already in existence. A study of the plan of the city and suburbs will show the position of these channels, which carry the water of natural springs, and which cannot be admitted to the sewers. These channels must therefore, either in their present or some improved position, always exist.

Springs not to be admitted.

Ferry Road ditch.

27. In addition to these outlets, it has been found necessary to excavate a ditch along the Ferry Road, for the prevention of floods, and this, together with the channels and the outfall sewer before alluded to, have up to the present time constituted the sole means of draining the entire area. My proposal is, that these means shall continue to be so employed for the removal of the surface water, viz., that of the creeks themselves, as supplied from springs, and the rain water falling on this area; and that such improvements as may be found necessary either to existing channels, or additions thereto, shall be made for the purpose of dealing with surface water on the surface.

Subsoil water to be admitted.

28. Under all these considerations, I therefore differ from Mr. Carruthers, in not admitting, or only to a very limited extent, the surface water into the sewers, as he proposed to do. And I would admit the subsoil water into the sewers, whereas Mr. Carruthers proposed

separately to discharge it into the creeks and rivers by separate pipes laid in the sewer trenches; there would, I think, be some difficulty in keeping them to a regular gradient, and moreover, they could not in most cases drain the soil to so great a depth as the pipe sewers will do, and for the removal of subsoil water, which I hold to be of the greatest importance, would be less efficient.

Size of drains.

29. On the subject of the size of sewers I must remark, with reference to the advantages of large sewers on which Mr. Carruthers insists, that if a given quantity of water has to pass through a sewer of given inclination, that it is a disadvantage to employ a larger sewer than that which is found to be sufficient for the purpose.

This is the argument constantly and properly urged against the admission of rain water, that it necessitates a larger sewer, which is efficient probably for 65 days in the year, while for the remaining 300 days the sewer is not only more expensive, but it is less efficient, because larger than is necessary for the work it has to do. Mr. Carruthers' case can only occur where the laying of a sewer for a small quantity, at an inclination which it is known is insufficient to keep it clean, is unavoidable. In that case, of course deposit occurs, and an occasional flush by a large body of water through a large sewer will clean it when a less body of water would be insufficient to do so.

Flushing.

30. I am aware that Mr. Carruthers intended that his sewers generally should be capable of being flushed, and that he devoted much time and care to arranging his system with this view; also, that the very abundant flushing power which here is available would have enabled him to supply the required quantity, without expense for water or for pumping, in his gravitation scheme. My experience, however, induces me to estimate, as of less importance, the power to flush the sewers than the means of preventing its necessity.

By eliminating road grit from among the substances to be dealt with in the sewers I am enabled to do this, while the abundant water supply of the city and suburbs insures at all times a sufficient flow to render it unnecessary. I, however, by no means undervalue the power of flushing, and in my revision of Mr. Carruthers' pumping scheme, which in its general features, so far as the arrangement of the sewers is concerned, I adopt, I have carefully retained the means of flushing all the sewers, when it can be done from the rivers or creeks without entailing unnecessary depth or a doubtful gradient.

Situation of Pumping Station.

31. At a point on the present outfall sewer, near the Matheson road, where the brick-built portion terminates and the open sewer begins, the Drainage Board own a small paddock of about 2½ acres; here, or in its neighbourhood, I would erect the Pumping Station, for the purpose of pumping the combined sewage and subsoil water through an iron pipe on to the Sandhills, a portion of which would be required to be levelled for the purpose. The daily flow would be poured over successive portions of this area, and open ditches and drains would be necessary to carry the effluent water, purified by its passage through 9 or 10 feet in thickness of sand, as a minimum, to the Estuary. The land is of an exceedingly absorbent character, and the area is abundantly large for any probable extension of the City of Christchurch. The action of the sewage will be to cause a deposit within the first few inches in thickness of the sand, as is the case in an ordinary filter, on which grass will grow luxuriantly, when occasionally watered, as here it could be, and still within the limits of saturation.

Quantities of drainage fluids.

32. I may now more particularly examine the quantities of drainage fluids to be dealt with, and the dimensions which it will be necessary to give the sewers, with the falls obtainable.

Present water supply.

I learn from Mr. Bell, Engineer to the Board, that he estimates the quantity of artesian water now discharged at 350 cubic feet per minute, which amounts to a daily supply of 144 gallons per head of the 22,000 population. This artesian supply may probably increase somewhat, but inasmuch as it would furnish three times the present population, or 66,000 persons with what is usually estimated as a good supply of 48 gallons per day, it is probable that the supply from this source will not largely increase.

33. As, however, it is necessary to consider what may be required in the future, I propose to estimate the required capacity in another manner.

Future water supply.

It is usual to estimate about 47 as the population per acre in town areas, and 31 in the suburban districts. In Christchurch this will be:—

In the city 950 × 47 =	44,650	population.
Suburbs 1500 × 31 =	46,500	"
Total	91,150	"

Allowing 50 gallons = 8 cubic feet of water supply per head, half of which may be considered as delivered in 4 hours; this would amount to

$$\frac{91{,}150 \times 8}{60 \times 4 \times 2} = \quad 1{,}519 \text{ cubic feet per minute}$$

Or something more than four times the present flow of 350 cubic feet per minute. This, however, assumes that the flow continues for 4 hours only out of the 24 when the sewers would be conveying the maximum quantity, and according to this estimate, it would be reduced during the twenty hours to $\frac{4}{20} = \frac{1}{5}$ of the quantity; at such times, therefore, viz., during 20 hours each day, there would be ample accommodation for the subsoil water, which would enter the sewers at all times when they are not fully charged. The total capacity of the system would be:—

Capacity of the system.

	cub. ft.		gallons.
To remove in 24 hours	1,787,360	or	11,171,000
Of which the sewage would be (with a population of 91,000)	729,200	or	4,575,000

Thus, in addition to the sewage, the sewers would be capable of removing subsoil water and other fluids, to the extent of 6,596,000 gallons in 24 hours. This I consider to be ample for the subsoil water and for all purposes, even a portion of the surface water when required; but if rain water be admitted at the rate of ¼ inch per 24 hours over the entire area, the capacity of the sewers would require to be doubled.

Level at Pumping Station.

34. After a careful examination of the plan and levels of Christchurch, I have adopted the level 30 feet over datum, or 4·3 feet below high water line in the Estuary which Mr. Carruthers by his gravitation scheme, found to be necessary at the point above referred to—that is, 6·4 feet below the level of the bottom of the outfall sewer at that point. This level I find to be necessary to give the necessary depths and inclinations to the system of sewers within the area to be drained.

Position and Inclination of the Main Sewer.

35. Starting from the point on the present outfall, where the pumping station will be placed, the sewer follows its course to the East Belt, a distance of 50 chains, at a gradient of 3 feet 6 inches per mile. From this point the sewer on the East Belt rises to the South Belt, and to Kilmore Street at four feet per mile. Along Kilmore Street, crossing

the river by a syphon, and extending to Colombo Street, it rises with the same gradient. Along Madras Street to the North Belt, and along North Belt to Colombo Road, it rises at the rate of 1 in 880. Along South Belt to Madras Street the rise is 1 in 700. On the west of the river from Cashel Street to Colombo Street it is 1 in 570, and along Tuam Street it is 1 in 550.

In all other cases the inclination is 10 feet per mile and upwards, but generally 17 feet per mile, or $\frac{1}{300}$. In the table in Appendix, the length, dimension, and depth, will be found, and the particulars of the entire system.

36. Plans No. 1 and No. 1 A show the general arrangement of the scheme which comprises the following:—

Concrete and brick sewer	4·6 x 5 =	...	2,980 feet.
" "	3· x 4.6 =	...	3,230 "
" "	2·8 x 4 =	...	1,750 "
" "	2·6 x 3·9 =	...	1,640 "
" "	2.2 x 3·3 =	...	1,000 "
" "	2· x 3 =	...	3,160 "
" "	1·10 x 2·9 =	...	1,600 "
" "	1·8 x 2·3 =	...	3,210 "
" "		...	3,670 "
Pipe sewer 18in. =	...	...	... 20,005 or 3 and 3¼ miles.
" 15in. =	...	...	... 21,030 or 4 miles nearly.
" 12in. =	...	...	...236,940 or 45 miles nearly.
" 9in. =	...	...	
Total	...	...	300,215 feet or 57 miles nearly.

Disposal of the Sewage.

37. The Sandhills, as nearly as can be ascertained, lie below a level of 51 feet over datum,* and a head of 2 feet above this will enable the sewage to be carried over the entire area.

Lift.

The level of the invert of the main sewer at the pumping station is 30 feet over datum; the lift of the pumps will therefore be from 30 to 53, or a height of 23 feet, while the lift into the present open sewer leading to the Estuary is 6½ feet only.

38. The quantity to be lifted as represented by the water supply is large, 350 cubic feet per minute, or about three times the quantity usually supplied to a population of 22,000. In addition to this, the subsoil water will require to be lifted.

Pumping.

If the artesian tube wells could be closed even during the night, a very considerable economy in the useless pumping of clear water would be effected; in the Estimate, however, I have provided for pumping continuously day and night.

Outlet Pipes from Pumps.

39. The channel from the pumps to the Sandhills, I would advise, should be a cast-iron pipe, and for the present, one of 24 inches diameter would be sufficient; its length will be 145 chains, and it will terminate in a small tank, where the surface or "carrier" channels for the distribution of the sewage would commence.

Horse-power required.

40. To lift the quantity and overcome the friction through the pipe, a 25-horse-power engine will be required, and this should be provided in duplicate.

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* Maximum High Water in the Estuary is 33·5 feet over datum.
" " in the Sea ... 34·28 " "
The Rise of the Tide is 5 feet 9 inches.

These arrangements will, I believe, be found sufficient until a large increase of the water supply occurs, when additional power and capacity of outlet channel will be required, which it is not immediately necessary to provide.

Machinery.

Where coals are expensive, as in Christchurch, it is economical to adopt the most perfect kind of machinery, even though the first cost is greater, and in the estimate for the engines this is provided for—viz., for compound engines working at a high rate of expansion, and calculated not to consume more than 3lbs. of coal per horse-power indicated.

The pumps may be either centrifugal or reciprocating; the latter is the most expensive, and is provided for in the Estimate; the Engine-house will be a plain inexpensive building.

Apprehension of Nuisance from Pumping Station unnecessary.

41. It is probable that apprehension will arise as to a nuisance which will be caused in the neighbourhood of the pumping station, this, however, will be avoided. I annex a sketch, Plan No. 5, of an arrangement of centrifugal pumps, where three pumps are fixed in an iron tank adjacent to the covered pump-well, into which the main sewer discharges. It will be seen that the sewage is perfectly enclosed in brickwork, and that the pumping operation exposes no surface of the sewage whatever to the open air. It is drawn through the suction-pipe, and forced through the iron case of the pump direct into the pipe leading to the Sandhills, while the ventilating flue from the pump-well will carry the gases into the engine furnace and chimney shaft, and this is the only outlet by which the atmosphere of the pump-well and sewers will communicate with the outer air.

The means are thus available for constantly purifying the air through a furnace, which will effectually prevent any nuisance arising in the neighbourhood of the pumping station. It is not intended that this is to be the precise arrangement which will be followed, but it illustrates in a convenient way the principle which will be followed in designing the pumping arrangements.

Advantage of the Sandhills for disposal of sewage.

42. The majority of the towns in England where the disposal of the sewage is effected by irrigation have paid very large prices for the land required, and the rental has generally exceeded £5 per acre per annum. Christchurch is in this respect greatly favoured, having within a comparatively short distance a sufficient area for all its requirements, present and future, reserved, and without cost to the community. A very great advantage; and there can be no doubt whatever that after the first expense of conducting the sewage on to the Sandhills, it will very speedily pay all expenses of distribution. I have therefore only to add to the estimate a sum wherewith to commence the irrigating operations in one main "carrier" and a drainage channel.

The Board will probably be disposed to grant a lease of the land or a portion thereof for a limited number of years at a nominal rent, upon condition that the area is brought into cultivation, and the sewage disposed of in a satisfactory manner.

43. The high level of the Sandhills is very advantageous to the perfect disposal of the sewage, as it insures a great depth of dry sand and rapid absorption. The area over which the sewage is at any time passing, will not exceed 7 or 8 acres. All the other portions of the irrigation area will remain as dry as the adjacent country; I am perfectly aware that a natural apprehension may be felt by those who are not familiar

with the subject, that the concentrating the sewage of a City on such an area is a questionable means of disposal, but I think it will be admitted that of all other means available it is the best. I also know from experience and observation, that in an agricultural district such as the Sandhills, if the sewage be kept in motion till it reaches the land where it is at once absorbed, not the slightest nuisance or danger need be apprehended, and that the disposal of the sewage of Christchurch in the manner here indicated, may be effected so as to satisfy the most critical judgment.

Will eventually be profitable.

I do not attempt to describe the agricultural part of the question; undoubtedly land so cultivated, will be suitable for market gardens, for root crops, and for grazing, and will attain a value which land without the means of similar irrigation does not possess.

The sewage, lifted as is here intended, would command also any of the adjacent land, where it may be considered desirable to convey it.

Results to be expected from the Works.

44. The system of sewers above recommended will, I believe, drain very effectively the subsoil of the area in which they are constructed. When, as is the case here, the subsoil is of a sandy character, the influence of any one of them will be exercised over a very considerable breadth of area; their united action will be to diminish the exhalation from the present damp soil, and in this manner they will exert a very beneficial effect on the health of the population.

House Drained and Removal of Excreta.

They will also enable every house to be drained by a covered pipe drain, and admit of the removal of the excreta of the population in a convenient, efficient, and economical manner.

Difficulty in executing the works.

I by no means desire to ignore the fact that great difficulty will be found in carrying out the works in a soil so saturated as is that of Christchurch; that occasionally permanent running springs may be encountered which it will be impossible to admit into the sewers; in such cases, it will be necessary to collect these waters and convey them to the nearest creek or river, and in their vicinity to protect the sewer pipe with an additional amount of concrete and shingle. Also, to make the joints carefully to exclude the spring water from the pipes, all of which it is practicable to do. For the rest, the drainage of saturated land is chiefly difficult at the commencement of the operation, while the benefit arising from a dryer site to the habitations is incalculable.

Entire scheme not for immediate execution.

45. In making these proposals to the Board, I do not intend to intimate that there is an immediate and pressing necessity for the execution of the entire scheme. The drainage area, nearly 4 square miles,* is very large, and the population over a very considerable portion is so thin and scattered, that the works may in such cases be deferred; while, on the other hand, there are portions of the area where the drainage is more especially required than in others—thus, in the neighbourhood of the Hospital, at Waltham, and in those parts of the area where the artesian water does not rise to the surface, and the removal of the sewage by flushing through the side channels in the street cannot be effected, there the drainage works are especially required.

46. Desirable as is the drainage of the subsoil of the entire area, I am quite aware that the expenses of the work to a comparatively small population would be felt oppressive; under these circumstances the operations of the Board would be to construct the outfall arrangements

* This does not, as I believe, include the entire area under the jurisdiction of the District Drainage Board, but it would not, I am of opinion, be desirable to include any larger area in the present scheme Whatever may be required will probably be of a rural character, and should be separately dealt with by your Engineer.

and arteries of the system leading to the localities where the population is most dense, and where drainage is more especially required, leaving the minor street sewers to be constructed in such order as the exigencies of each case may demand. The possession of a general scheme for the whole area will enable the Board to do this systematically and correctly.

Paris and London.

47. With reference to the prejudice which exists against the removal of excreta by running water, it is scarcely necessary here to enlarge, the system is extending wherever drainage and water supply works are constructed. Paris and London are instances: in the one, night-soil is excluded; in the other, admitted; in Paris, the exclusion entails nuisance and expense by its storage under the houses and separate removal, while London is the healthiest of the large cities of the world.

Cost of sewers not increased by admission of excreta.

48. The cost of the system of sewers is entirely unaffected by the admission or exclusion of excreta. Having therefore constructed the sewers, to omit this use of them is to forego one of their most valuable advantages.

Undoubtedly, for a considerable time to come, the pan system must be continued, and more or less till the sewer system is completed; but to deny the use of the sewers for this purpose to those of the ratepayers who desire it, would be to deprive them of an advantage for which they pay their share of the cost, and have a right to the full measure of benefit so purchased.

49. The objections to the use of sewers for the purpose of conveying excreta has no force where, as is here intended, they have sufficient fall to secure their self-cleansing action; moreover, the removal of the sewage matter to the Sandhills, will admit of its perfect disposal by absorption and the growth of plants, &c., while no impurity whatever will be discharged either into the River or the Estuary.

Cost of house drains.

50. As a matter of cost, the covered pipe drain 4 inches diameter (which is generally sufficient for house drains), at 1s. per foot, will not exceed the cost of a surface drain. If well laid and properly jointed, they will remove all the fluid filth from the moment of its admission, perfectly and speedily to the sewer; and by leaving a small portion at the top of the joint of the pipe to be stuffed with clay instead of cement, the subsoil water will also gain admission.

Removal of excreta.

I am aware that the removal of excreta by the house drains is strongly opposed by some persons, but I am certain the opposition proceeds from an entire misapprehension as to what are the simple and inexpensive means necessary to effect it. Where water is obtained under pressure, and is expensive, purchased at a certain rate per 1000 gallons, where special cisterns, valves, etc., are necessary, the water-closets may cost £6 each. In Christchurch, however, where water is procured in abundance, a very much more simple arrangement may be made.

Water Privies.

51. This arrangement can be constructed under an ordinary privy seat by a bricklayer, and consists of a small, cement-lined, brick tank with a sloping bottom; its length is about 3 feet, and it is made to contain about 10 or 12 gallons of water. At the lower end of this tank, which is about 15 or 18 inches wide, a circular cast-iron socket is fixed, 4 inches in diameter, which communicates with the house drain. This socket is closed by a wooden plug with an iron handle, extending above the seat; the plug is hollow and about 10 inches in height, terminating at the top level of the water which the tank is to contain. Waste water from the artesian supply is admitted to the tank, which, when full,

overflows through the hollow plug. After one or more uses of the place, the plug may be lifted by the handle, and the entire contents of the tank discharged through the house drain to the sewer; nothing more is then required but to replace the plug in its proper position.

To prevent stones, bricks, and improper substances of that nature from entering the house drain, an ordinary dip trap is constructed outside the privy, and when obstructions occur which such matters would cause, they can easily be removed by lifting the cover. The abundance of waste water at all times available for the purpose here will ensure the places being at all times efficiently flushed and in good order. These water privies act perfectly, are inexpensive (about £2 10s.) and simple, requiring no plumber's work whatever. A sketch of the arrangement is given on Plan No. 7. The use of this arrangement will, I am quite certain, require no enforcement; the comfort, cleanliness, and the absence of a payment of 7d. per week, will be quite sufficient to ensure its adoption by a large majority of the population.

Pipe Sewers.

52. The greater part of the material required for the sewers will be stoneware pipes. To ensure their durability and proper action, these should be of the very best quality—no soft pipes should under any circumstances be used. The material of properly burned and glazed pipes is indestructible, and entirely non-absorbent, the glazed surface affords no foothold to rats, which avoid them, while in brick sewers they are occasionally troublesome and destructive.

Perfect shape and superior quality required.

The pipes should not only be of good material, but their shape should be as nearly perfect as possible, straight in their length and truly circular, each spigot end fitting accurately into the socket of the adjoining pipe without "lip" or irregularity of level at the junction. The joints should be made with good Portland cement, so as to be watertight, and any cement which may be forced into the interior of the pipe in making the joint should be at once carefully wiped out.

Should be laid in straight lines.

53. The pipes should be laid in straight lines, and where any deviation from the straight line occurs, a "man hole" should be constructed.

Man-holes.

These "man holes" also form junctions for other pipe sewers; the arrangement is shown on Plan No. 3. One of these "man holes" is provided for every 250 feet in length of pipe sewer.

Their use is to facilitate the examination of the sewers before they are brought into use; also the examination and cleansing, should it be required in the future.

Subsoil water admitted to sewers.

54. At these "man holes" the subsoil water would be admitted. The trench in which the pipe is laid will always collect the water from the ground on either side of it, and if a patch of shingle be laid near the "man hole," and a small earthen pipe carried from it through the brickwork into the "man hole," the water collecting in the shingle will be discharged into the sewer, and mingle with the stream. The shingle will keep back the sand; and, should occasion require it, the pipe can be stopped, and the water from the exterior excluded. The subsoil water can also be admitted into the sewers at other points, by inserting at intervals a special length of pipe with an aperture and perforated plug, covered with shingle. This is shown on Plan No. 2.

Concrete under pipe sewers.

55. The pipe sewers should be bedded in 6 to 8 inches of concrete, carried high enough just to cover them. Every care should be taken to

get out the bottom of the trench with regularity, so as to preserve a uniform thickness of concrete beneath the pipe; its use being to prevent any displacement or irregularity of settlement of the pipes when the weight of the earth comes upon them.

Junction of house drains.

56. The junction pipes for house drains, &c., should as far as possible be inserted when the pipe is laid; the end of the branch, when not immediately used, being carefully and securely stopped with a suitable stoneware plug and clay, to prevent the entrance of the surrounding soil. An occasional half-socket pipe may also be inserted with advantage where junctions are likely to be required. This will admit of a length being taken out generally without breakage; there is always some risk that the pipe line when disturbed for the purpose of making connections will not be replaced with the same solidity and accuracy as when originally laid. Special pipes are made by some manufacturers to overcome this difficulty; they are somewhat more expensive, but I have always found that with care competent workmen can, with the arrangements I have alluded to above, do all that is necessary.

Only workmen employed by the Board to make junctions.

57. It is, however, important that only qualified workmen in the employ of the Board should be permitted to make the connections with the public sewers, and that not only the material, but the workmanship to the private drains which are to be connected with the public sewers should be subject to official inspection and approval. Those tradesmen only who have proved their competence to do the work, and who hold licenses from the authorities, should be permitted to undertake the house drainage work.

58. Those sewers which are so large as to exceed the pipe sizes can either be made in concrete or brickwork; cement, not lime, should be used in either case, with hard, non-absorbent material.

Brick sewers.

The brickwork should be of the very best quality. Where any spaces or broken ground at the back of the brickwork occurs in the construction of the sewer, it should be filled in entirely with concrete and shingle, back to the solid ground; it should not be refilled with the original soil, or the sewer will crack and probably get out of shape.

The size of the biggest sewer required is not large, 9-inch work will be sufficient; but it should be backed with concrete, and a thickness of 6 inches up to the springing of the arch is included in the estimate. The interior should be rendered with cement up to the same level, and the work in the arch carefully pointed. Stoneware invert blocks, set in concrete, as shown on Plan No. 2, are a great improvement, and facilitate the drainage of the work when in progress.

Drain-pipe under brick sewers.

59. When these are not used, and water appears in the trench, it is necessary to lay a drain-pipe in concrete or shingle to carry it off, so as to insure good work in the invert. The extra expense will be more than repaid by the quality of the work obtained.

This pipe may be retained for the purpose of collecting the subsoil water after the sewer is in operation. When this is not done, agricultural drain pipes 1 inch in diameter should be built through the brickwork a little below the springing of the arch, at intervals of about 50 feet in the side of the sewer, with a patch of shingle on the outside to collect the water and prevent the entrance of sand.

Flushing.

60. Flushing is an operation which is often considered as absolutely necessary to the proper condition and action of the sewers, as it is

affirmed that they are unable to discharge without some such aid the matter which finds access to them. This, however, is not the case where there is an abundant water supply for domestic purposes, and the sewers are so constructed as not to allow of its leakage into the surrounding soil. There is no tendency to deposit if, as is here intended, the road surface water is excluded; for then the material which constitutes deposit in sewers, viz, road grit, is also excluded. The man-holes can at all times be used for the purpose if needed, and no further special arrangement for the flushing of the sewers is required. Solid refuse, which must be removed in the dust cart, or by the scavengers, should not find access to the sewers.

Trapped inlets.

Every inlet except the water-closet pipe which is trapped, will be protected by an iron grid and trap, and it will be impossible to put such substances into the sewers to interfere with their proper action.

Ventilation of sewers.

61. In every system of sewers provisions for perfect ventilation must be made. Every cubic foot of fluid which is admitted will displace a similar quantity of air. If no provision be made for escape, the air in the sewer would be under pressure, and tend to force its way through every imperfectly trapped inlet which may be existing; and should such inlet be within the house, the atmosphere thereof would be vitiated. It is explained below that direct communication between the houses and the sewers should not, except in the case of water-closets be made. The usual means of ventilation is shown in the Plan No. 3. A small brickwork box is constructed in connection with a man-hole, at or near the centre of the street. The air in escaping passes through a basket of charcoal, and afterwards through an iron grid fixed at the level of the street surface. The charcoal is intended to render the air inodorous. The arrangement also provides that any water which may enter the grid, shall pass on with the current in the sewer, but the road grit will be arrested, and will require occasional removal. These ventilators should be fixed at convenient places, five or six hundred feet apart.

62. A more active ventilation has in some cases been attempted by connecting the sewers with the furnace or chimney of manufacturing establishments, the proprietors of which may be willing to permit it. Undoubtedly a more rapid change of the air of the sewer would thus be effected, as the draught would be promoted by the heated chimney. Another means which may be adopted is to take a pipe from a man-hole situated near to a wall—not that of a dwelling-house—and to affix a vertical pipe thereto of any convenient height; free escape of the air may thus be obtained.

Practically, however, if the sewer be properly constructed, so that no stagnation occurs in the flow of the sewage, and its removal be effected before decomposition takes place, all that is actually required is a free passage for the inlet and the outlet of the air at the street surface.

Sewer pipes.

63. Among the objections which have been frequently made to a system of sewers for towns is one "that the house drains act similarly to the gas pipes, except that in the latter case illuminating gas is conveyed into the interior of a house for a useful purpose; by the other, malarious gases find access, which engender fevers," &c., &c. The sewers are, in fact, considered in the light of cesspools, and an inevitable nuisance. The cases are, however, widely different. The cesspool means stagnant filth stored for months, and in a state of active decomposition. The sewer, if properly constructed, means constant

removal before decomposition can take place. If any stagnation should occur in the future sewers of Christchurch, it will be due to errors of construction.

House drainage.

64. The usual points in a house to which the drainage requires to be carried are the—1st, kitchen sink; 2nd, water-closet; 3rd, stopcock in the paved yard, where water may be drawn for washing carriages, &c.; 4th, where after use it can be removed; 5th, the stable; and 6th, rain-water pipes. In the 1st and 6th cases the pipe can be brought down on the wall of the house, and should terminate a few inches above the trapped opening, as is shown in plan No. 6; in 3, 4, and 5 a similar grating and trap placed in the yard surface, or in the stable, will receive the water. For all these cases it is impossible that the sewage gas can enter the house, as they have no direct connection with it. The 2nd point, viz., the water-closet, is the only one having a direct connection.

In this case, if the soil pipe be carried for its full size up to the top of the house, and a syphon trap be fixed at its lower end, the ventilation of the pipe will be perfect, and the danger of gas entering the house will be reduced to a minimum. The arrangement is shown on plan No. 6. The principle is simple, if the proprietors of houses will only insist on its being carried out.

Dip trap.

65. When there are several branches to the house drains it is desirable to carry them all to one point, as shown at PT on the plan. This should be trapped by a similar arrangement of dip-trap, and, if carried up to near the surface, can be readily opened for inspection. If this be done, no further trapping at the junction of the house-drain with the public sewer will be required. A direct communication from this trap to some convenient wall, where a ventilating pipe (not near to a window) can be fixed, is desirable, as it removes all chance of pressure within the pipe, and ensures a perfect ventilation. Stackpipes are commonly used for this duty, but this is not to be recommended, as at the time the stackpipe is discharging rain-water downwards it does not readily admit of the upward escape of the air which is then necessary.

Position of the sewers

66. In carrying out the works, doubtless some modifications will be made. On the general plan, which accompanies this Report, the sewers are shewn as in the streets, and, doubtless, the principal sewers must there be constructed. For many of the minor sewers, however, this need not be. The sewers will not have to carry off the street surface drainage, and for that purpose will not there be required.

67. The points where drains are generally wanted are at the back of the house, and where it is conveniently practicable, very great economy in the house drains, as well as efficiency, will be obtained by placing the public sewer there also.

Back Drainage.

This arrangement, or what is called "Back Drainage," is most economical and applicable where the houses are in continuous rows, or nearly so; in that case the necessity for conveying the house drain under the house, which is always undesirable, is avoided. Christchurch, at present, contains but few localities of this character. Plan No. 4, however, illustrates the principle recommended, and even in the case where the houses are very few in number, this arrangement is worthy of consideration.

Six inch pipes may be substituted for 9 inch pipes in places.

68. All the minor drains in the scheme are shewn to be 9 inches in diameter. For a very large portion of the length 6 inches would be amply sufficient to carry all that will be required of them. The difference in the price of the 6 in. and 9 in. pipe laid, however, is so very small that, the larger size has been adopted for the estmate. In the event, however, of the above plan being carried out, I would recommend two 6 in. pipes for back drainage to be substituted for the one 9 in. pipe in the street.

69. For improving the present means of carrying off the rain water and surface drainage, Mr. Bell is of opinion that the following works would be required, and the cost, £19,128, is included in the Estimate.

Outlets for storm-water.

To drain the large quantity of rain water which collects in the District of Waltham, near the Gasworks, it is proposed to divert it from its present course down the Ferry Road, by deepening out a portion of the old bed of Jackson's Creek, and cutting a new drain where necessary, to straighten it. Into the storm-water channel will be drained the water from the sewer in the south-west and the south city drain, the water from Gasworks stone drain and its large pipe in Third street, which pipe and the stone drain would be put into a thorough state of repair.

Antigua street

A pipe drain would be laid in the old Antigua street drain to the river, taking all rain water from South Addington; and the open drain on the Park side of Lincoln road would be kept open as it is at present. When these are all constructed, there would be no further use for the south city drain, which could be filled up.

Tuam street

The present brick sewer would be used for taking away rain water from the north-east and central parts of the city.

Free's Creek and Springfield district.

The water from these districts would be collected at Madras street, and carried in a brick culvert to the river. The water in the North Belt drain would by this means be lowered, and might be covered in if found necessary. Free's Creek in the Springfield district would only be covered in by a pipe where necessary. East Belt next to the Cemetery would receive a 15 inch pipe to the river, to convey the rain water from Upper Bingsland and Packe's road district.

St. Albans Creek would receive the drain along the north side of the Edgeware road, covered in by an 18 inch pipe; it would also receive the drain on the St. Albans lane, covered in by a 15 inch pipe, if necessary. The lower part of Knightstown would also be drained into St. Albans Creek by a pipe drain. St. Albans Creek would be deepened if necessary, to give good drainage for rain water.

Ferry Road

Ferry Road would receive a 12 inch pipe from Matheson's Road to Bell's Creek, to carry both the rain water and the house drainage from dwellings along the road, and the mouth of Bell's Creek would be deepened to give this pipe the requisite fall.

Outfall brick sewer

Outfall brick sewer might be reconstructed of a smaller size which would be permissible, as most of the storm-water which it carries at present would then be diverted from it into other channels.

Estimate

70. The estimate for the works before described is as follows :—

	£	s.	d.
For 57 miles of sewers as per statement	132,805	0	0
2 syphons under the river	1,200	0	0
Pumping station, including two 25 h.p. engines, boilers, pumps, and pump well	8,500	0	0
24in. iron pipe to Sandhills	8,000	0	0
Levelling Sandhills, carrier, drains, &c....	2,000	0	0
Houses for Workmen	1,000	0	0
Storm overflows at Waltham and others places, &c., &c., for improvement of present surface drainage ...	19,128	0	0
	172,633	0	0
Contingencies, engineering, &c., 10 ℔ cent.	17,263	0	0
Total	£189,896	0	0

	£	s.	d.
Working Expenses—			
Fuel at 1·3 tons per day, coal 38s. per ton, 475 tons per annum...	850	0	0
Oil, tallow, and waste	130	0	0
Establishment—			
1 engineer at £3 10s. per week and residence			
1 assistant at £3 0s. " "			
1 labourer at £2 0s. " "			
Per week £8 10s. Per annum... ...	442	0	0
Repairs and depreciation	200	0	0
Total per annum	£1,622	0	0

	£	s.	d.
Total Annual Charges—			
Interest on £190,000 @ 5½ ℔ cent	10,450	0	0
Working expenses	1,650	0	0
Total per annum	£12,100	0	0

The annual value of the premises on the area proposed to be drained is £235,249, and is rapidly increasing. One shilling in the £ per annum on this value will yield £11,762, or very nearly the annual sum required for payment of interest and working expenses. A loan obtained at 5 per cent. to be repaid in 50 years, would require an annual payment of £5. 9s. 6¾d, per cent., or 5½ per cent. per annum.

Further Legislation.

71. As it is probable that some further powers will be required by the Board when carrying out these works I would recommend for consideration those clauses of the Public Health Act of England. 11 and 12 Victoria, 1848, which refer to the construction and maintenance of sewers and the drainage of private houses, Sections 43 to 49 inclusive, by which power is given to take works through any place or land whatever, making compensation for damage.

72. In Christchurch there are at present but few cellars; their construction is, however, on the increase. And in order that damp unhealthy houses should not be erected, it is very important that their construction should be subject to proper regulation. Sections 51 to 54 of the above Act provides for these regulations, and empowers the Local Board to fix the level of the cellar and lowest floors of houses to be erected. The depth is regulated by that of the adjacent sewer, and must be such as the sewer will effectually drain; 2 or 3 feet above the invert will

generally be sufficient to keep the cellar dry. The possession of the general scheme for the city will thus enable the Board to regulate the depth of cellars. These clauses also refer to the proper construction and management of cesspools, privies, &c.

The rating clauses also are worthy of consideration. The special district rates give the power to the Board to levy rates on districts especially benefitted by any particular drain.

73. The power to levy Private Improvement Rates I have found to be very useful and acceptable to the Ratepayers. These rates are for the purpose of recouping the Board for any works and necessary improvements to private property which the owner may be unable or unwilling to do, and the Board have executed. In these cases the outlay is secured as a first charge on the property, and provides that principal and interest shall be repaid in a limited number of years.

W. CLARK,

(Member of the Institute of Civil Engineers.)

For the purpose of illustrating this report the following plans have been prepared :—

1. General Plan of the City, shewing position and direction of sewers and pumping station.

1A. Plan shewing outfall and irrigation area.

2. Sections of brick-work and pipe sewers with inlets for sub-soil water.

3. Plans and sections of man-holes, ventilators, &c.

4. Block plan shewing back drainage.

5. Diagram shewing pumping tanks &c.

6. Diagram shewing general arrangement of house drainage.

7. Plan and section of water-privy.

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APPENDIX.

LIST OF SEWERS.

Name of Sewer.	Height of Invert		Length in Feet.	Gradient 1 in	Drainage Area.	Size of Sewer.	Average Depth.
	Upper	Lower					
	in.	in.	ft.		Acres.	in.	ft. in.
St. Albans Lane	57.0	52·3	1830	400	33	9	3·6
Crescent Road	52·3	46·3	2940	500	71	12	6·0
Edgeware road, Springfield to Colombo	48·3	46·3	1075	540	132	15	6·0
High Street, Knightstown	51·1	47·3	1130	300	...	9	5·0
Abberley Road	54·3	48·3	1790	300	23	9	6·6
Springfield Road North	53.0	48.3	1640	370	...	9	5·6
Edgeware Road Creek to Colombo	49.3	46.4	820	280	...	9	4·0
Colombo Road North	46·1	40·7	2720	500	207	15	7·6
Northern Road	47·7	44·7	1200	400	...	9	5.6
Ditto ditto	45·5	40·5	1510	300	...	9	7.6
Cross Road, Northern to Colombo	44·7	43·7	360	360	...	9	7·0
Holly Road	47·2	45·1	1080	510	...	9	7·0
Caledonian Road	48·3	45·5	830	300	...	9	5.0
Ditto ditto	47·8	41·5	1880	300	...	9	7·0
Springfield Road South	50·3	47·5	830	300	...	9	6·0
Ditto ditto	50.0	43·7	1880	300	...	9	7·6
Papanui Road	55·3	...	1630	400	...	9	6·5
Ditto ditto	...	47.2	1520	400	75	12	9·5
North Belt, Papanui to Colombo	47·2	41·7	2270	400	186	15	10·0
Ditto Colombo to Madras	40·7	35·9	1590	880	446	27 x 18	9·0
Edgeware Road Creek to Packe's Road	49·3	45·3	1420	350	...	9	4·6
Packe's Road, Edgeware to North Belt	45·3	40·3	2630	520	99	12	8·5
North Belt, East Belt to Packe's Road	45·3	40·5	1580	230	...	9	6·0
Ditto Packe's Road to Madras	40·0	38·9	660	600	114	15	9·0
Madras Street, North Belt, to Cambridge	38·9	36·6	2070	900	619	24 x 36	8·0
Whately Road, North Belt, to Salisbury	50·7	46·0	1440	300	...	9	8·0
Ditto Salisbury to Kilmore	45·8	42·0	1130	310	42	9	8·0
Ditto Kilmore, Chester	42·8	39·8	540	180	...	9	7·0
Cambridge Terrace, Barbadoes to Madras	38·5	36·5	1050	525	20	12	3·6
Ditto Cashel to Worcester	43·2	41·7	820	570	...	9	4·0
Ditto Worcester to Kilmore ...	41.7	38·3	1950	570	77	12	8·5
Kilmore, Park Terrace to Durham	46·0	41·0	1430	285	22	9	7·5
Ditto Durham to Colombo	41·0	38·3	800	300	99	12	9·0
Ditto Colombo, Madras	37·8	36·5	1620	1250	193	30 x 20	8·0
Peacock Street	47·1	44·4	800	300	...	9	6·0
Aldred Street..	47·7	45·0	800	300	...	9	6·0
Conference Street	50·0	47·3	800	300	...	9	6·0
Salisbury Street, Park Terrace, to Montreal ...	48·4	46·0	690	300	...	9	7·0
Ditto Montreal, Madras...	48·2	37·5	3200	300	...	9	7·0
Ditto Madras, Barbadoes	42·0	39·3	800	300	...	9	3·0
Peterborough Street, Park Terrace, Montreal ...	48·5	46·5	620	310	...	9	6·0
Ditto Montreal to Whately	46·8	45·5	330	250	...	9	5·0
Ditto Whately to Madras	46·8	37·5	2870	300	...	9	7·0
Ditto Madras, Cambridge	39·7	38·0	500	300	...	9	4·0
Cambridge Terrace, Colombo to Madras	42·9	36·5	1860	300	...	9	4·0
Chester Street, Park Terrace to Square	47.8	46·0	600	300	...	9	7·0
Ditto Square to Cambridge Terrace ...	48·0	39·8	1010	123	...	9	7·0
Armagh Street, Antigua to Durham	49·3	44·4	1600	330	...	9	5·5
Ditto Durham, Cambridge Terrace ...	44.4	40·7	240	65	...	9	8·0
Gloucester Street, Antigua to Cambridge Terrace...	46·0	41·3	1600	340	...	9	7·0
Worcester ditto ditto ditto ...	46·0	42·0	1400	350	...	9	5·0
Hereford ditto ditto ditto ...	46·5	42.7	1400	370	...	9	4·0
Cashel ditto ditto ditto ...	46·7	43·2	1400	400	...	9	3·0
Antigua, North Belt to Salisbury	53·0	48·5	1320	300	...	9	2·5
Ditto Salisbury to Kilmore	50·3	44·3	880	335	...	9	5·5
Ditto Kilmore to Chester	50·3	48·3	400	200	...	9	4·0
Ditto Chester to Armagh	49·3	48·0	400	300	...	9	5·0
Ditto Armagh to Gloucester	50·0	48·0	400	200	...	9	5·0
Ditto Gloucester to Worcester	48·5	46·5	400	200	...	9	4·0
Ditto Worcester to Hereford	48·3	47·0	400	300	...	9	3·6
Ditto Hereford to Cashel	48·0	46·7	400	300	...	9	3·0
Montreal Street, North Belt, to Salisbury... ...	50·6	46·3	1270	300	...	9	6·0
Ditto Salisbury, Kilmore	48·0	44·0	800	200	...	9	6·0

Datum, 34·28 below H.W.S.

Name of Sewer.	Height of Invert Upper	Height of Invert Lower	Length in Feet.	Gradient 1 in	Drainage Area.	Size of Sewer.	Average Depth.
	in.	in.	ft.		Acres.	in.	ft. in
West side of Square ...	47·3	44·5	800	286	...	9	7·0
East ditto ditto ...	48·0	44·0	400	100	...	9	7.0
East ditto ditto ...	48·0	46·5	400	266	...	9	7.0
Montreal, Armagh to Gloucester ...	46·0	44·0	400	200	...	9	7·0
Ditto Gloucester to Worcester ...	45·3	44·0	400	300	...	9	4·0
Ditto Worcester to Hereford ...	45 0	43·7	400	300	...	9	3·0
Ditto Hereford to Cashel ...			400	300	...	9	2·5
Durham, North Belt, to Aldred Street ...	48·0	46·0	600	300	...	9	6·0
Ditto Aldred to Salisbury ...	48·0	45·7	680	300	...	9	5·0
Ditto Salisbury to Peterborough ...	47·0	45·7	400	300	...	9	5·0
Ditto Peterborough to Kilmore...	47·0	45·0	400	200	...	9	4·0
Kilmore to Chester ...	43·0	41·0	400	200	...	9	8·0
Chester to Armagh ...	43·0	41·7	400	300	...	9	8·5
Armagh to Gloucester ...	46·2	44·2	400	200	...	9	5·0
Colombo Street to North Belt ...	44·0	41·0	870	300	...	9	8·0
Ditto Salisbury Street...	45·0	43·0	400	200	...	9	7·0
Ditto Salisbury to Kilmore ...	46·0	40·0	800	133	...	9	7·0
Manchester Street, North Belt, to Madras ...	43·7	41·0	700	260	...	9	6·0
Ditto Madras 4 to Salisbury ...	45·0	41·0	580	145	...	9	7 0
Ditto Salisbury to Peterborough ...	43·5	40·5	400	133	...	9	5·5
Ditto Peterborough to Kilmore ...	40·2	38·0	400	180	...	9	6·0
Ditto Chester to Kilmore ...	39·6	38·3	400	300	...	9	5·0
Barbadoes Street, North Belt, to Cambridge Terrace	43·5	38·5	1500	300	...	9	4·0
Ditto Madras, No. 1 ...	43·0	39·0	800	200	...	9	8·0
Ditto " No. 2 ...	42·3	39·0	800	240	...	9	7·0
Ditto " No. 3 ...	39·8	38·5	400	300	...	9	7·0
Ditto " No. 4 ...	41·0	38·3	740	270	...	9	8·0
Oxford Terrace, Lichfield Street to Cashel Street...	43·7	42·6	450	409	...	9	·8·0
Ditto Cashel Street to Hereford Street...	42·6	41·7	450	500	...	9	8.0
Ditto Hereford Street to Worcester Street	41·7	40·8	400	444	..	9	4·0
Ditto Worcester Street to Armagh Street	40·8	38·8	860	430	32	9	3·0
Ditto Armagh to Colombo ...	41·2	39·3	610	320	...	9	3·0
Ditto Colombo Street to Manchester Street	41·2	38·2	860	290	...	9	4·0
Ditto Manchester Street to Madras Street	39·7	36·7	940	310	...	9	6·5
Ditto Madras Street to Kilmore Street...	36·2	35·8	360	1900	119	21	8·0
Ditto The Syphon, Madras Street ...	36·5	35·8	181	260	846	18 cast iron pipe	
Kilmore Street, Syphon to East Belt ...	35·8	34·5	1750	1340	983	48 x 32	11·5
Stanmore Road to Salisbury Street East ...	41·3	37·0	2170	500	54	12	6·5
Salisbury Street East, Stanmore, to unformed road	37·0	36·2	800	1000	60	12	8·5
Ditto Stanmore Road to River ...	40·4	38·5	560	300	...	9	6·0
Ditto New Brighton Road, Bingsland	45·7	40·7	1500	300	...	9	4·5
Ditto East Belt ditto ..	43·8	41·0	820	300	...	9	5·5
Ditto Unformed Road ditto ...	40·5	36·5	1170	300	38	9	6·5
Ditto Terrace Road, West ditto ..	41·0	38·5	830	330	8	9	5·5
Ditto ditto East ditto ...	40·9	38·5	730	300	...	9	6·0
Salisbury Street East to River ...	36·2	35·0	1200	1000	94	15	8.0
The Syphon, East Belt ...	35·0	34·4	90	160	94	9 cast iron pipe	
East Belt, Kilmore to Tuam...	34·4	32·0	3230	1350	1287	34 x 51	12·0
Armagh Street, Stanmore to Avonville ...	39·4	37·3	850	400	...	9	6·0
Ditto Avonville ...	37·3	36·5	320	400	...	9	9·0
Ditto to East Belt...	36·5	34·1	870	360	28	9	11·0
Gloucester, Stanmore to East Belt...	42·0	36·4	1740	360	17	9	10·0
Worcester ditto ditto ...	41·5	35·7	1750	300	11	9	9·0
Hereford ditto ditto ...	40·3	34·5	1750	300	14	9	8·0
Cashel ditto ditto ...	40.3	34·5	1750	300	15	9	7·0
Old Stanmore Road ...	37·8	34·0	1130	300	9	9	8·0
Lincoln Road, South Belt to Tuam...	54·7	45·3	2800	300	36	9	4·0
Tuam Street, Lincoln, to East Belt...	44·8	33·0	6420	550	182	12 & 1	11·0
Oxford Terrace, Antigua, to Montreal ...	48·5	45·8	820	300	...	9	3·5
Ditto Montreal to Lichfield ...	45·8	43 7	600	300	...	9	6·0
Chester Street, Oxford to Madras ...	37·7	36·9	250	300	...	9	7·3
Ditto Madras to Barbadoes ...	42·0	39 3	800	300	..	9	6·0
Ditto Barbadoes to East Belt ...	42·0	38·0	1270	300	...	9	7·0

Name of Sewer.	Height of Invert Upper	Height of Invert Lower	Length in Feet.	Gradient 1 in	Drainage Area.	Size of Sewer.	Average Depth.
	in.	in.	ft.		Acres.	in.	ft.in.
Armagh Street, Oxford to Madras ...	38·8	36·8	2000	1000	100	15	7·0
Ditto Madras to Barbadoes ...	42·0	39·3	800	300	...	9	7·0
Ditto Barbadoes to East Belt ...	42·0	38·0	1270	320	...	9	7·0
Gloucester Street, Oxford to Colombo ...	42·3	40·3	570	285	...	9	3·0
Ditto Colombo to Manchester ...	42·5	39·8	800	300	...	9	5·0
Ditto Manchester to W. Square ...	43·0	40·0	620	210	...	9	5·0
Ditto W. Square to Madras ...	39·2	38·6	170	300	...	9	9·5
Ditto Madras to E. Square ...	39·2	38 6	170	300	...	9	9·5
Ditto E. Square to E. Belt ...	43·3	37·3	1900	310	...	9	7·5
Worcester Street, Oxford to W. Cathedral ...	42·6	41·3	400	300	...	9	2·0
Ditto E. Cathedral to Manchester ...	44·2	42·6	450	300	...	9	5·5
Cathedral Square North (2 pieces)... ...	42·6	40·7	900	300	...	9	4·0
Ditto South ditto ...	44·0	42·6	900	300	...	9	6·0
Worcester Street, Manchester to W. Square ...	44·2	41·0	620	200	...	9	6 5
Ditto E. Square to E. Belt ...	44·0	37·8	1900	300	...	9	8·0
Hereford Street, Oxford to Colombo ...	44·4	42·0	700	300	...	9	5·0
Ditto Colombo to Manchester ...	45·1	42·5	800	300	...	9	5·5
Ditto Manchester to W. Square ...	44·1	42·0	620	300	...	9	7·0
Ditto W. Square to East Belt ...	44 0	37·8	2240	360	...	9	7·5
Cashel Street, Oxford to Colombo ...	46·7	44·0	760	280	...	9	7·5
Ditto Colombo to East Belt ...	46·7	34·5	3650	303	30	9	8·5
Lichfield Street, Oxford to Durham ...	43·7	42·7	310	310	...	9	8·0
Ditto Durham to Colombo ...	45·7	43·0	800	300	...	9	8·0
Ditto Colombo to East Belt ...	46 2	34·5	3650	300	40	9	7·0
St. Asaph Street, Antigua to Montreal ...	47·0	44·	800	320	...	9	5·5
Ditto Montreal to Durham ...	47·0	44·3	800	300	...	9	6·5
Ditto Durham to Colombo ...	47·0	44·3	800	300	...	9	7·0
Ditto Colombo to East Belt ...	47·7	35·5	3650	300	26	9	6·0
High Street, Hereford to Cashel ...	45·5	43·6	560	300	...	9	6·0
Ditto Cashel to Lichfield ...	45·5	43·8	550	330	...	9	6·5
Ditto Lichfield to Tuam ...	44·0	42·1	570	300	...	9	6·5
Ditto Tuam to St. Asaph ...	43·0	41·1	550	290	...	9	6·0
Ditto St. Asaph to Barbadoes ...	43·0	40·3	860	320	...	9	4·5
Ditto Barbadoes to East Belt ...	41·5	37·0	1350	300	...	9	5·0
Antigua Street, No. 1 ...	49·0	46·6	750	300	...	9	3·0
Ditto No. 2 ...	50·7	48·0	830	300	...	9	4·5
Ditto No. 3 ...	50·0	447·0	840	280	...	9	5·5
Ditto No. 4 ...	50·3	47·3	600	200	...	9	5·0
Barbadoes Street, Oxford to Kilmore ...	37·4	36·2	360	300	...	9	7·5
Ditto Kilmore to Chester ...	43·0	41·0	400	200	...	9	5·0
Ditto Chester to Armagh ...	43·0	41·0	400	200	...	9	6·0
Ditto Armagh to Gloucester ...	43·0	41·0	400	200	...	9	6·0
Ditto Gloucester to Worcester ...	42·0	40·0	400	200	...	9	7·5
Ditto Worcester to Hereford...	43·0	41·0	400	200	...	9	7·0
Ditto Hereford to Cashel ...	44·0	42·0	400	200	..	9	6·0
Ditto Cashel to Lichfield ...	42·5	40·5	400	200	...	9	6·0
Ditto Lichfield to Tuam ...	41·5	39·5	400	200	...	9	6·0
Ditto Tuam to St. Asaph ...	41·3	40·0	400	300	...	9	6·5
Ditto St. Asaph to High Street ...	41·9	41·0	260	300	...	9	3·5
Ditto High Street to South Belt ...	40·4	37·0	1020	300	...	9	5·0
Madras Street, Oxford to Armagh ...	36·8	36·2	600	1000	120	15	9·0
Ditto Armagh to Gloucester ...	38·3	37·0	400	300	...	9	10·0
Ditto East Square (Latimer) ...	41·7	39·2	800	320	...	9	8·5
Ditto West ditto ...	41·7	39·2	800	320	...	9	8·5
Madras Street, Hereford to Cashel... ...	43·1	41·8	400	300	...	9	6·5
Ditto Cashel to Lichfield ...	44·5	42·5	400	209	...	9	5·0
Ditto Lichfield to Tuam ...	42·0	40·0	400	200	..	9	7·0
Ditto Tuam to S Asaph ...	43·0	41·0	400	200	...	9	5·5
Ditto St. Asaph East Belt ...	43·0	38·0	1300	260	...	9	5·5
Manchester Street, Oxfor 'o Armagh ...	38·2	37·7	150	300	...	9	6·0
Ditto Arma, to Gloucester...	39·3	38·0	400	300	...	9	5·5
Ditto Gloucester to Worcester ...	40·6	39·3	400	300	...	9	8·0
Ditto Worcester to Hereford ...	42·0	40·6	400	300	...	9	9·0

Name of Sewer.	Height of Invert Upper	Height of Invert Lower	Length in Feet.	Gradient 1 in	Drainage Area.	Size of Sewer.	Average Depth.
	in.	in.	ft.		Acres.	in.	ft. in.
Manchester Street, Hereford to Cashel	45·0	43·0	400	200	...	9	7·0
Ditto Cashel to Lichfield	45·0	43·7	400	300	...	9	7·0
Ditto Lichfield to Tuam	45·0	43·0	400	200	...	9	6·5
Ditto Tuam to St. Asaph	45·0	43·0	400	200	...	9	6·0
Ditto St. Asaph to South Belt	45·5	40·5	1300	260	...	9	6·5
Colombo Street, Chester to Armagh	40·1	38·8	400	300	...	9	5·0
Ditto Armagh to Cashel...	44·3	39·0	1600	300	...	9	6·0
Ditto Cashel to Tuam	43·7	41·0	800	300	...	9	10·0
Ditto Tuam to St. Asaph	44·5	43·0	400	270	...	9	8·0
Ditto St. Asaph to South Belt	46·7	42·2	1300	300	...	9	7·0
Durham Street, Cashel to Tuam	46·9	44·2	800	300	...	9	5·5
Ditto Tuam to South Belt	49·0	43 3	1680	300	...	9	5·0
Montreal Street, Oxford to Tuam	45·8	45·2	170	300	...	9	6·0
Ditto Tuam to Antigua 1	46·6	43·0	1100	300	...	9	6·0
Ditto Antigua 1 to South Belt...	47·5	45·5	580	290	...	9	5·0
Antigua Street, Oxford to Tuam	48·5	47·5	300	300	..	9	5·0
Ditto Tuam to Antigua 1	47·8	44·4	1100	320	...	9	5·5
Ditto Antigua 1 to South Belt	47·8	45 8	570	285	...	9	6·0
Lincoln Road, Paulson to South Belt	67·5	54·7	2700	210	46	9	6·0
South Belt, Lincoln to Selwyn	50·6	48·5	1050	500	184	12	7·0
Ditto Selwyn to Antigua	48·5	45·3	1570	500	173	15	7·0
Ditto Antigua to Montreal	45·3	43·9	710	440	281	18	8·0
Ditto Montreal to Colombo	43·9	40·7	1600	500	330	18	8·0
Ditto Colombo to Madras	40·7	37 5	1600	500	551	*22 x 33	8·0
Ditto Madras to Gasworks	37 5	36·0	1090	700	584	*24 x 36	7·5
Ditto Gasworks to East Belt	36·0	34·5	1000	700	822	26 x 39	8·0
East Belt, South Belt to Tuam	34·3	33·1	1640	1360	930	30 x 45	10·0
Paulson Street, Lincoln to Bend	68·9	65·8	1130	360	...	9	5·0
Ditto Bend to Square	65·8	61·5	1540	350	22	9	6·5
Park Street, Square to Harman	61·0	57·5	720	200	...	9	7·7
Ditto Harman to Belt	57·5	57·0	890	130	45	9	6 5
Paulson Street, Square to Selwyn	61·5	58·1	1020	300	...	9	6·5
Selwyn Street, Jackson's Creek to Paulson	61 7	57·6	1230	300	16	9	6·5
Ditto Paulson to Belt	57·6	49·0	1610	190	62	12	8·5
Harman Road, Lincoln to Park Street	61·0	58·0	930	300	...	9	7·0
Ditto Park to Selwyn	60·0	55·9	1020	250	...	9	5·0
Hazledean Street, Lincoln to Park ...	57·5	54·3	570	170	...	9	6·0
Ditto Park to Selwyn ...	56 0	52·0	1010	255	...	9	5·5
Ditto Selwyn to Windmill	53·6	48·2	1620	300	...	9	8·0
Ditto Windmill to Montreal	53·5	51·2	710	300	...	9	6·0
Ditto Montreal to Colombo	50·0	42·0	1600	200	...	9	6·5
No. 1 Street, Montreal to Colombo	50·5	42·5	1600	200	...	9	6·0
Ditto Colombo to Gasworks	46·5	38·0	2800	330	...	9	4·0
No. 2 Street, Montreal to Colombo	51·2	43·2	1600	200	...	9	8·0
Ditto Colombo to Gasworks	45·2	38·5	2670	390	...	9	4·0
No. 3 Street, Montreal to Colombo	51·0	44·0	1600	230	...	9	6·0
Ditto Colombo to Gasworks	46·1	39·4	2670	400	...	9	4·5
No. 4 Street, Montreal to Colombo	52·0	45·0	1600	230	...	9	5·5
Ditto Colombo to Gasworks	46·9	40·2	2670	400	...	9	5·0
No. 5 Street, Montreal to Colombo	45·0	46·0	1600	200	...	9	6·0
Ditto Colombo to Gasworks	47·7	41·0	2670	400	...	9	4·5
No. 6 Street, Montreal to Colombo	54·5	46·5	1600	200	...	9	7·0
Windmill Lane, Pound to South Christchurch Road	60·0	58·0	800	400	...	9	5·0
South Christchurch Road, Windmill to Restall's ...	60·0	55·1	1450	300	...	9	5·0
Restall's Road, South Christchurch to Colombo	55·1	49·0	1900	300	...	9	7·0
Pound Road, Windmill to Colombo	58·0	47·0	2300	210	32	9	6·0
Ditto Colombo to East	49·0	47·0	610	300	...	9	4·0
Ditto East to Gasworks	49·0	41 9	2070	300	74	12	4·0
Gasworks Road, Pound to South Belt	41·9	36·5	2710	500	221	15	7.0
Windmill Road, Pound to South Belt	58·2	49·0	2730	300	102	9 & 12	7·5
Montreal Street, Pound to 5th Street	57·0	55·0	580	300	...	9	5·0
Ditto 5th Street to 3rd Street ...	54·5	51·8	800	300	...	9	5·0
Ditto 3rd Street to 2nd Street ...	53·0	51·7	400	300	...	9	4·0

DATUM, 34·28 BELOW H.W.S. * OVAL.

Name of Sewer.	Height of Invert Upper	Height of Invert Lower	Length in Feet.	Gradient 1 in	Drainage Area.	Size of Sewer.	Average Depth.
	in.	in.	ft.		Acres.	in.	ft. in.
Montreal Street, 2nd Street to Belt	52·7	49·2	950	275	..	9	5·0
Durham Street, Pound to 3rd Street	52·4	48·1	1370	275	...	9	5·0
Ditto 3rd Street to 2nd Street ...	49·2	47·9	400	300	...	9	5·5
Ditto 2nd Street to Belt...	48·7	45.6	950	300	...	9	4·5
Harper Street, Pound Road to 3rd Street ...	54·3	49·8	1370	300	..	9	5·0
Ditto 3rd Street to Belt ...	51·5	47·0	1350	300	..	9	5·5
Colombo Road, Restall's to Pound ...	49·0	46·5	1180	470	70	12	8·0
Ditto Pound to Belt	46·5	41·0	2720	500	227	15 & 18	7·0
Madras Street, Pound to 5th Street	46·1	44·1	580	300	...	9	3·5
Ditto 5th Street to 4th Street	44·5	43·2	400	300	...	9	3·5
Ditto 4th to 3rd Street	43·6	42·3	400	300	...	9	3·5
Ditto 3rd to 2nd Street	42·6	41·3	400	300	...	9	3·5
Ditto 2nd to 1st Street	43·1	41·8	400	300	...	9	3·0
Barbadoes, Pound to 5th Street	44·5	46·2	580	300	...	9	5·0
Ditto 5th to 3rd	43·4	40·9	780	300	...	9	5·0
Ditto 3rd to 2nd	41·5	40·2	400	300	...	9	4·0
Ditto 2nd to 1st	41·0	39·7	400	300	...	9	3·5
Stanmore Road, River to Armagh ...	39·9	35·9	870	215	...	9	5·0
Ditto Armagh to Gloucester	43·0	39·9	750	240	...	9	5·0
Ditto Gloucester to Outfall	43·0	36·2	2050	300	15	9	5·5
Barbadoes Street, Jackson's Creek to Ferry	41·1	37·1	700	175	...	9	5·0
Matheson's Road, Ferry to Outfall...	38·5	32·0	2000	300	...	9	7·0
Wilson's Road, Jackson's to Ferry...	42·7	38·5	1370	310	...	9	5·5
Duncan's Road, Ferry to Outfall	37·3	32·5	1750	340	...	9	10·0
Philip's Street, Ferry to Outfall	38·0	33·4	1400	300	...	9	9·0
Ferry Road, South Belt to Philip's...	41·7	38·5	970	300	...	9	5·0
Ditto Philip's to Duncan's ...	39·3	37·3	590	300	...	9	5·0
Ditto Duncan's to Wilson's...	38·0	37·3	220	300	...	9	4·5
St. Asaph Street, Belt to Philip's ...	38·7	35·0	1150	310	...	9	5·5
Ditto Philip's to Duncan's ...	38·7	36·4	760	240	...	9	7·0
Outfall Sewer to Pumps	31·7	29·7	2980	1508	2494	*60 x 54	13·0

DATUM, 34·28 BELOW H.W.S. * OVAL.

Christchurch, District Drainage Board,
Hereford Street, April 6, 1878.

W. CLARK, Esq., C.E., The Club, Wellington.

Sir,—Herewith I send you newspaper extracts having reference to your scheme for the drainage of the Christchurch district.

You will observe two questions raised therein, viz.:—Is it a matter of sanitary necessity that the excreta should be removed by sewers?

And: Are you aware that the normal wind of Christchurch is easterly, and that for four or five days each week (on the average) the wind blows from the Sandhills direct to the town?

The Town Clerk informs me that heretofore the pans have been emptied, on an average, about once in ten days. By a new contract, which has just been concluded, they will be emptied not less often than once a week.

You are already aware that pans are used over only a portion of the district.

May I ask you to favour the Board with your answer to the above questions at your early convenience.

I remain, &c.,

R. J. S. HARMAN, Acting Chairman.

To R. J. S. HARMAN, Esq., Acting Chairman Christchurch District Drainage Board.

Sir,—I have the honour to acknowledge the receipt of your letter of April 6, and with reference to my report on the drainage of Christchurch, requiring my opinion.

1st. Whether it is a matter of sanitary necessity that the excreta should be removed by the sewers?

A simple assent to the question so put would ignore all other modes of dealing with this matter, which I do not desire to do, for there are many possible ways of treating and removing it; but, in my opinion, if economy, completeness (with the absence of nuisance), and possible return for the outlay in the future, be taken into consideration, then I say, in the case of Christchurch, *there is* a necessity. I have pointed out in my report that the system of sewers for subsoil drainage and the removal of house slops is necessary, and that no extra expense will be incurred in the construction of the sewers by their use for this purpose also.

2nd. As to the prevailing wind which blows from the Sandhills towards the city.

When I state that the utilisation of the sewage, if properly regulated, will produce little or no nuisance at the Sandhills, I scarcely expect it to be credited; but it must be borne in mind that the filth will be removed and absorbed by the land while in a fresh condition; it will not stop from the moment of production to that of absorption, and certainly not more than three or four hours would be occupied in its journey from the most distant part of the city, during which it will not have time to decompose.

This, however, is a matter a right understanding of which is of so much importance, and so few persons have had the opportunity of visiting a sewage farm, that I must endeavour to put the case in a form which may be better appreciated than by a mere statement of my own opinion.

Imagine then a row of 20 or 30 pan closets, at the Sandhills, with their one-week-old and decomposing contents. What the nuisance arising from these places, and the still worse cess-pits, amounts to, the inhabitants of Christchurch are familiar with; imagine this row at the Sandhills, and I will guarantee that, if any ordinary precautions be taken to keep the sewage flowing over the land, it will not produce one-half the nuisance due to the closets. How far, then, will the nuisance from the closets travel on the wind? or, it may be asked, how far *does* it travel from the 1500 or 1600 of these pans *in* Christchurch?

Any inquirer can thus estimate for himself, and I think most will agree with me, that a few hundred yards of distance would be quite sufficient to render the supposititious nuisance of the 20 or 30 pan closets at the Sandhills inappreciable.

I was not aware that the wind—probably for five days in the week—blows from the Sandhills towards the city; but now I am so informed, I am of opinion that at say one quarter of a mile from the point of utilisation or from the point of its discharge from the iron conduit which conveys it to the Sandhills, its presence could not possibly be detected.

3rd. Regarding the suggestion that the estimate I have formed for carrying out the works may be considerably exceeded, I would remark that I am familiar with the difficulties which will have to be overcome, and the means of overcoming them; I have consulted Mr. Bell on the matter, and the estimate has been formed from my experience, aided by his knowledge of the locality and rates of labour and material; to this we have added 10 per cent. for contingencies, and to the best of my belief the work will not exceed the estimate so formed.

I have, &c.,

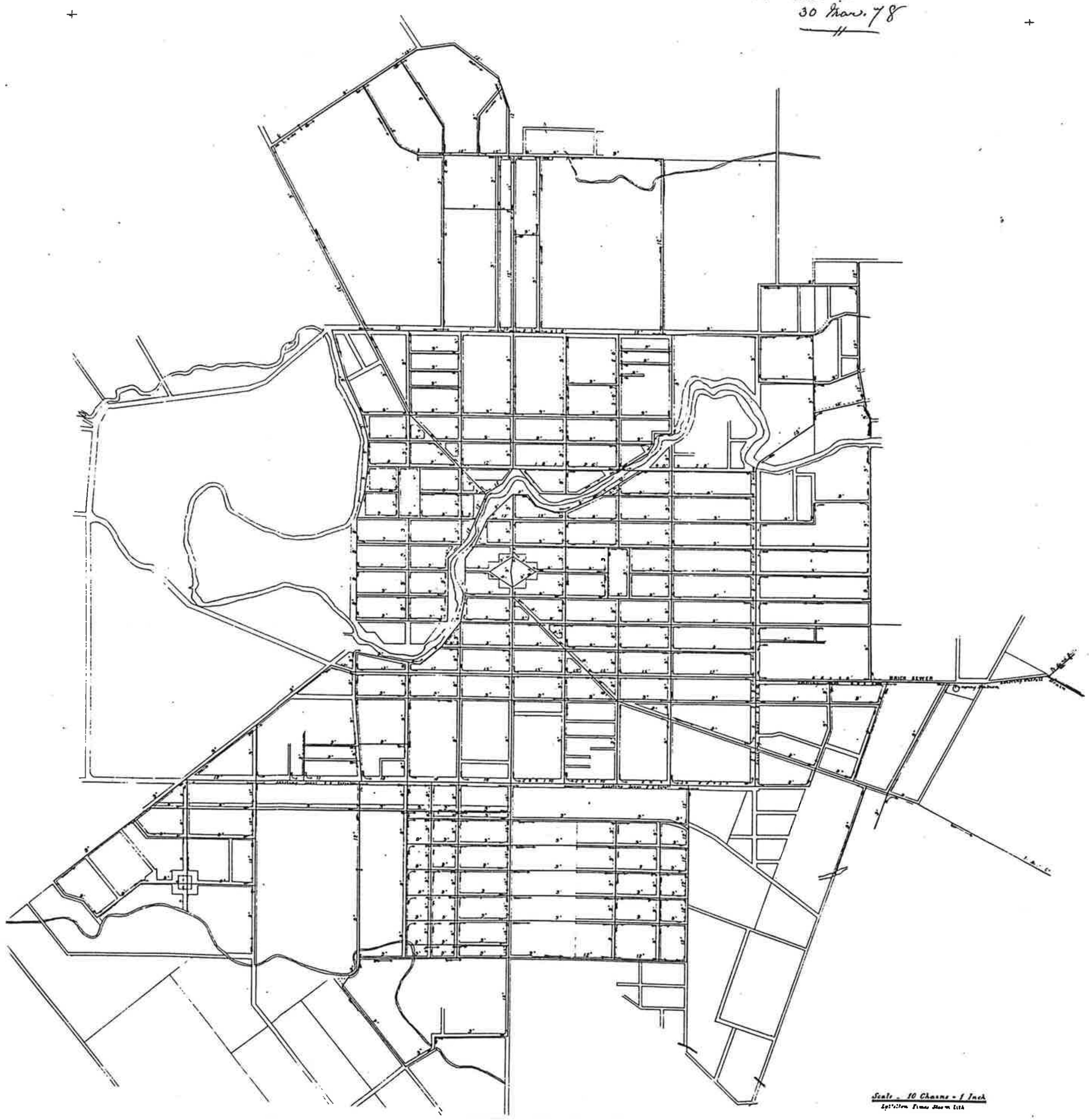
W. CLARK.

Wellington, April 11, 1878.

PLAN No I

PLAN OF CHRISTCHURCH

W Clark
30 Mar. 78



Scale _ 10 Chains = 1 Inch

PLAN Nº 1A

CHRISTCHURCH DRAINAGE.

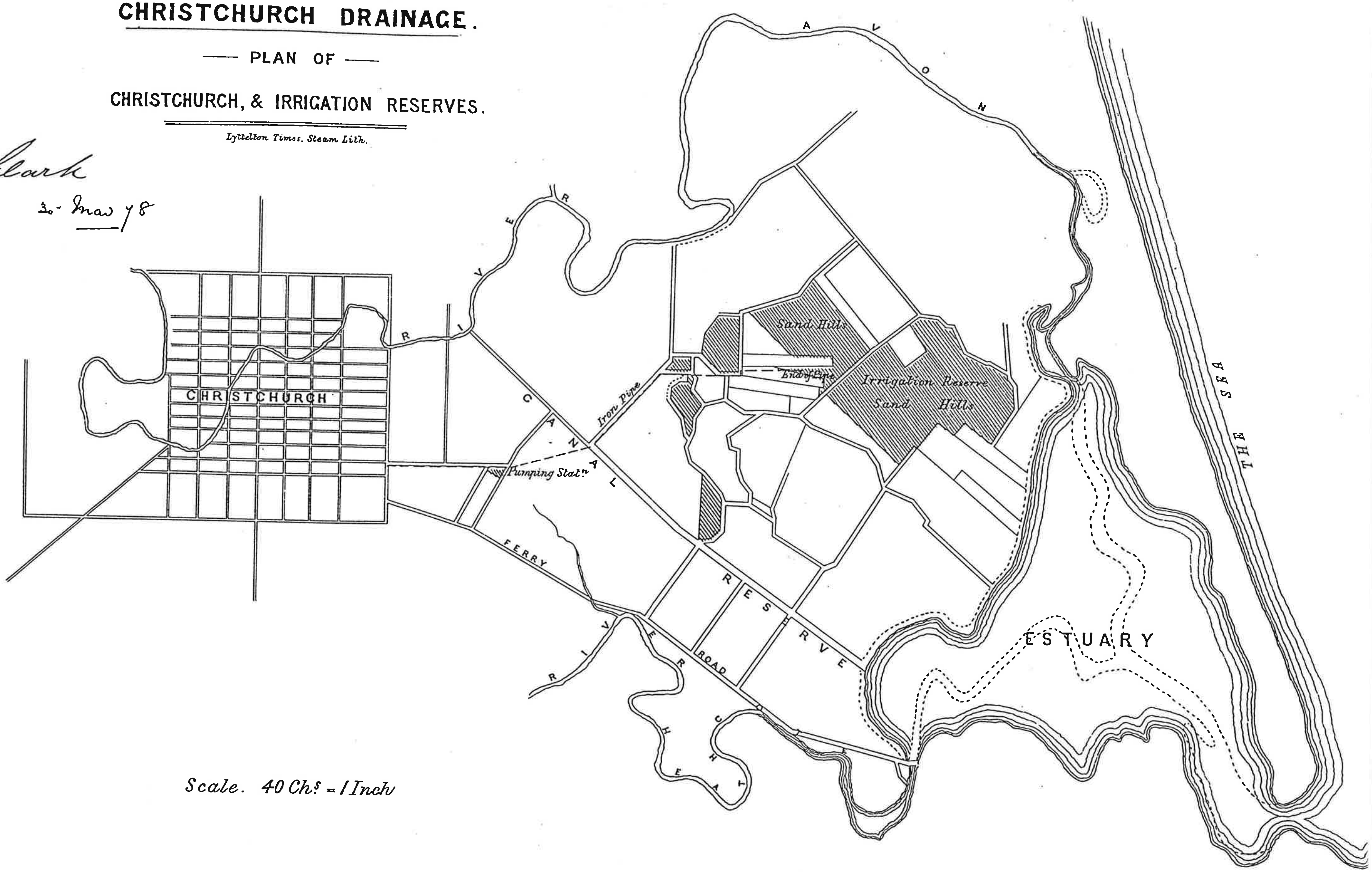
— PLAN OF —

CHRISTCHURCH, & IRRIGATION RESERVES.

Lyttelton Times. Steam Lith.

W Clark

30 - May 78



Scale. 40 Chs = 1 Inch

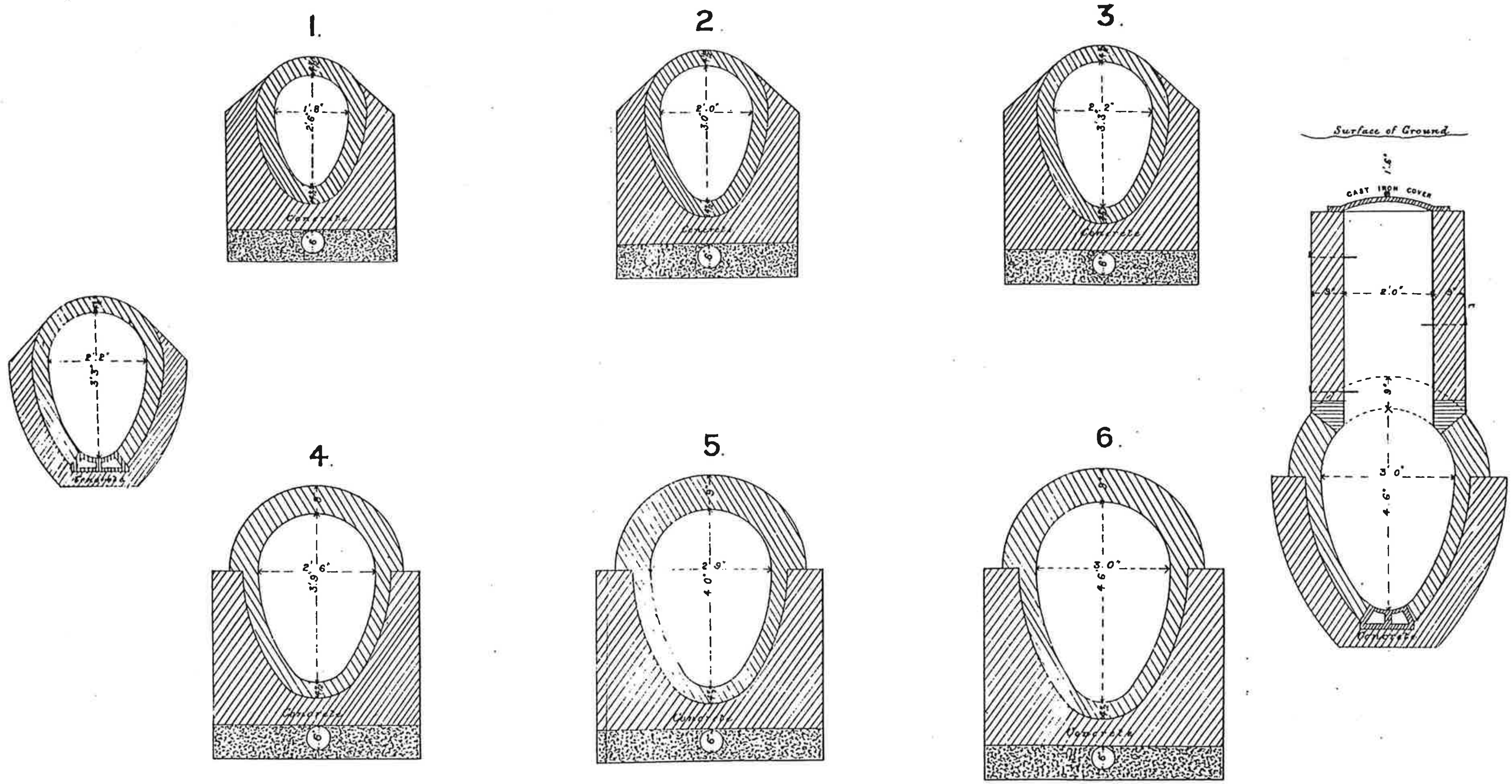
PLAN Nº 2

CHRISTCHURCH DRAINAGE

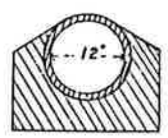
SECTIONS OF SEWERS

W Clark
30" Mar 78

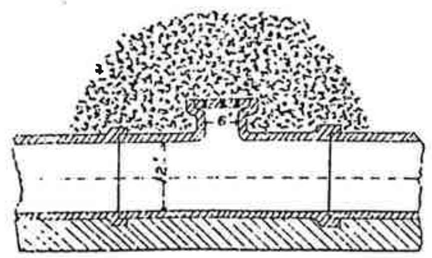
SCALE ¼ INCH — 1 FOOT



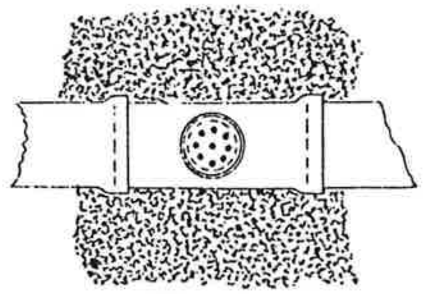
PIPE SEWER



INLET FOR SUBSOIL WATER



Section



Plan

Lyttelton Times Steam Lith.

PLAN No 3.

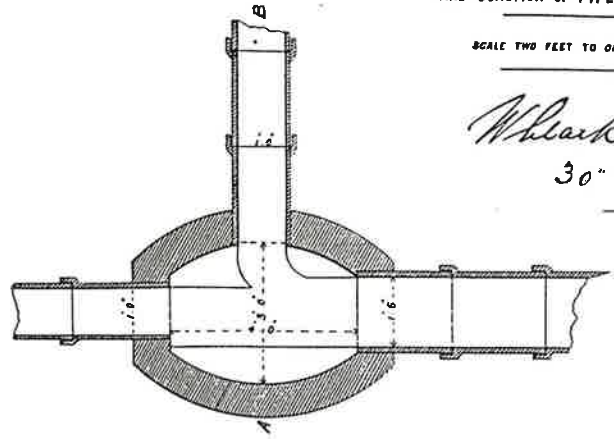
DETAILS FOR PIPE SEWERS

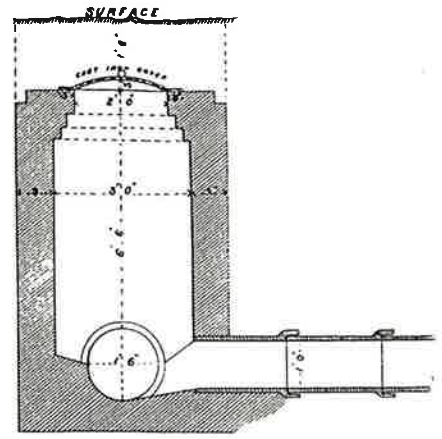
— MAN HOLE —

AND JUNCTION OF PIPE SEWERS

SCALE TWO FEET TO ONE INCH

W Clark
30" Mar 78

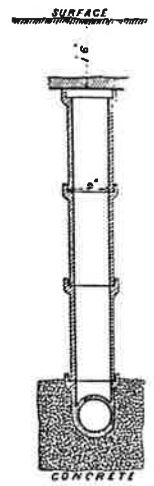




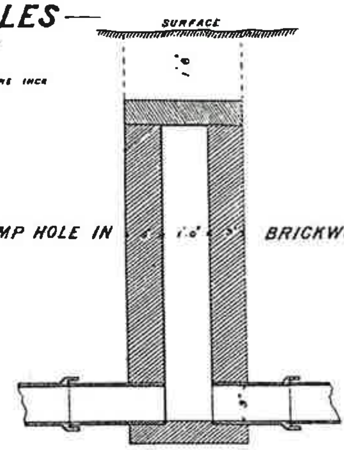
VERTICAL SECTION THROUGH A.B.

— LAMP HOLES —

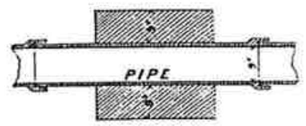
SCALE TWO FEET TO ONE INCH



LAMP HOLE FOR 9 INCH PIPE SEWER



VERTICAL SECTION

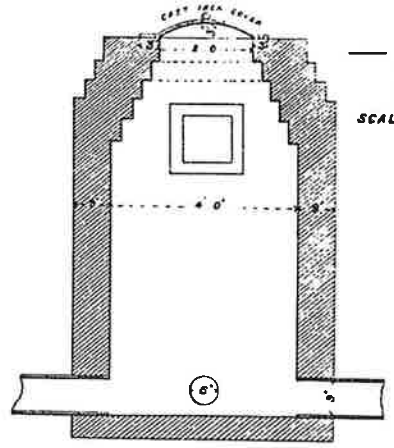


PLAN

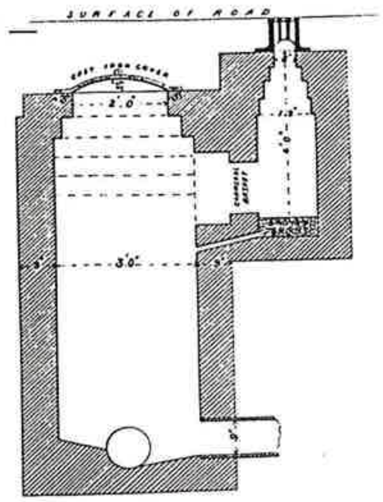
— VENTILATOR — AND — MAN HOLE —

FOR PIPE SEWER

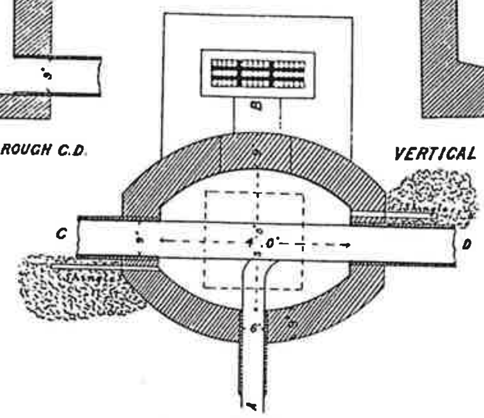
SCALE TWO FEET TO ONE INCH



VERTICAL SECTION THROUGH C.D.



VERTICAL SECTION THROUGH A.B.



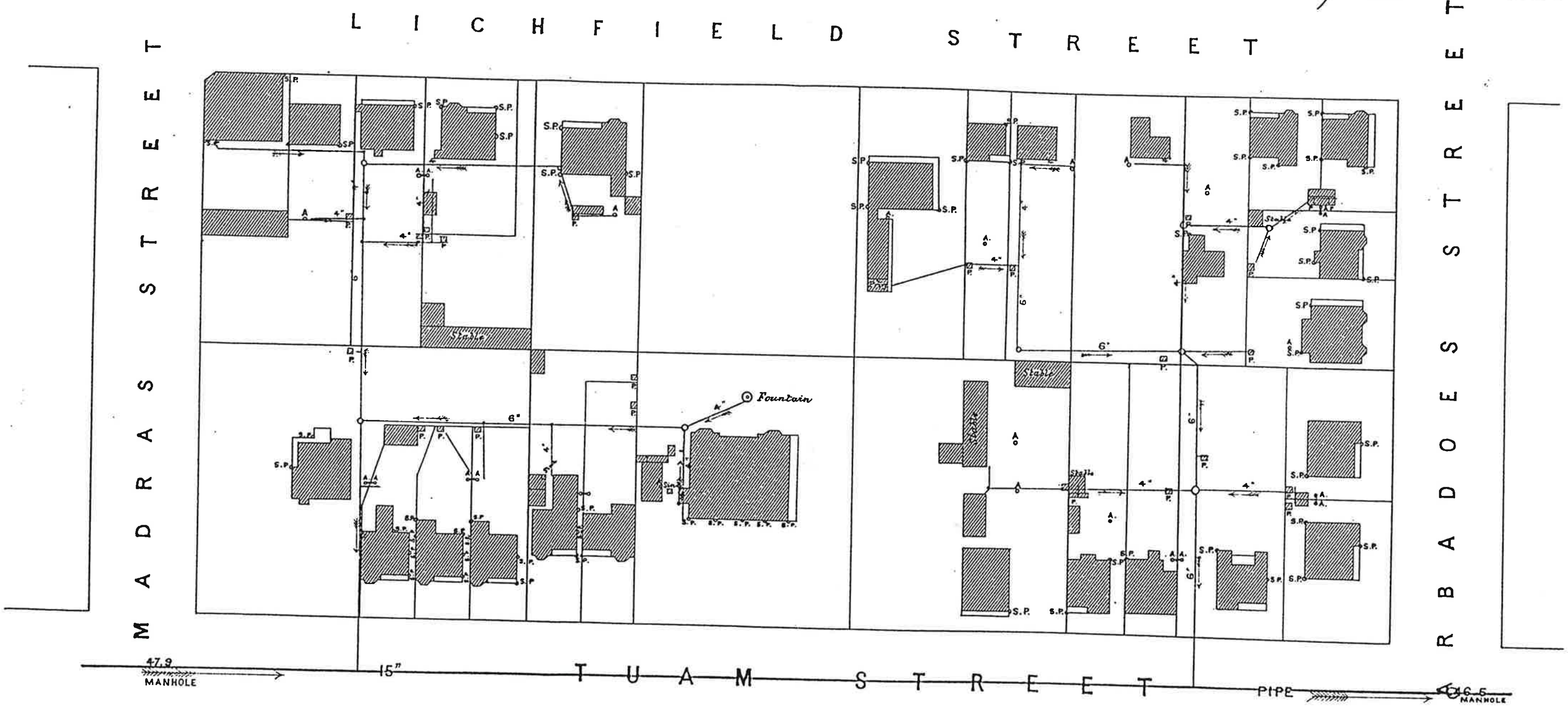
PLAN

PLAN No 4

PART OF CHRISTCHURCH

— DIAGRAM —

ILLUSTRATING BACK DRAINAGE



NOTE

A. Artesian Well.
P. Privy.
S.P. Stack Pipe.
O MANHOLE
• LAMPHOLE

This diagram shews that a block bounded by four Streets can if required be drained into one Street Sewer.

Lyttelton Times, Steam Lith.

PLAN Nº 5

CHRISTCHURCH DRAINAGE

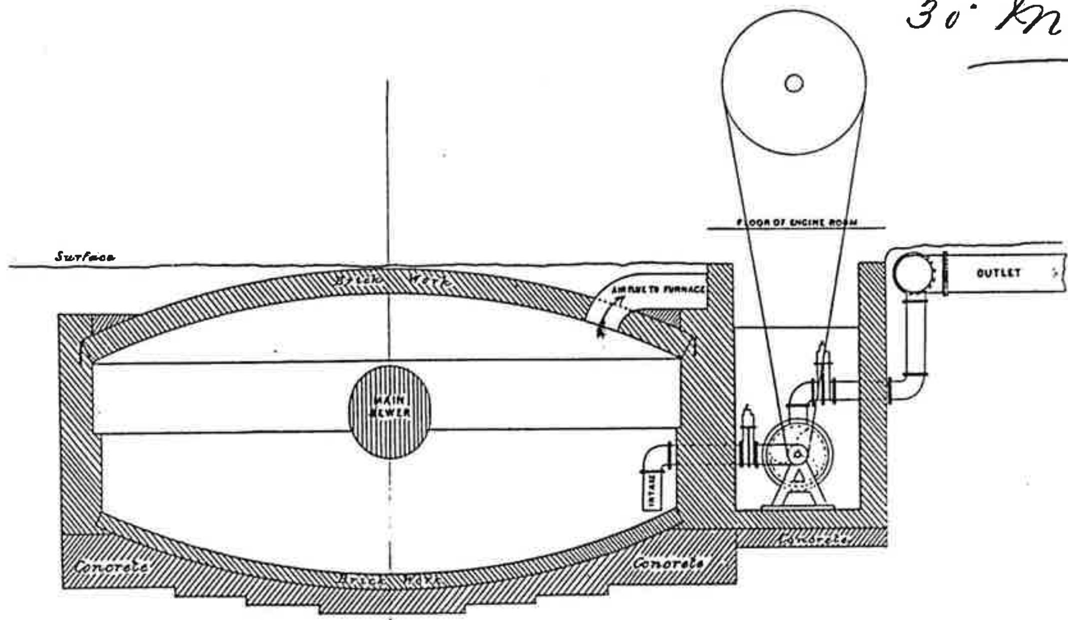
— DIAGRAM —

ILLUSTRATING PUMPING ARRANGEMENT

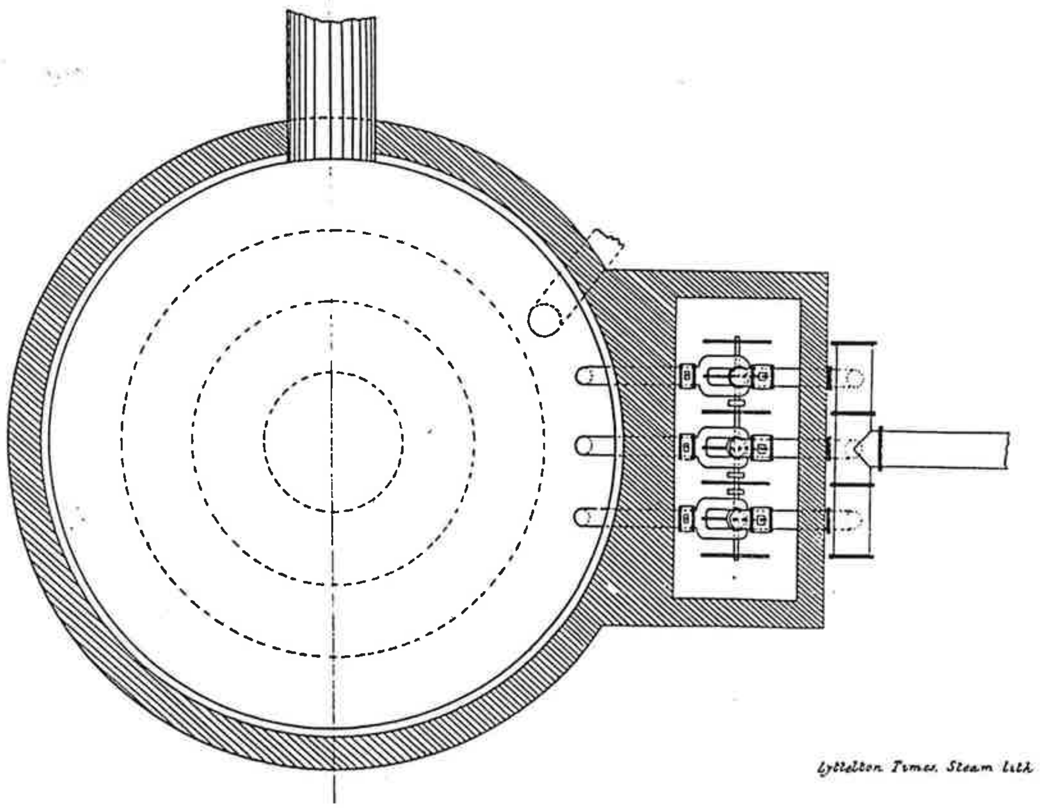
SCALE 8 FT = INCH

W Clark

30 Mar 78



SECTION



PLAN

Lyttelton Times, Steam Lith

PLAN Nº 6

HOUSE DRAINAGE
— DIAGRAM —

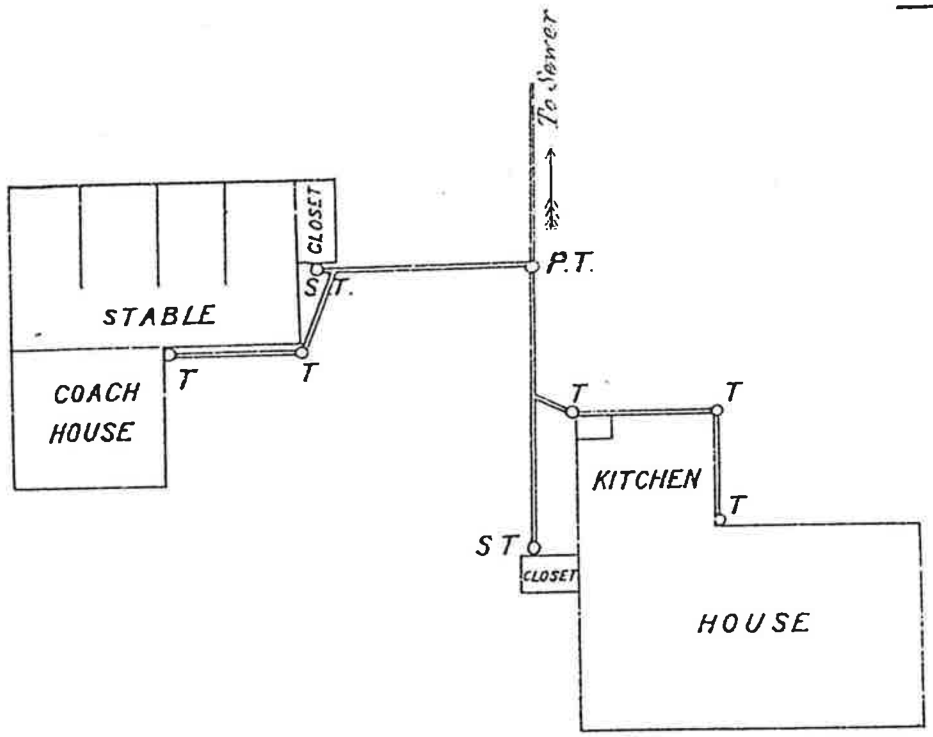


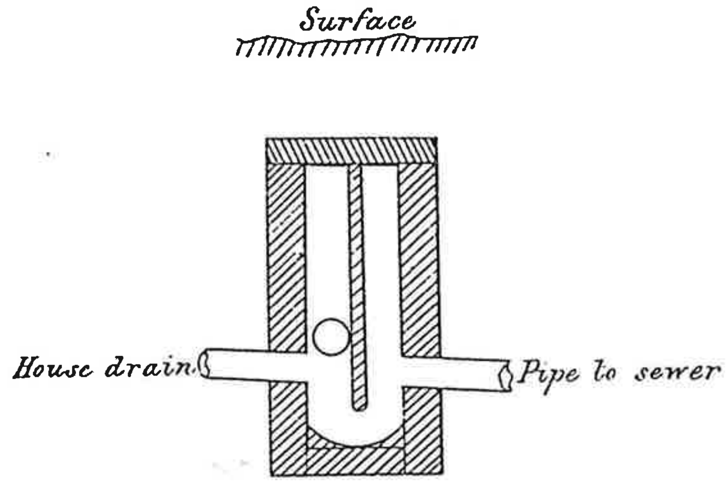
DIAGRAM PLAN OF HOUSE AND OUT OFFICES
Shewing general arrangement of House drains etc.

T.T. indicates position of Traps with inlets through surface gratings

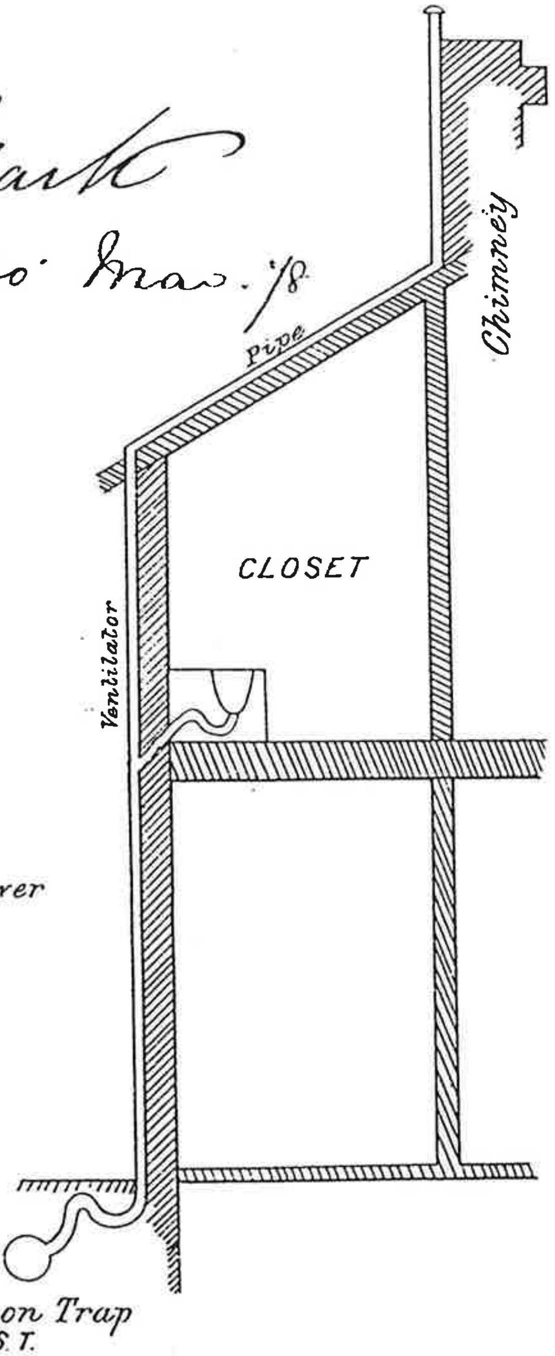
S.T. Syphon Traps in Closet pipes

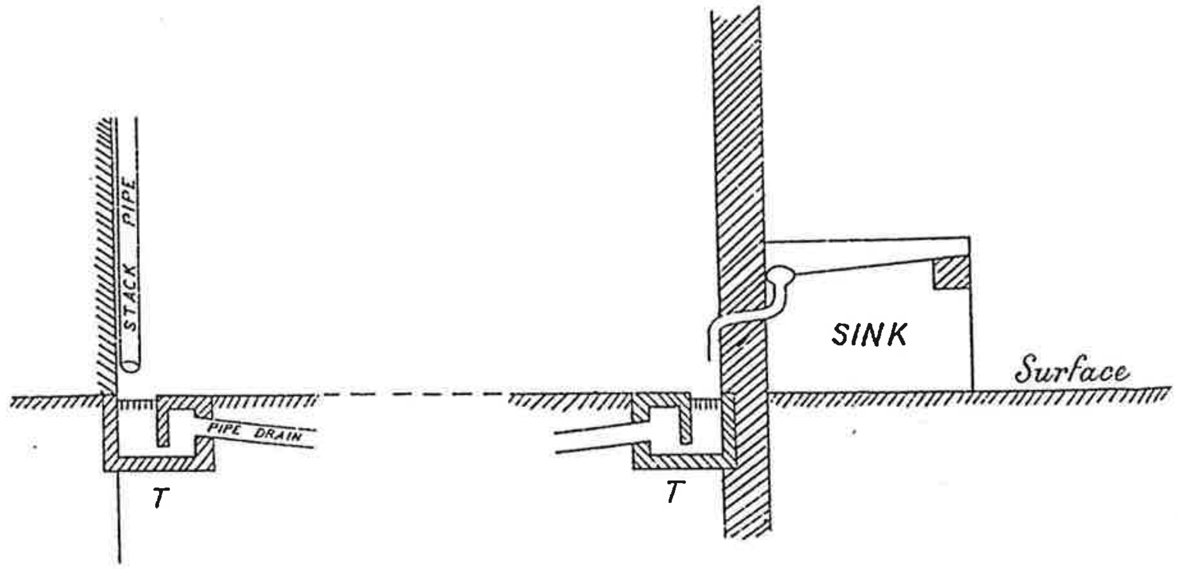
P.T. Pit Trap receiving all the drains

W Clark
30 Mar. '18



PIT TRAP
P.T.





SURFACE TRAP LINED WITH CEMENT

Lyttelton Times, Steam Lith.

PLAN No 7

CHRISTCHURCH DRAINAGE

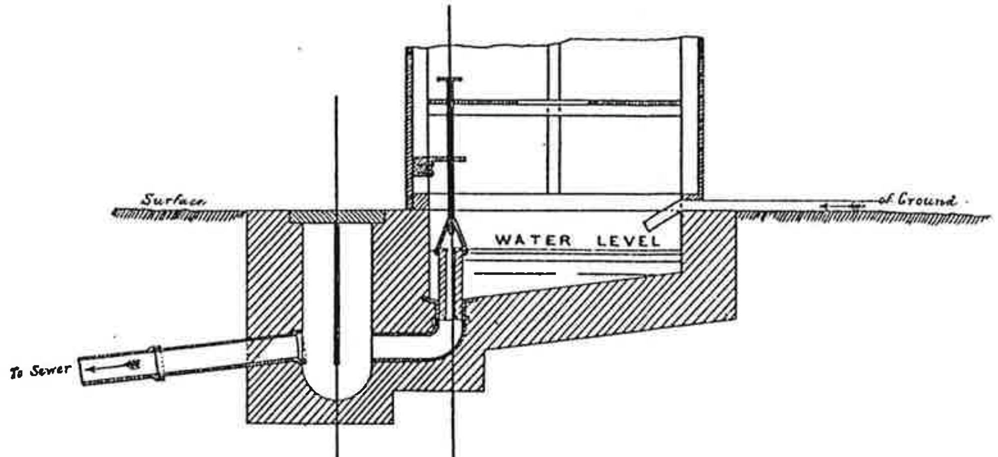
— PLAN OF —

WATER PRIVY

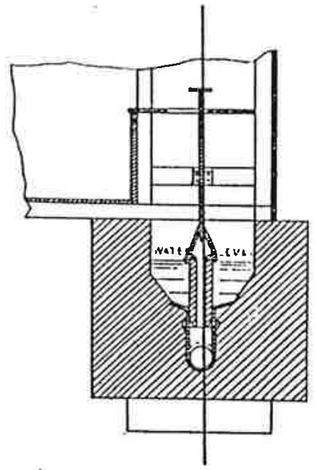
SHEWING ARRANGEMENT FOR CLEANSING BY WASTE WATER FROM ARTESIAN WELL

SCALE 2 FEET = 1 INCH

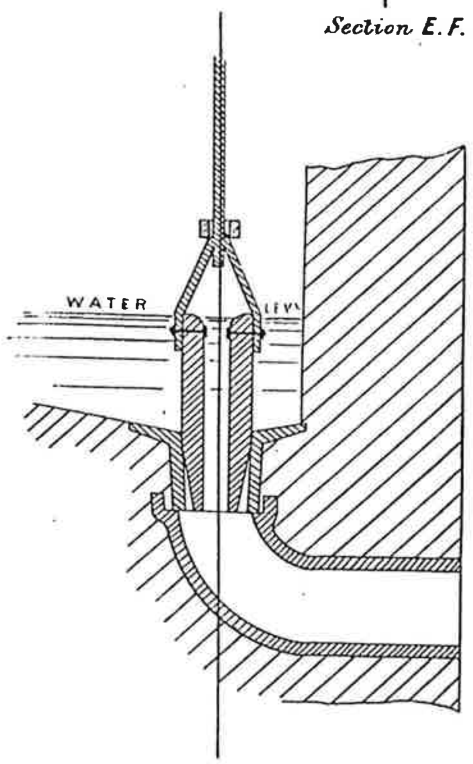
W Clark
30th Mar 78



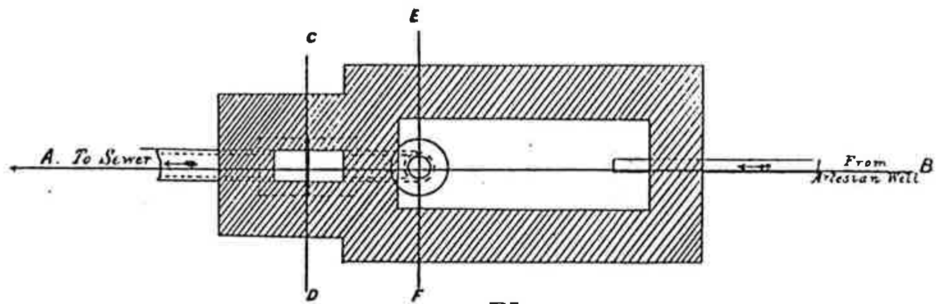
Section A.B.



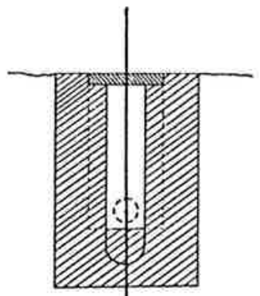
Section E.F.



Detail of Plug
Scale 1½ in = 1 ft.



Plan



Section C.D

Lyttelton Times Steam Lith